Nomination Dossier

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Rjukan – Notodden Industrial Heritage Site

Nomination to the UNESCO World Heritage List
Norway

Nomination Dossier

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EXECUTIVE SUMMARY

Country:	**Norway**
State, province or region:	**Telemark County**
Name of the property:	**Rjukan – Notodden Industrial Heritage Site**

Geographical coordinates to the nearest second:

Notodden	UTM Zone 32N	Easting: 514 850	Northing: 6 602 270	Hydro's Admini building (Centre point)
Rjukan	UTM Zone 32N	Easting: 477 250	Northing: 6 637 960	Rjukan Town Hall (Torget 1) (Centre Point)

Degrees, minutes and seconds:

Notodden	WGS 84	Easting: 009° 15′ 45″	Northing: 59° 33′ 31″	Hydro's Admini building (Centre point)
Rjukan	WGS 84	Easting: 008° 35′ 37″	Northing: 59° 52′ 43″	Rjukan Town Hall (Centre Point)

Description of the area's boundaries

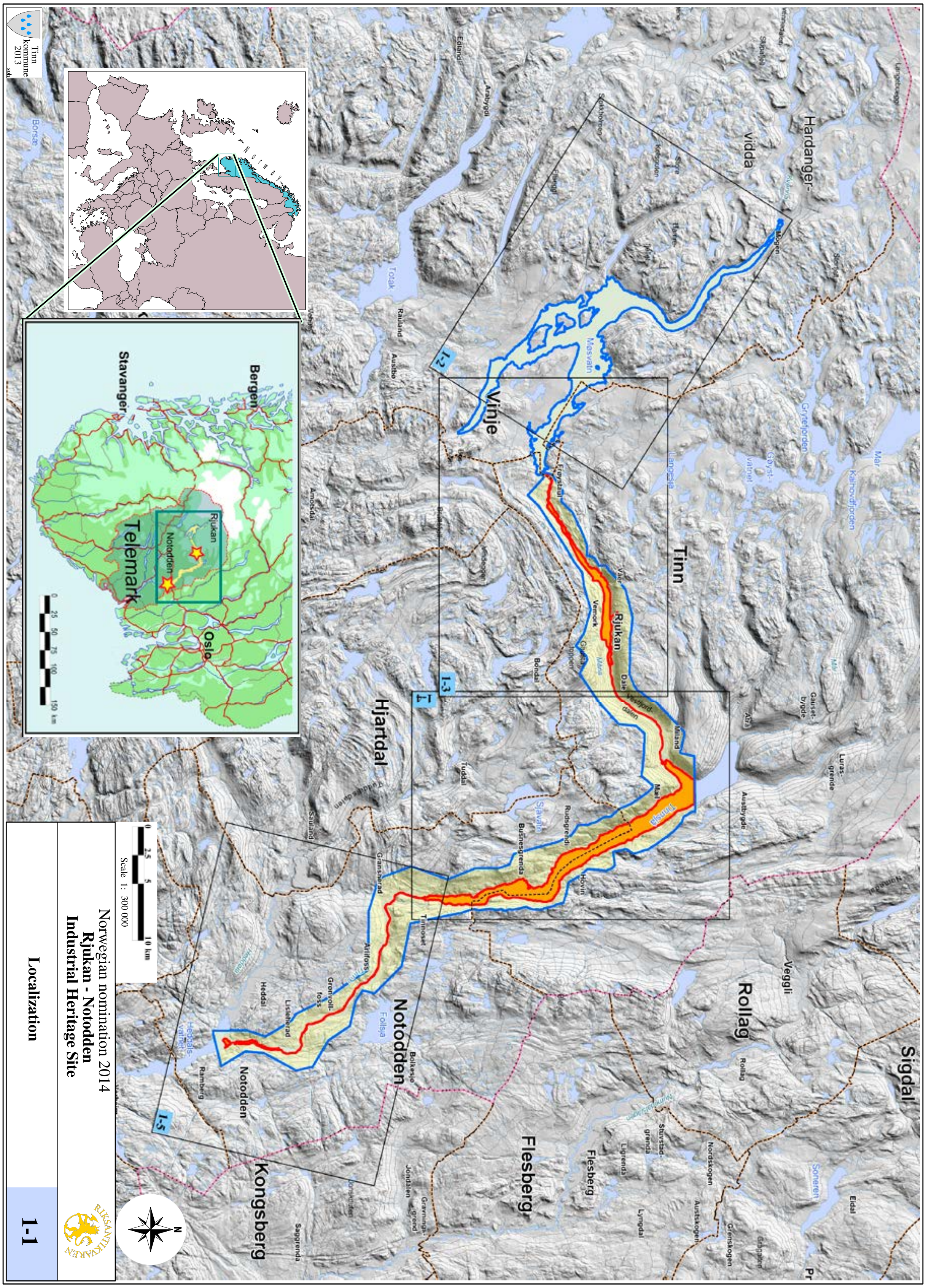
The boundaries form a geographically coherent area, in which four different components successively constitute this whole in different ways. The delimitation of the nominated area relates to distinct characteristics of each of the components. The distinctions are based on historical facts, property boundaries and topographic conditions.

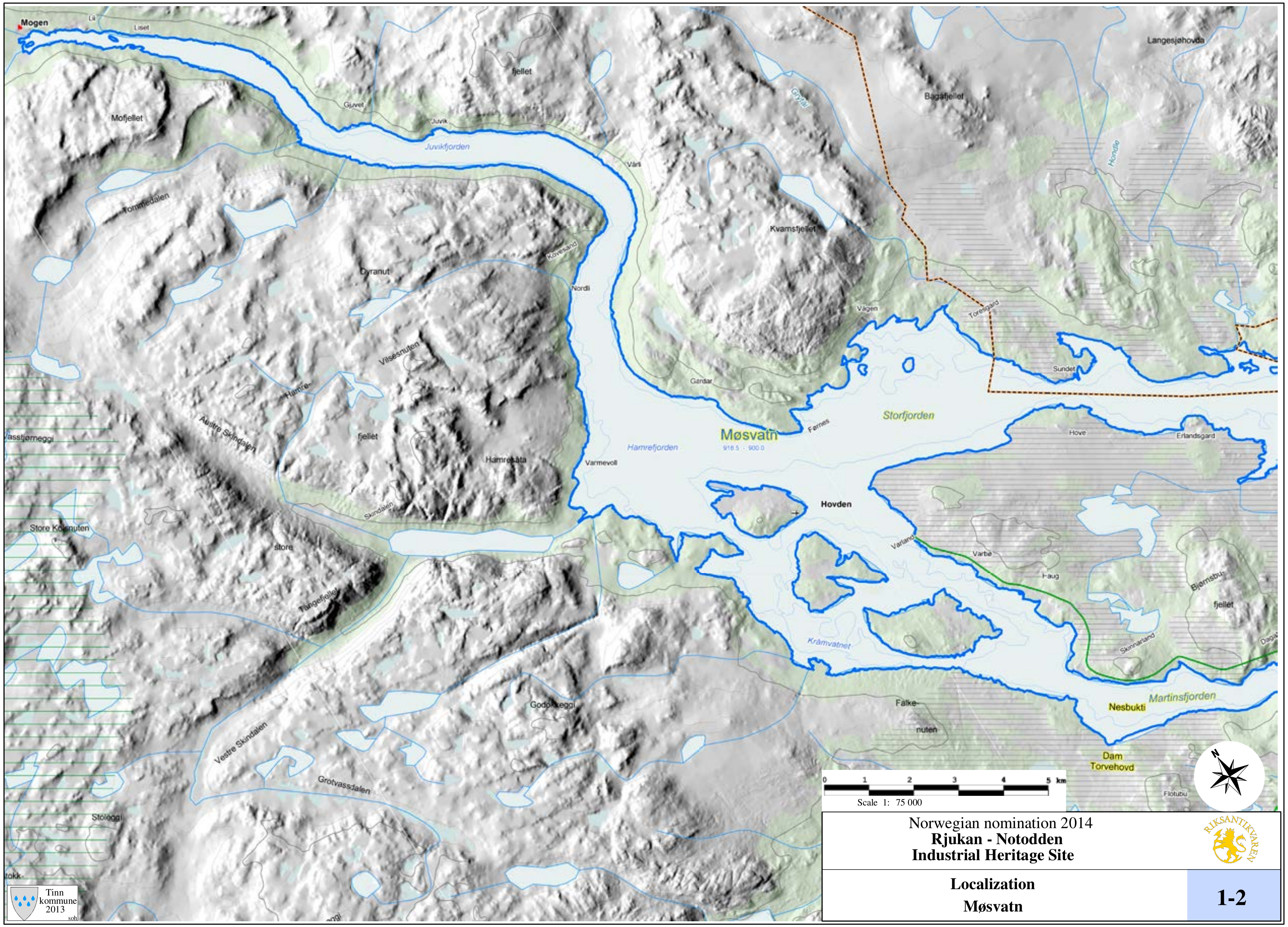
The historical basis is the industrial company Norsk Hydro and its subordinate enterprises. The company has been restructured, properties have been sold and enterprises have either been closed down or modernised. In many cases, the property boundaries reflect the original historical conditions.

Geographically, the boundaries of the World Heritage Site follow the water flow from the Møsvatn regulating reservoir on the Hardangervidda mountain plateau down to Heddalsvatnet lake, a stretch of 93 km. The basis for the boundaries is formed by the Måna river from the old Møsvatn dam through the Vestfjorddalen valley down to Tinnsjøen lake, and the water surfaces of Tinnsjøen from Vestfjorden southwards to Tinnoset and then Tinnelva river. Where the water leaves its natural course and runs through tunnels and pipes to be used in power production, the boundaries follow the outside of these installations. The same principle applies where the railway forms the outer line of technical installations along the watercourse. The areas between the natural watercourses and the linear structures will then fall within the boundaries of the proposed World Heritage Site. The course of water as it defines the boundaries only include sections where the water was actually used by Hydro and Tinfos AS for power production around 1920. Subsequently, the Måna river downstream of Såheim and the Tinnelva river upstream of Svelgfoss have been left out. Between Svelgfoss and Såheim, it is the transport system that connects the areas, i.e. the railway sections and (part of) the water surface of Tinnsjøen. By Rjukanfossen in Måna, the river canyon is included, and the boundary then follows the power line's path down to the town of Rjukan. In the urban communities of Rjukan and Notodden, and some junction points in the systems, the communities are included as far as to what they had extended during Norsk Hydro's establishment phase until this phase was complete. In Rjukan, where areas used for industry and housing form a long, integrated area in which the river divides the functions, the boundaries follow the outer edge of the built-up area as it was in 1930. In Notodden, Hydro's housing areas in the immediate vicinity of its own factories are included and the end of the transport system by the lake. The boundaries leave the Tinnelva river at the Tinnfoss waterfall, and are connected to the Hydro areas in the southern part of the town through the railway tunnel.

The buffer zone covers the landscape spaces in which the proposed World Heritage Site is located. The topography creates a very distinct landscape. From the mouth of Møsvatnet lake, the boundaries cover the landscape areas where the Måna river runs through a valley (Vestfjorddalen valley), the Tinnsjøen basin (south of the Neset-Tverrberg line), and the course of the Tinnelva river through a valley to Heddalsvatnet lake. The boundaries of the buffer zone run between distinct peaks in the terrain – including the summit of Mount Gaustatoppen at 1 883 metres – and roughly match the horizon as seen from the valley floor, or from vessels on Tinnsjøen lake. The buffer zone ends in the south in a straight line from Eikeskard (416 metres) across Heddalsvatnet to the road upside of Kastet point on the west side, and northwards from this towards the top of Tinnesåsen (327 metres). From the upper side of the old Møsvatn dam, the lake becomes a representation of the natural resource that is made up of its total drainage area. Here the contours of the surface of Møsvatnet lake at the highest regulated water level define the buffer zone for the nominated World Heritage Site.

Maps showing the boundaries of the nominated area and buffer zone





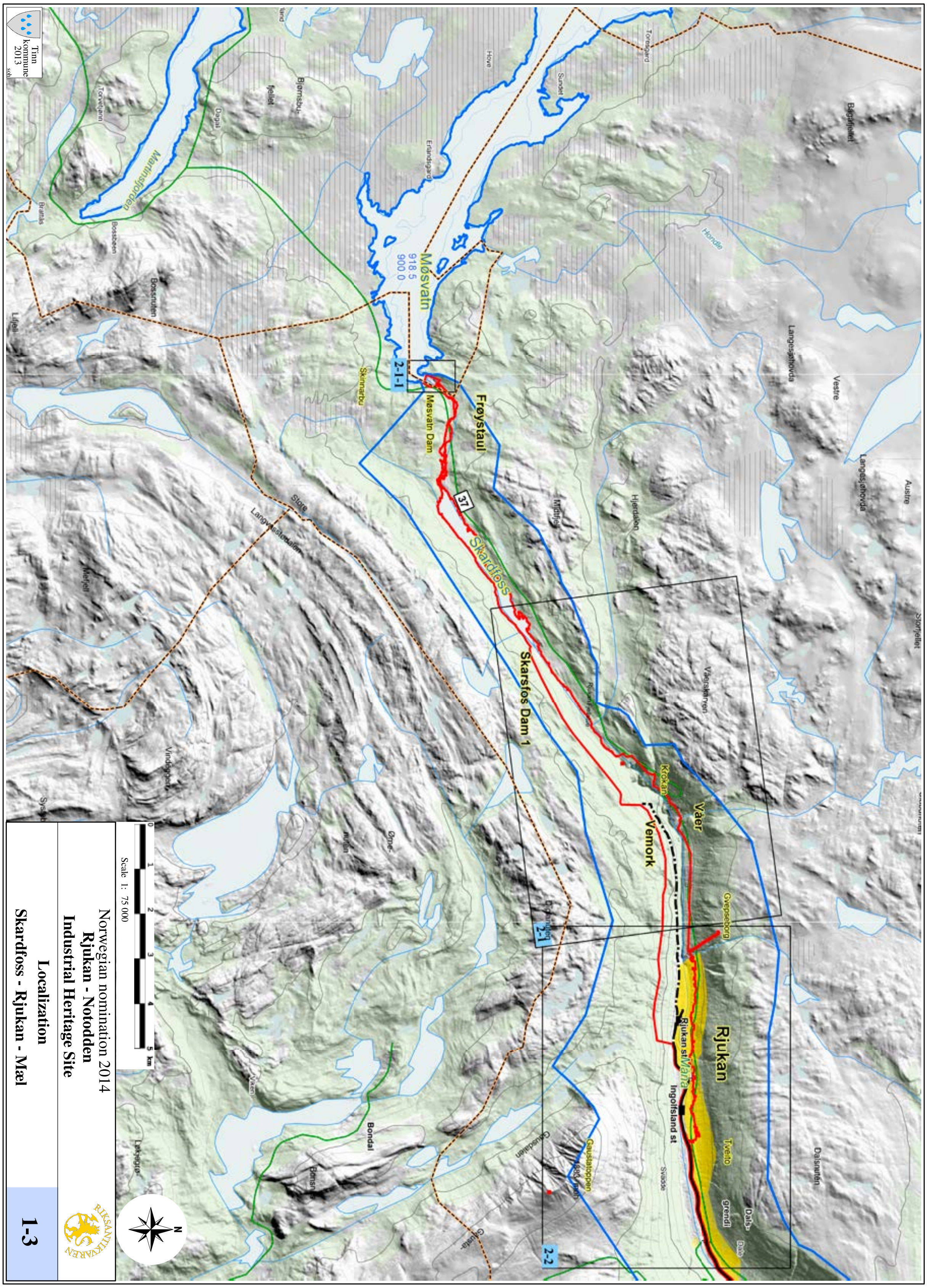
0 1 2 3 4 5 km

Scale 1: 75 000

Norwegian nomination 2014
Rjukan - Notodden
Industrial Heritage Site

Localization
Møsvatn

1-2



Norwegian nomination 2014
Rjukan - Notodden
Industrial Heritage Site
Localization
Skardfoss - Rjukan - Mæl
1-3
Scale 1: 75 000
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Tinn kommune 2013
Møsvatn
918.5
900.0
Møsvatn Dam
Frøystaul
Skardfoss
Skarsfos Dam 1
Krokan
Vemork
Våer
Rjukan
Rjukan st
Ingolfsland st
Tveito
Dals-grendi
Martinsfjorden
Gaustatoppen
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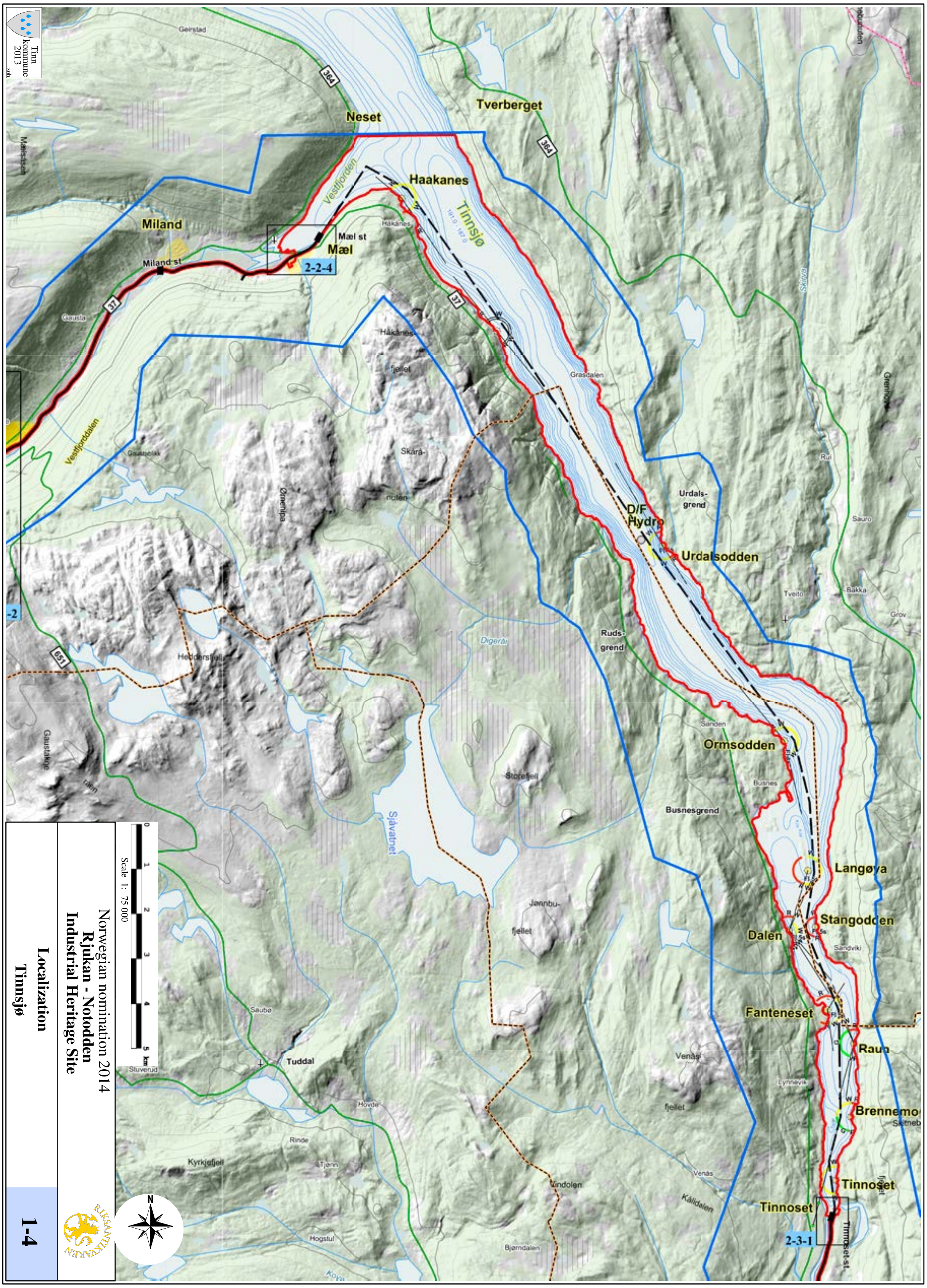
2-1-1
2-1
2-2
37


Norwegian nomination 2014
Rjukan - Notodden
Industrial Heritage Site
Localization
Tinnsjø
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Tverberget
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Vestfjorden
Miland
Miland st
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Mæl
2-2-4
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D/F Hydro
Urdalsodden
Urdals-grend
Ruds grend
Ormsodden
Busnesgrend
Langøya
Stangodden
Dalen
Fanteneset
Rauh
Brennemo
Tinnoset
2-3-1
Sjåvatnet
Tuddal
Storefjell
Jønnbu-fjellet
Heddersfjell
Skårå-
Håkanes
Gausta
Geirstad
Grasdalen
Sanden
Busnes
Sandviki
Venås
Lynnevik
Kåldalen
Bjørndalen
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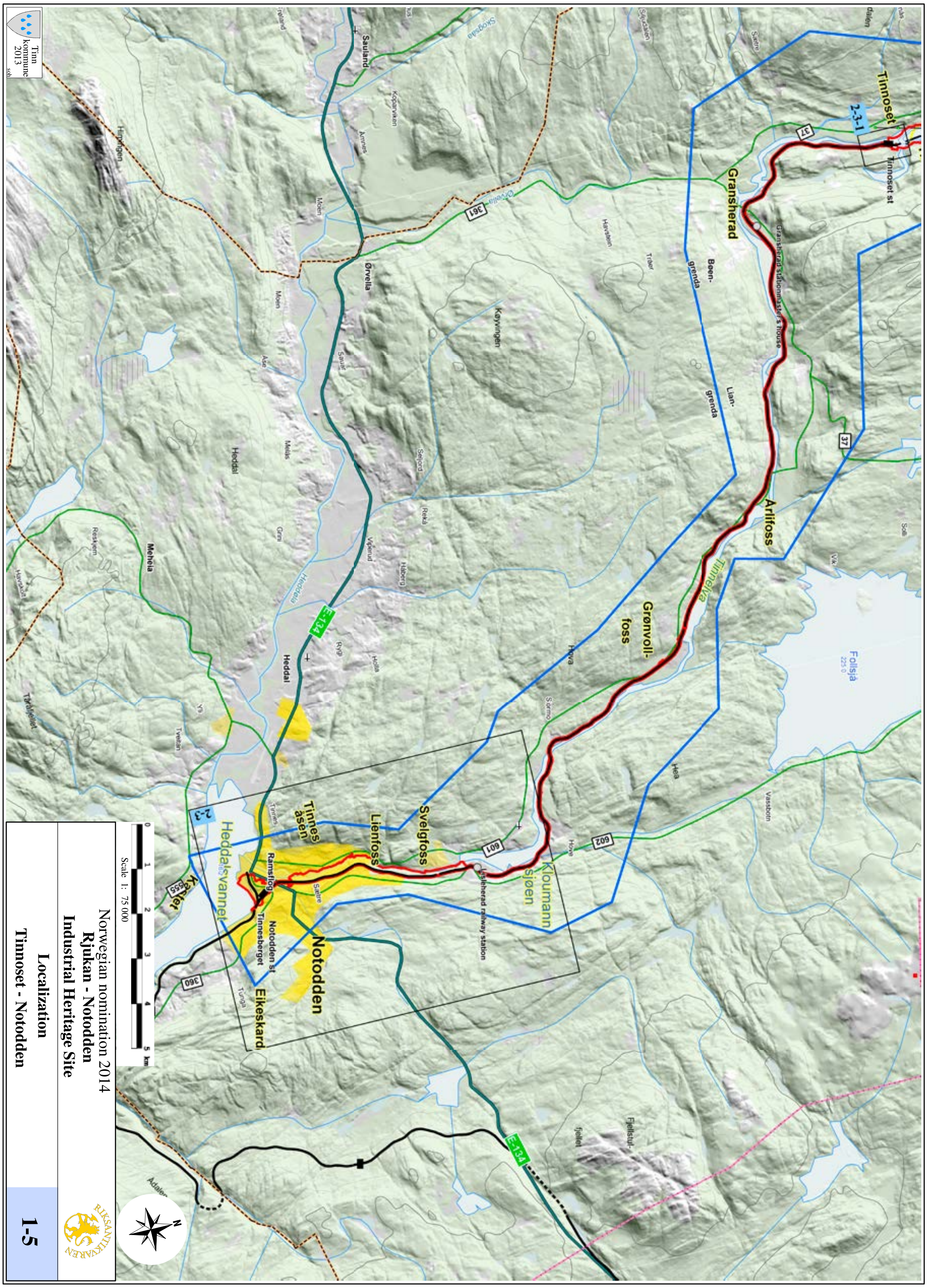
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Kloumann-sjøen
Svelgfoss
Lienfoss
Tinnes-åsen
Heddalsvannet
Notodden
Eikeskard
Heddal
Meheia
Sauland
Ørvella
2-3
E-134
37
361
601
602
360
Scale 1: 75 000
Norwegian nomination 2014
Rjukan - Notodden
Industrial Heritage Site
Localization
Tinnoset - Notodden
1-5

Proposed statement of outstanding universal value (OUV)

a) Brief Synthesis

The industrial towns of Rjukan and Notodden in Telemark county in Norway are outstanding examples of a ground-breaking industrial development and a testament to the social transformation that took place in the Western world at the beginning of the 20th century. This was a time when scientific and technological progress interlocked with economic and political factors and created what is known as 'the second industrial revolution'.

With its dramatic scenery and numerous waterfalls, Norway was an ideal location in which to establish the new type of energy-intensive industry. The industry project represents the transition from coal to hydroelectric power for industrial use, and thereby a gateway to the second industrial revolution in Northern Europe. At a time when the ways of transmitting power over long distances were limited, manufacturing facilities and local communities were set up where the power was found. Building what was then the world's largest power stations in a remote valley under Northern Europe's biggest mountain plateau was an achievement in itself. Rjukan and Notodden were built as new industrial towns for the production of previously unknown products using newly developed methods, targeting an international market. This development was performed due to domestic scientific achievements and an active entrepreneurship in close cooperation with foreign financial investors. Technologically and organisationally, the Rjukan and Notodden area emerges as a focal point for developments that took place simultaneously within and in interaction between several countries.

The two industrial towns were created as a direct response to the Western world's great demand for artificial fertilizer for agriculture. The aim was to supply the international community with a product that at the time was considered a necessity for the future of civilisation.

The transport system that had to be built to connect the factories and industrial town to the outside world and the global market is a further expression of the pioneering aspect of the industrial project in inland Norway. The system of two railway sections connected by railway ferries across a lake is in itself unique. The electrified railway contributed to the breakthrough of an international standard for electric rail operations.

The whole ensemble of power stations, factories, transport systems and company towns was created by visionary, ambitious people, whose plans were achieved through hard work and the efforts of an extensive labour force under the organisational framework of one single company: *Norsk Hydro-Elektrisk Kvælstofaktieselskab (Norsk Hydro)*. Rjukan – Notodden is thereby an outstanding manifestation of how innovation, capital and man's creative power shaped a fundamental new reality in the early 20th century.

b) Justification for Criteria

Criterion (ii)

The industrial towns of Rjukan and Notodden were established as the result of an international industrialisation process in which the use of hydroelectric power for energy production had been sufficiently developed. Internationally, the growth of new industrial products and the range of technological inventions that were created within a limited period of time led to sweeping social changes. What made these events possible was the exchange of results from science and research across national borders, of capital in an international arena for investments, and the sale of goods in a global market.

Rjukan – Notodden is the result of the changes that took place, but the towns themselves have also contributed to these changes. The production of artificial fertilizer using the electric arc method was the invention of the Norwegian physicist Kristian Birkeland. Later, the Haber-Bosch method was used and further developed in Rjukan. Rjukan – Notodden was the scene of outstanding achievements that represent an important step forward for mankind in the fields of science and engineering.

Criterion (iv)

The era of the second industrial revolution started first in the Western world, where electric energy replaced coal as a source of energy in industry, creating new types of industries, products and places. Rjukan – Notodden is one physical result and expression of this development. The proposed World Heritage includes four thematic components with associated heritage attributes for hydroelectric power, industry, transport and company towns. The whole ensemble of dams, tunnels and pipes to take water to the power stations, power lines to the factories, the industrial areas and industrial equipment, the factory towns with houses and social institutions, railway lines and ferry service with navigational devices, was created against the background of a powerful natural environment. Together, they form an outstanding example of technological innovations and industrial landscapes created under historical conditions that were present during early 20th Century, and that characterises this limited period of time.

c) Statement of Integrity

Within the proposed limitation of the World Heritage Site, all important parts of the complex industry project will be preserved. As a whole, they document the story of Rjukan and Notodden as outstanding representatives of the second industrial revolution. The nomination area will be framed by a proposed buffer zone that ensures that the whole landscape around the nominated power stations, production plants, urban communities and transport facilities is protected. There are no factors that can pose a material threat to the World Heritage values in Rjukan and Notodden.

d) Statement of Authenticity

The World Heritage Site comprises environments and individual objects with a varying degree of authenticity. All the thematic components comprise a sufficient number of environments/objects with a high degree of authenticity, so that the area as a whole contains outstanding examples in the fields of technology, urban planning and architecture.

e) Requirements for protection and management

The World Heritage Site is sufficiently protected under the Norwegian Cultural Heritage Act for the most important individual objects, and the Norwegian Planning and Building Act for bigger, more complex areas. A management plan has been prepared for the World Heritage Site. All management levels have signed a declaration of intent for protection of the World Heritage values. A World Heritage Council with representatives of all management levels will coordinate the management and contribute to positive development and sustainable use of the World Heritage status.

Contact addresses

Case officer responsible for the nomination

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Fax: +47 35 01 50 01
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N-3890 Vinje, NORWAY
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Fax: +47 35 06 23 01
E-mail: Postmottak@vinje.kommune.no

Official websites for the World Heritage Site

http://www.riksantikvaren.no/?module=Articles;action=Article.publicShow;ID=134730

Contents

1 IDENTIFICATION OF THE PROPERTY

1a. Country

Norway

1b. State, province or region

County: Telemark

1c. Name of the Property

Rjukan – Notodden Industrial Heritage Site

1d. Geographical coordinates to the nearest second

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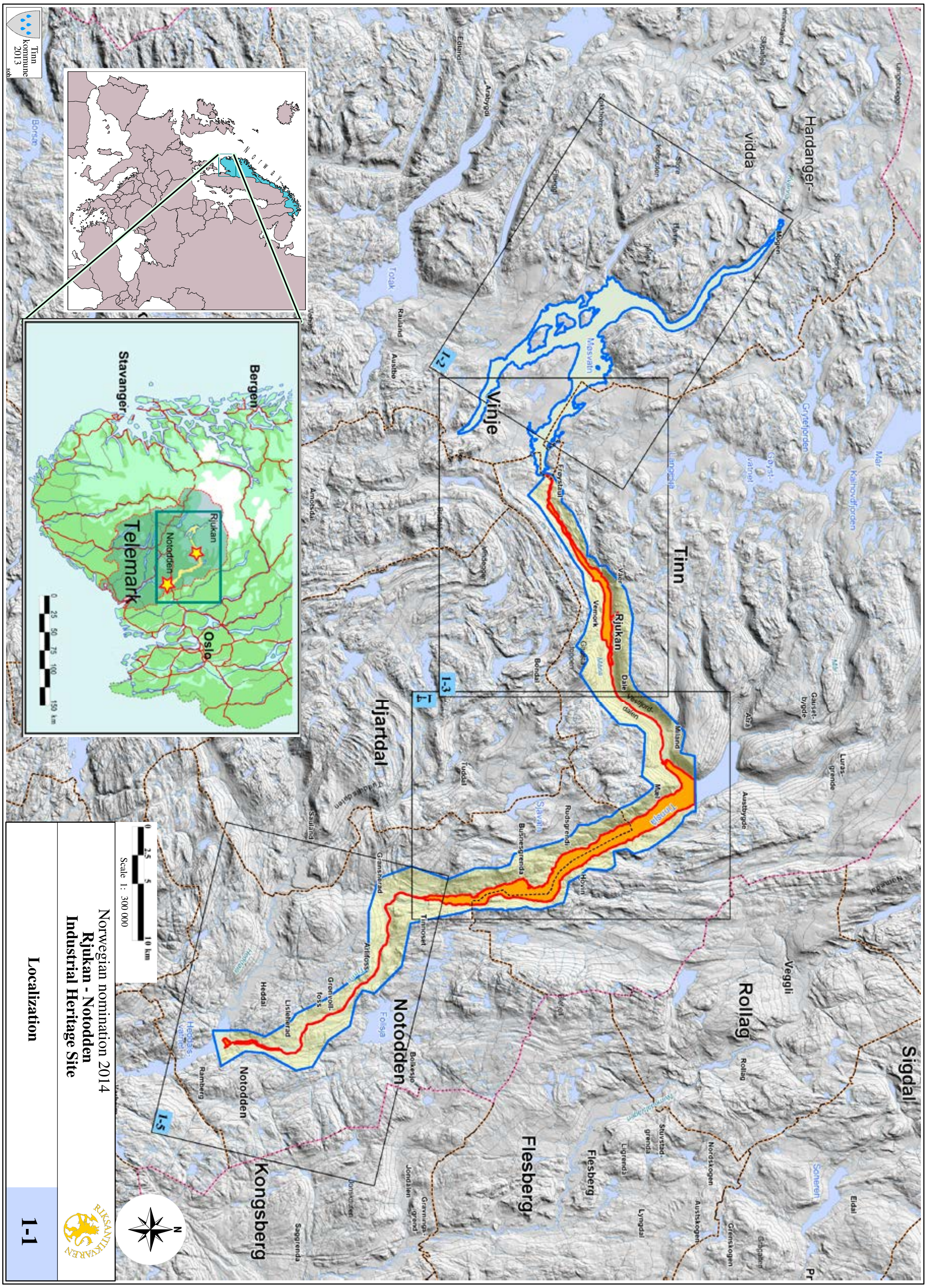
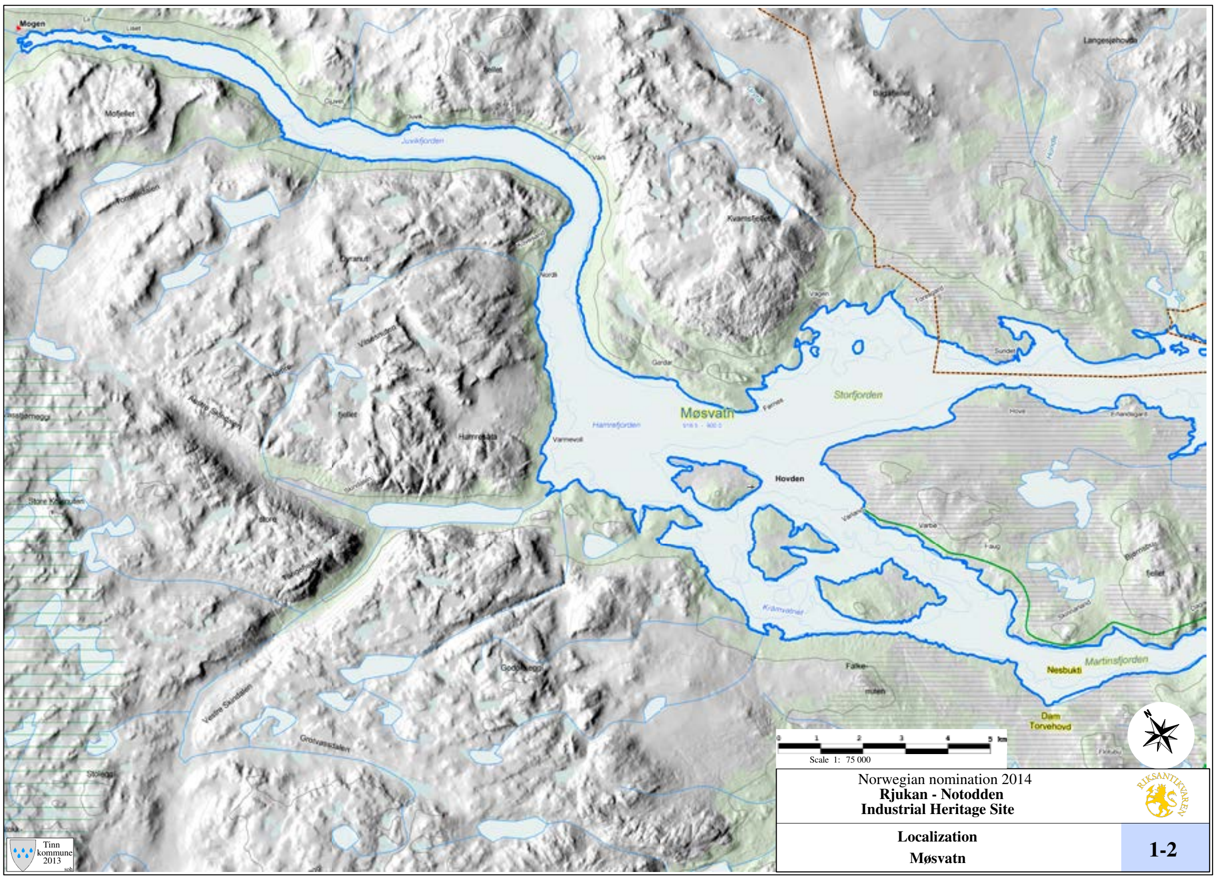
1e. Map and plans showing the boundaries of the nominated area and buffer zone

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Storfjorden
Hovden
Nesbukti
Martinsfjorden
Dam Torvehovd
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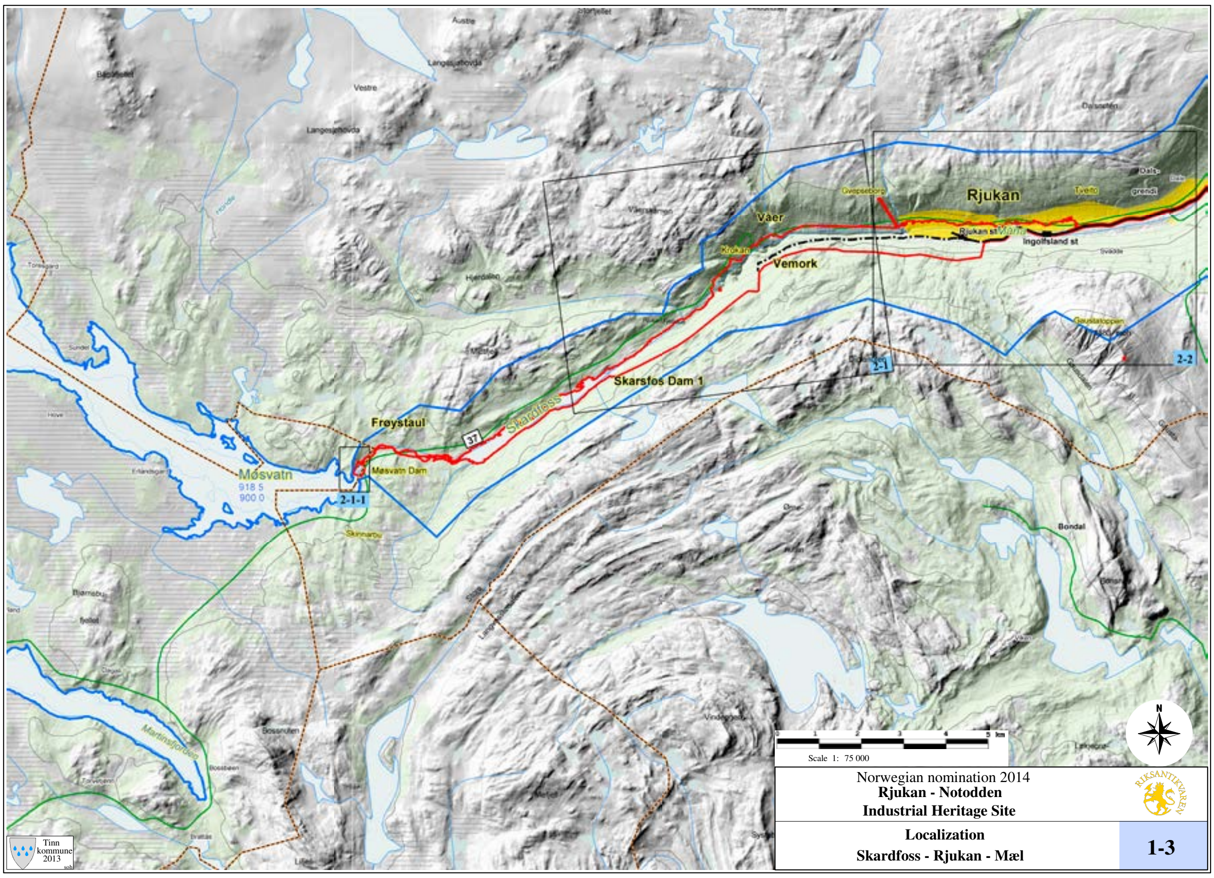
Norwegian nomination 2014
Rjukan - Notodden
Industrial Heritage Site
Localization
Møsvatn
1-2
Tinn kommune 2013


Rjukan
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Skardfoss
Frøystaul
Møsvatn
918 5
900 0
Møsvatn Dam
2-1-1
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2-2
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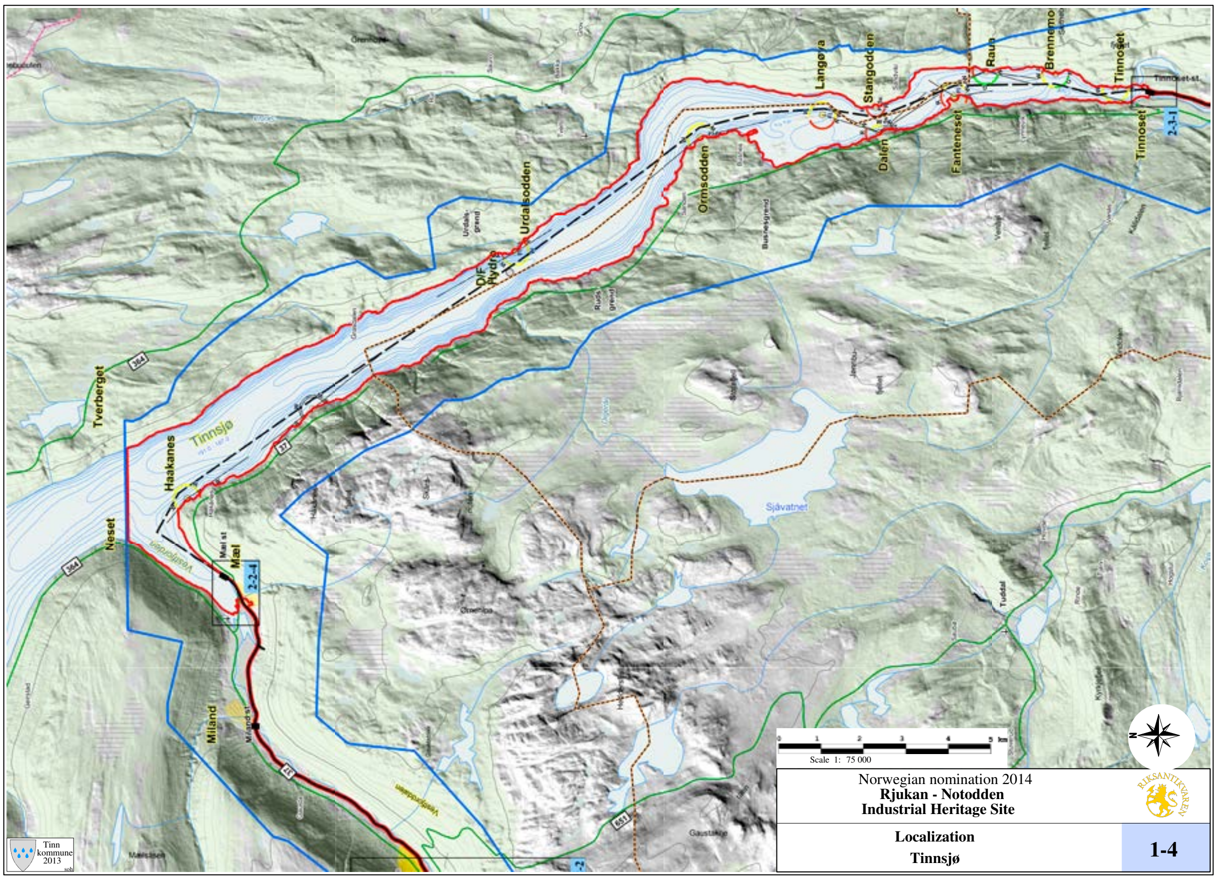
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Haakanes
Neset
Mæl st
Mæl
2-2-4
Miland
D/F Hydro
Urdalsodden
Ormsodden
Langøya
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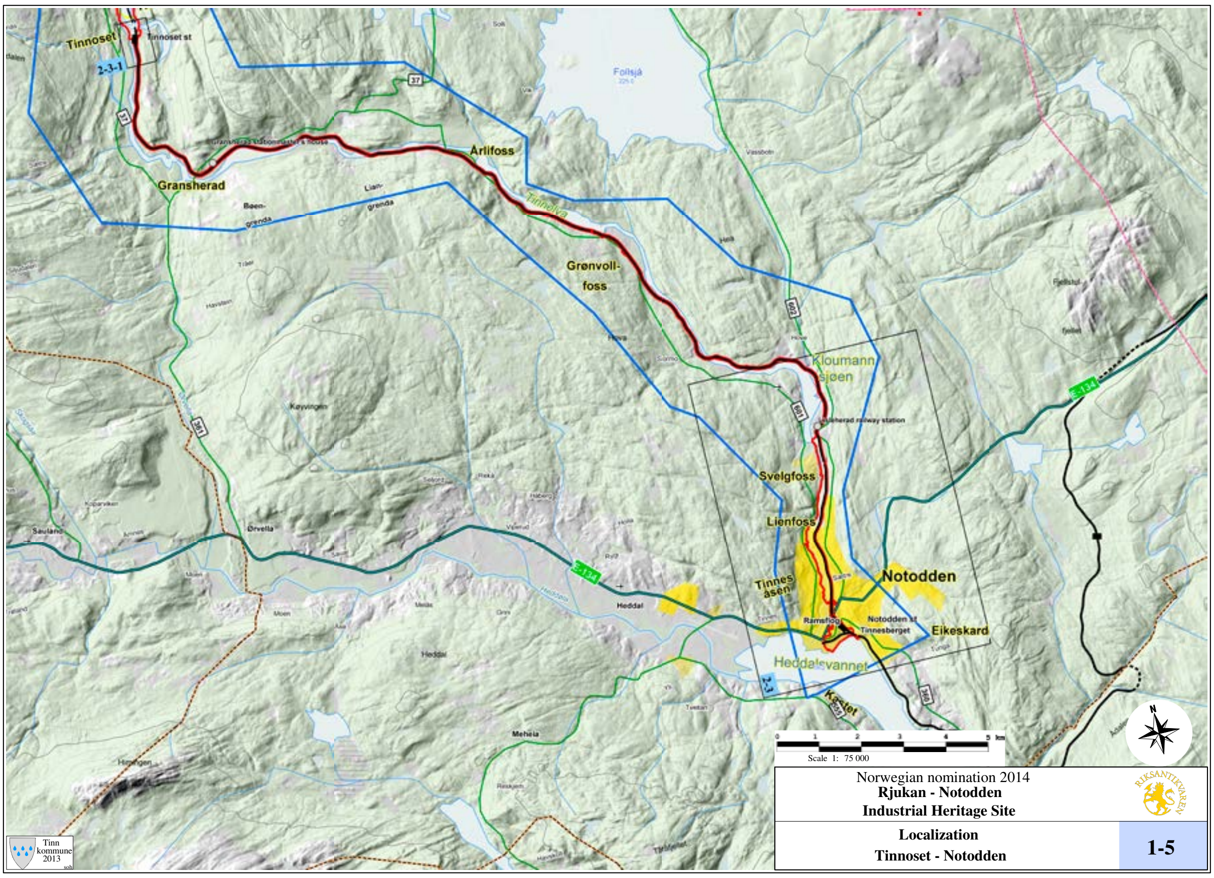
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2-3-1
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Årlifoss
Grønvoll-
foss
Kloumann
sjøen
Svelgfoss
Lienfoss
Tinnes
åsen
Notodden
Eikeskard
Heddalsvannet
Heddal
Folsjå
2-3
Tinn kommune 2013

1f. Area of nominated property and proposed buffer zone

Municipality	Nominated area ha	Buffer zone ha	Area of property + buffer zone ha
Notodden	1 690.5 (16.9 km^2)	13 314.1 (133,1 km^2)	15 004.6 (150.0 km^2)
Tinn	3 247.1 (32.5 km^2)	13 364.6 (133.6 km^2)	16 611.7 (166.1 km^2)
Vinje	5.1 (0.05 km^2)	7 305.8 (73.1 km^2)	7 310.9 (73.1 km^2)
Total area	4 942.7 (49.4 km^2)	33 984.5 (339.8 km^2)	38 927.2 (389.3 km^2)

Description of the area's boundaries

The boundaries form a geographically coherent area, in which four different components successively constitute this whole in different ways. The delimitation of the nominated area relates to distinct characteristics of each of the components. The distinctions are based on historical facts, property boundaries and topographic conditions.

The historical basis is the industrial company Norsk Hydro and its subordinate enterprises. The company has been restructured, properties have been sold and enterprises have either been closed down or modernised. In many cases, the property boundaries reflect the original historical conditions.

Geographically, the boundaries of the World Heritage Site follow the water flow from the Møsvatn regulating reservoir on the Hardangervidda mountain plateau down to Heddalsvatnet lake, a stretch of 93 km. The basis for the boundaries is formed by the Måna river from the old Møsvatn dam through the Vestfjorddalen valley down to Tinnsjøen lake, and the water surfaces of Tinnsjøen from Vestfjorden southwards to Tinnoset and then Tinnelva river. Where the water leaves its natural course and runs through tunnels and pipes to be used in power production, the boundaries follow the outside of these installations. The same principle applies where the railway forms the outer line of technical installations along the watercourse. The areas between the natural watercourses and the linear structures for water tunnels or the railway track will then fall within the boundaries of the proposed World Heritage Site. The course of water as it defines the boundaries only include sections where the water was actually used by Hydro and Tinfos AS for power production around 1920. Subsequently, the Måna river downstream of Såheim and the Tinnelva river upstream of Svelgfoss have been left out. Between Svelgfoss and Såheim, it is the transport system that connects the areas, i.e. the railway sections and (part of) the water surface of Tinnsjøen. By the lighthouses, the boundaries of the proposed World Heritage Site run from the shoreline of Tinnsjøen and then onshore in a circular arc around the lighthouses. By Rjukanfossen in Måna, the river canyon is included, and the boundary then follows the power line's path down to the town of Rjukan. In the urban communities of Rjukan and Notodden, and certain junction points in the systems, the communities are included as far as to what they had extended during Norsk Hydro's establishment phase until this phase was complete. In Rjukan, where areas used for industry and housing form a long, integrated area in which the river divides the functions, the boundaries follow the outer edge of the built-up area as it was in 1930. In Notodden, Hydro's housing areas in the immediate vicinity of its own factories are included and the end of the transport system by the lake. The boundaries leave the Tinnelva river at the Tinnfoss waterfall, and are connected to the Hydro areas in the southern part of the town through the railway tunnel.

The buffer zone is a protective zone around the four components. Its limits cover the landscape spaces in which the proposed World Heritage Site is located. The topography creates a very distinct landscape. From the mouth of Møsvatnet lake, the boundaries cover the landscape areas where the Måna river runs through a deep valley (Vestfjorddalen valley), the Tinnsjøen basin (south of the Neset-Tverrberg line), and the course of the Tinnelva river through a valley to Heddalsvatnet lake. The boundaries of the buffer zone run between distinct peaks in the terrain – including the summit of Mount Gaustatoppen at 1 883 metres – and roughly match the horizon seen from the valley floor with its river, buildings and railway, or from vessels on Tinnsjøen lake. The buffer zone ends in the south in a straight line from Eikeskard (416 metres) across Heddalsvatnet to the road upside of Kastet point on the west side, and northwards from this towards Tinnes, following the edge of the hill to the top of Tinnesåsen (327 metres). From the upper side of the old Møsvatn dam, the lake becomes a representation of the natural resource that is made up of water from its total catchment area. Here the contours of the surface of Møsvatnet lake at the highest regulated water level define the buffer zone for the nominated World Heritage Site.

2 DESCRIPTION

2a. Description of property

The industrial heritage that is proposed for inscription on the World Heritage List comprises a cluster of power plants, factories, transport systems and towns that were created to manufacture artificial fertilizer from the nitrogen in the air for delivery to the world market, all under the auspices of Norsk Hydro, a company whose establishment was based on this very idea. The area consists of central parts of the industrial towns of Notodden and Rjukan, and includes the watercourse with its plants for hydroelectric power production, from the Møsvatn dam upriver from Rjukan to Heddalsvatnet lake at Notodden, as well as the overland and lake transport systems between the industrial sites.

The towns of Rjukan and Notodden were established as industrial communities in the 20th century. The same industrial magnates were involved in the founding of both towns and, from an industrial perspective, they constitute an integrated functional unit even though the distance between them is 80 km. The processes and objectives on which Norsk Hydro's factories based their manufacturing were the same, though the work was to some degree divided between the two towns. The distance was surmounted by the inclusion of a transport system in Hydro's project, together with housing and a social infrastructure in the urban communities that were established next to the factories, and the power plants that supplied them all with electricity. The cultural heritage that is proposed for inscription on the World Heritage List is made up of selected buildings and facilities based on four different thematic components that were synchronically created by the same powers to form a unit that effectively functioned as a single entity. The unit represents a unique expression of new industrial developments during the Western world's second industrial revolution. The description of the individual parts of the Cultural Heritage nomination is structured on the basis of each of the four components.

The proposal is made up of the following four components:

- **Hydroelectric power production**: Power plants and facilities for the utilisation of water courses for electrical power production, upstream as far as the water reservoir dam.
- **Industry**: Remaining parts of facilities, building stock and plant and machinery for the electrochemical processing industry that was adjoined to the power plants or was supplied by them.
- **Transport system**: The infrastructure that was built to export manufactured goods from the factories to the existing point of contact with the world market (i.e. from Rjukan to Notodden that was situated along the already canalised river system).
- **Urban communities** of the 'company town' type, i.e. planned and built by the enterprise that was behind the industrial development, as a necessity in order to achieve its economic goals.

The towns of Rjukan and Notodden are vibrant urban communities. The proposed world heritage site includes physical structures and objects that are a testimony to a period of industrial pioneering, where all four components are **delimited in time** on the basis of Norsk Hydro's establishment and operation. The selection of objects included in the nomination reflects the distinctive nature of the components going forward in time (on the time axis). Schematically:

- **Hydroelectric power production:** First-generation plants (1915).
- **Industry:** Up to and including World War II (1945).
- **Transport system:** Establishment and consolidation phase with upgrading (up to the 1950s).
- **Housing and societal infrastructure:** The establishment phase leading up to the complete urban community (approximately 1930).

Hydroelectric power production

The four components were established for the purpose of providing the fertilizer Norway saltpetre to the world. Here a barrel from the early years. Photo: Norsk Hydro.

The company **Norsk Hydro** was formed with the object of manufacturing synthetic nitrogen fertilizer based on the patented **Birkeland/Eyde process**. The production of 'Norway saltpetre' (calcium nitrate) using Birkeland/Eyde furnaces was very energy-intensive. Access to relatively inexpensive hydroelectric energy from Norwegian watercourses was a key factor in Hydro's success. Transporting electrical energy over wide distances appeared to be costly and technically immature, however. Notodden and Rjukan are inextricably linked through the development of hydroelectric power plants that quickly developed from small first-generation plants to plants of a size and complexity that placed them at the global forefront.

Hydro's test facility in Notodden was based on power supplied by the industrial company **Tinfos AS's power plant in Tinnfossen waterfall** outside Notodden, the Tinfos I power plant from 1901. Both Tinfos I and Tinfos II (completed in 1912) were relatively small plants. Tinfos II is interesting, however, because of the special system whereby water was supplied through a separate canal. By 1907, Hydro had built a first power plant of its own, 4 km upriver: **Svælgfos Power Plant**, which, at that time, was the **biggest in Europe** and the second-biggest in the world after Ontario Power by the Niagara River. This was a time of breakthroughs in the large-scale use of electricity for industrial processes, and Svælgfos was a pioneer plant at a time when there was little experience internationally. Vemork Power Plant in Rjukan was likewise a **pioneer plant** for the production of hydro-electricity. With its great height, the Rjukanfossen waterfall had an energy potential of 250 000 hp, which was much more than the energy potential of around 45 000 hp that Svelgfoss waterfall represented. A development the size of Rjukanfossen had never been tried before. Because of the rugged terrain, the water had to be supplied through a headrace tunnel, a method that required the development of blasting techniques and the production of machinery and pipes. At the same time, the uneven water supply had to be controlled, and this was achieved through extensive regulation of

Møsvatn lake, which became the site of the first concrete dam in Norway. In principle, **a completely new type of power plant** was created: a high-pressure system with a great head of water, rock tunnels and watercourse regulation in the high mountains. **Vemork** and **Såheim** were pioneering plants in the development of hydroelectric power. Vemork (Rjukan I) was the **world's biggest** power plant when it started up in 1911. It was followed by Såheim (Rjukan II) in 1915, which was even bigger.

The industrial component

The industrial component of the nominated area is made up of Norsk Hydro's original industrial areas in Notodden and Rjukan. The fact that Notodden was already a traffic hub and industrial community was a key factor in Norsk Hydro's decision to invest in Rjukan. During a critical phase of development, **calcium nitrate fertilizer ('Norway saltpetre')** was manufactured in a separate **Test Factory in Notodden**, yielding results that the foreign investors found satisfactory.

The two industrial sites have several features in common, in that production is to some extent based on the same processes. In Rjukan, the facilities are on a different scale, as they were designed for large-scale production, while the facilities in Notodden were intended for test production. The **Furnace House** and **Tower House** are prominent elements in a production line based on the electric arc process. This piece of history is conveyed through different structures in Notodden and Rjukan – Notodden has preserved the shell of a tower house while Rjukan has preserved an acid tower as relics of the original facilities. When the industrial process was changed in 1928–29, the two industrial sites developed differently. In both places, industrial production has continued inside the factory buildings that were part of Hydro's facilities, now also with Rjukan as the centre of larger-scale production, by enterprises that are historically linked to Hydro and its activities.

The transport component

Norsk Hydro's decision to establish factories next to the power plants in the Vestfjorddalen valley made it necessary to construct a transport system for contact between Rjukan and the global market, where the products were to be sold. The transport system that was essential for Rjukan's factories also functioned as the urban community's contact with the outside world. The transport system was organised in Norsk Transportaktieselskab, a separate company owned by Norsk Hydro, and consisted of **two railway sections** and two **ferry crossings**. Both railway sections ran as far as the quay at Tinnsjøen. The terrain alongside the lake is steep and inaccessible, and instead of laying expensive railway tracks through difficult terrain, the lake was crossed using railway ferries. The railway ended at the quayside by Heddalsvatnet lake in Notodden, where the watercourse running down to Skagerak had been canalised as early as in 1861 via the Telemark Canal in Skien. The two railway sections, the **Tinnoset** and the **Rjukan Line**, including the ferry sections, are no longer in use, but the system is still operative. The interconnected transport system between Notodden and Rjukan is one of the grandest and most ambitious infrastructure systems still in existence from Norway's early industrial history.

The urban community component

The establishment of an industry for the production of artificial fertilizer using hydroelectric power on a massive scale led to the construction of a transport system and, as a result of the location, also to the establishment of urban communities around these facilities. **Rjukan** was built from scratch as a **Hydro town**. Parts of **Notodden** were built by Hydro, though the Tinfos Company was also an important force. The housing that was built by these companies was characterised by the contemporary architectural style, though Hydro did more to develop its own style of housing than Tinfos did. The British garden city concept is a principle of urban design that can be recognised in both communities. Although it is on a smaller scale in Notodden, Notodden came first and served as a model for the construction of Rjukan.

Rjukan has all the features of a 'model town' or 'company town', and was, as such, the first planned industrial town in Norway. Rjukan has a more extensive Hydro history than Notodden, and Hydro's imprint is generally greater and much more dominant in the urban landscape there than it is in Notodden. Nonetheless, there are many features in Notodden's spatial design and urban development that can be ascribed to Sam Eyde and Hydro's dispositions and activities. Sam Eyde drew on experience from Notodden when planning Rjukan, where better organisation of planning activities for instance meant that water and sewage networks were designed at an early stage.

Norsk Hydro and the properties of today

In recent years, Norsk Hydro has been restructured and it is no longer involved in industrial activity in Rjukan or Notodden. The company is now named Hydro ASA and listed as an energy and metallurgical company (aluminium) on the stock exchange. Of the original industrial activities, the company is still active in power production and remains an important industrial player in that area. Hydro has retained its **hydroelectric power plants**. The power plants are owned by Hydro Energi, which is a separate division within the group. With 17 power plants in different parts of Norway, it plays an important role and is Norway's second biggest producer of hydroelectric power. Several of its power plants are also among the biggest in the country. The power production is administered from Oslo and monitored from a joint control centre in Rjukan. Today, the power plants have either been modernised or the original power plants have been supplemented by new ones. Hydro Energi is Norway's biggest listed energy company outside the petroleum sector, with an annual production of 9.4 TWh in a normal year.

The parent company has sold the industrial areas that held Norsk Hydro's factories in Notodden and Rjukan, which now have commercial owners that lease out the premises and areas to a large number of different enterprises. The area previously occupied by Norsk Hydro's factories in Notodden is now a single property called Hydroparken ('the Hydro Industrial Park'). With a few exceptions, Rjukan Industrial Park covers the entire factory area that was previously owned by Hydro in Rjukan. Today, the company Hydro focuses on the production of aluminium. Hydro Agri, the artificial fertilizer division, was hived off as a separate company in 2004 and is now listed on Oslo Børs under the name Yara International ASA. Yara continues to manufacture artificial fertilizer in its factories at Herøya and in several places overseas. Symptomatically, Yara has also taken over Norsk Hydro's old logo with the Viking ship motif. Gas is being produced in the uppermost and newest part of the industrial site in Rjukan, in buildings from 1928 where Hydro manufactured nitrogen fertilizer based on the Haber-Bosch method, by a subsidiary called Yara Praxair, which is now under US ownership.

The **Rjukan Line** was closed down in 1991 when production in Rjukan was cut back and then closed down completely. The track, rolling stock and vessels are intact and have museum value. They have been owned by a foundation, which was consolidated into the Norwegian Industrial Workers' Museum at Vemork in 2012.

The housing is currently privately owned. Hydro started to sell off the houses in the 1980s.

The development of the logo from the initial ears of corn with Birkeland and Eyde's initials arranged around stylised electric arc furnace (to the left). The Viking ships, designed by Thorolf Holmboe, was introduced around 1910. Simplified versions were designed in the 1950's and 1960's, until Leif Anisdal stylised the design in 1972 and dropped the waves. The name Hydro was added i 1990 and later Yara.

Overall description of the components and their attributes

In the following section, the thematic components of the nomination proposal and their attributes are described at the overall level. A catalogue with detailed descriptions of significant objects that fall under the individual attributes is provided at the end of section 2.a, starting on page 80.

Table of the components' attributes and pertaining significant objects

Attribute	Number	ID no	Total no of significant objects
Hydroelectric power production	6	1–6	18
Industry	3	7–9	32
Transport system	2	10–11	20
Company town	2	12–13	27
Total	13	_	97

Hydroelectric power production. Buildings and facilities (1–6)

The hydroelectric power production component is made up of power plants, penstocks, tunnels with adits and waste rock dumps, intake and distribution reservoirs, regulating dams and other objects that belong or have belonged to this activity, including transmission systems to the industrial areas. The power plant facilities thus have a certain geographic distribution, and some of them are inside rock caverns and invisible from the surface. The area thus includes and is bound together by drained river beds and waterfalls. Traces of construction work and temporary facilities will constitute supporting values where the loss of authenticity and/or integrity is considerable.

The power plants that are proposed as World Heritage are those that were built by or delivered to the company Norsk Hydro for its production of calcium nitrate from the start in 1905 until 1940. They are all located along the East Telemark watercourse before it runs into Heddalsvatnet lake in Notodden. A total of 10 power plants are currently in operation along this watercourse, three of which are included in the nomination proposal. The largest and most important are Hydro's own **Vemork (Rjukan I)** and **Såheim (Rjukan II)** power plants in the Måna river outside Rjukan. The production equipment has been upgraded, but the plants are otherwise intact. From the time that Hydro started production in Notodden, only the company Tinfos AS's **Tinfos II** remains intact and operative. The **Tinfos I** plant has been replaced by a new plant and only the empty shell of a building remains. Hydro's own Svælgfos I and II and Lienfos plants in the lower part of the Tinnelva river have been demolished down to the turbine generator floor and replaced by one new underground plant in a rock cavern.

Today, Hydro Energi is among the biggest producers of hydroelectric power in Norway. The company's history as a power producer started at the Svelgfoss waterfall in Tinnelva. Hydro, whose majority owners were foreign at the time, built a series of large power plants in a short space of time, mainly in order to supply the new calcium nitrate industry in Telemark. This gave rise to a political process that ended up with the adoption of laws whereby, subject to certain conditions, government concessions were required to utilise Norway's watercourses for the production of electricity. However, Hydro's plants from the initial phase were built before the concession laws were adopted and are therefore exempt from the requirement that they revert to the state (after 60 years).

During the period from 2011 to 2015, Hydro Energi is investing a total of NOK 850 million in upgrading the five power plants in the Rjukan string between Møsvatn and Tinnsjøen. These are mandatory measures imposed by the authorities. The plants have an aggregate annual capacity of approximately three terawatt hours (TWh), corresponding to approximately 30% of Hydro's total production in a normal year. The waterways are being upgraded, including the construction of a new dam at Skardfoss waterfall, new control and power distribution systems are being installed and generators and turbines are being renovated. A higher level of safety will be achieved and production loss due to faults and outages will be reduced.

Power plants that represent central values in the nomination proposal

	Central values in the nomination proposal			Supporting value
Company	**In operation. Original buildings and plant**	**In operation. Modernised plant**	**Phased out. Buildings intact, plant removed**	**Phased out and demolished. Foundations and remains ofbuildings**
Norsk Hydro		Vemork Såheim		Svælgfos I Svælgfos II Lienfos
Tinfos AS	Tinfos II		Tinfos I	

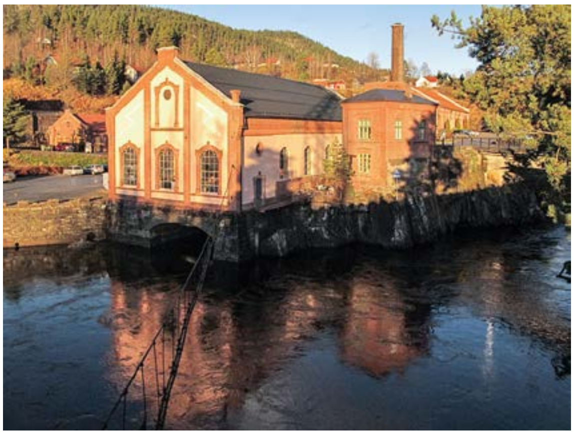
Ruins and remains of temporary power plants can be found below Rjukanfossen and at Kvernhusfossen waterfall in the Måna river, inside the proposed World Heritage Site. The same applies to certain facilities left behind from the pre-electricity era of hydroenergy resource exploitation, including the timber flume in the Tinnelva river from Kloumannsjøen lake below Tinnfossen waterfall in Notodden. This is described in the section *Supporting values*.

A number of power plants in the Tinnelva and Måna rivers are not part of the nomination. The New Tinfos I power plant in Tinnelva in Notodden is within the proposed World Heritage Site, but since that plant is of more recent origin and not linked to Hydro's history, it is not being emphasised as of material value. The rest of the power plants are in the buffer zone. This applies to a number of power plants built by Hydro after 1945: New Svelgfoss in Tinnelva in Notodden, and the Mæl, Moflåt and Frøystul II power plants in or near the Måna river in Tinn. All these plants are underground plants built inside rock caverns. The buffer zone also includes the river power plants at Grønvollfoss and Årlifoss waterfalls, both located in the Tinnelva river in Notodden, and Mår power plant which is located in Vestfjorddalen valley in Tinn but utilises water transferred from reservoirs by Mårvatn lake and Kalhovd east of Møsvatn lake. These power plants are described in the section on *Cultural conditions in general* under 2.a on page 226-229.

Tinfos AS's power plants (1)

The Tinnfossen waterfall in Notodden was the starting point for fumbling and hectic industrial activity around 1900. A pulp mill was followed by a paper mill. Following the bankruptcy of the paper mill, Tinfos AS focused on carbide, and then ironworks, both of which were new and energy-intensive industries. ***Tinfos I*** power plant *(object 1.1)* was a river power plant put into operation in 1901, and was thus one of the nation's first. An intake dam was built in the former intake for the paper mill by the western river bank. ***Tinfos II*** power plant *(object 1.2)* was opened in 1912, to supply power to the ironworks at Heddalsvatnet, which were the first in Norway to use electric furnaces. The plant was on the eastern shore of the lake, and was fed with water from a 900-metre-long headrace canal so that most of the fall of the river could be utilised. The canal is the only one of its kind. Today, the power plant has been in continuous operation for more than 100 years.

Tinfos I just after 1907, painted by Thorolf Holmboe for Tinfos AS.



Tinfos I today. Photo Trond Taugbøl.

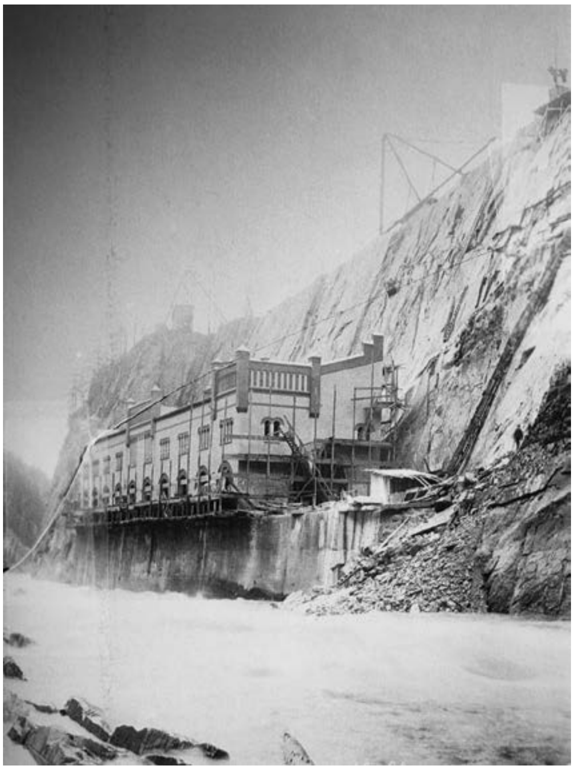
When a test plant was built there to produce nitrogen in accordance with Birkeland/Eyde's method, Sam Eyde leased 2 000 hp in January 1904 from the company Tinfos AS for *'continued Test Operation with a Method invented by Professor Birkeland to recover Nitrogen from the Air'*. In a contract of 16 April 1904 between Tinfos and Hydro (signed by Knut and Marcus Wallenberg and Sam Eyde), Tinfos undertook to deliver 2 000–2 400 hp for three years starting in mid-1905. Only a couple of months passed before a further 3 000 hp was requested. This required the building of a nine-metre extension to the power plant and a small annex. During World War I, Hydro was constantly in need of more power and, in 1916, it once again bought additional power, this time from Tinfos II under a private agreement between Hydro and Tinfos. The power from Tinnfossen waterfall was a key factor in the establishment of Norsk Hydro.

At present there are also two power plants in Tinnfoss, and both use a total head of 29 metres created by damming up the Sagafossen waterfall upstream of Tinnfossen. The Sagafoss dam was built for the New Tinfos I power plant in 1955, whereby the Myrens dam and the old Tinfos I power plant were phased out. Tinfos AS's two power plants in Tinnfossen, New Tinfos I and Tinfos II from 1912, are the lowermost power plants in the East Telemark watercourse, and they enjoy a stable water supply through the regulating reservoirs that were established for the power plants further upstream. Tinfos II still uses the original power production machinery.

Hydro's power plants in the Tinnelva river (2)

The first power plant that Hydro built itself was at Svelgfossen waterfall, approximately 5 km from the factories that were to be built down by Heddalsvatnet lake. ***Sværlgfos I*** was a pioneer plant in hydroelectric power production, situated in a narrow river gorge. The power plant was run in direct cooperation with the calcium nitrate plant in Notodden.

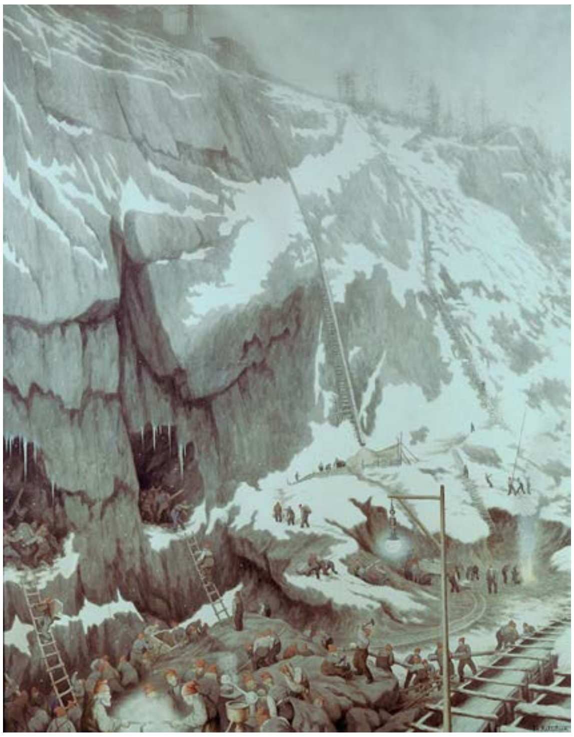
When Sværlgfos I was built, the only available regulating capacity was provided by the regulating dam for Tinnsjøen that was built around the same time, and the first regulation of Møsvatn. With the extension of Møsvatn dam and the regulation of Mårvatnene lakes, the water flow in Tinnelva could be increased. Sværlgfos II was built to utilise this water flow and to provide backup power. Sværlgfos I proved to have numerous and persistent teething problems and its operation was unstable for several years. The generators were constantly burning out, thereby shutting down the plant and threatening its operations. Internationally there was little experience of power plants the size of Svelgfoss, but, as it turned out, similar problems were encountered in the big plants for electrically powered metros in Paris and Hamburg and in a large power station in Mexico. The manufacturers' engineers were repeatedly summoned to Notodden. Hydro convened an expert committee of electrical engineers, and it concluded that the commutator for switching power to the rotor coils was incorrectly constructed and generated such high temperatures that the insulation burnt out. Hydro had implemented numerous measures to remedy the problem. A *separate* ***lightning arrester and workshop building*** *(object 2.1)* was built for the power plant. The light-



Sværlgfos I in 1908. Photo: Norsk Hydro ning arrester was probably the world's biggest. The world's first big power station, Adams Station at Niagara, was equipped with a lightning arrester and probably served as a model. The lightning arrester building is representative of the trial-based pioneering activity that was carried out to eliminate functional faults in the system. The construction of Svælgfos II as a backup plant can also be seen from this perspective. During this period, Hydro would occasionally buy power from the Tinfos plants to ensure stability.

Seen as a whole, the power plants were pioneering facilities, not only because they were the biggest in Europe and second-biggest in the world after Ontario Power Company's facilities at Niagara, but also because of the development of satisfactorily functioning large pieces of machinery – no larger generators had ever been built. The challenge of constructing a dam across a flood-prone watercourse and the decision to locate the power plant beside the river at the bottom of a gorge made the construction work very difficult. Four hundred men worked continuous shifts, and several weeks' work was destroyed by floods on several occasions. The calcium nitrate plant in Notodden, the recipient of the power, was also an industrial pioneer in electrochemistry, and Norsk Hydro, which was behind it all, was innovative in its coordinated operation of the facilities. After visiting the plant, the German industrial leader Carl Duisberg of the Bayer Group was of the opinion that even Niagara could not compare to Svelgfoss, – *'Never before have I seen such a beautiful and magnificent hydrotechnical plant'* he acknowledged. Svælgfos I and II are described in more detail in the section *Supporting values*, under Svelgfoss cultural environment, on page 197-201.

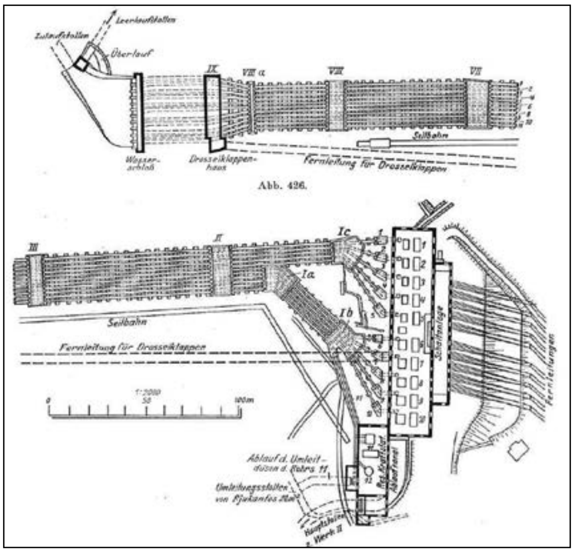
"Svælgfos" by Theodor Kittelsen for Sam Eyde. The vision of Sam Eyde visualised by the artist. Owned by Norsk Hydro.



"Groundwork" by Theodor Kittelsen. Starting to realise the vision of Sam Eyde visualised by the artist. Owned by Norsk Hydro.

Hydro's power plants in the Vestfjorddalen valley (3–4)

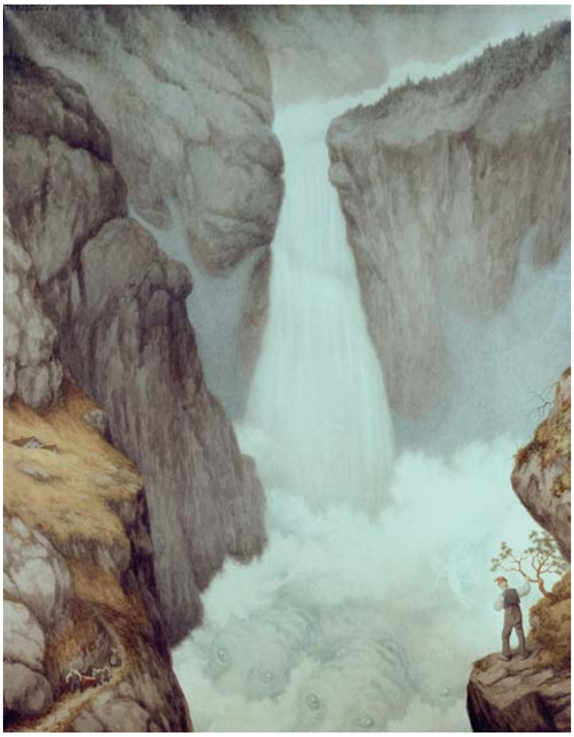
It is the power plants that Hydro built in Vestfjorddalen before 1920 in order to utilise the fall of the Måna river from Møsvatn to Såheim in Rjukan that are included in the nomination, with the Vemork plant furthest upstream and Såheim furthest downstream. These power plants include a system of tunnels, adits and spillways between the water intake at Skardfoss and the distribution reservoir, and penstocks down to the power plants and generator sets. The Vemork Power Plant's position on a plateau approximately 125 metres above the valley floor is quite unusual for a power plant and was the result of a decision to utilise the total fall of approximately 570 metres between Skarsfoss and Rjukan town in two plants, each utilising approximately half of this fall. The factory plant was put into production in step with the opening of the power plants, with Vemork supplying power to Rjukan I and Såheim to Rjukan II.



The general arrangement plan for Vemork power plant, from Ludin Adolf: Die Nordische Wasserkräfte, Ausbau und wirtsch. Ausnutzung, 1930.

Vemork Power Plant *(objects 3.1–3.5)* was **the world's biggest** when it was completed in 1911. It utilises 299.5 metres of the fall of the Måna river down to past the Rjukanfossen waterfall. With a length of 110 metres, the stone-clad buildings of the power plant stand out in the landscape, creating a harmonious interplay between the majestic buildings and the magnificent natural surroundings. The building has the appearance of an illuminated fairy-tale castle, particularly in wintertime. It was designed to be a genuine and sound Norwegian construction, *inter alia*, through the use of carved granite in the foundations and façade cladding. Sam Eyde wrote that *'The stern lines of the building were in excellent harmony with the steep, hard landscape and, at night, it would shine with its plenitude of electric light like a Soria Moria castle up on the mountainside.'* With the turbines used in those days, the plant's 10 generator sets ran on a water intake of 47 m^3 and produced 140 000 effective hp (103 MW). The penstock from the valve house at Vemorktopp runs overground. The completion of the plant was a grand feat of technical engineering and logistics. A labour force of up to 600 was employed, supervised by 7 engineers and 8 foremen. A separate 5 km railway track had to be build across a mountainside that was prone to landslides in order to transport the pipelines and generators, each weighing 5 000 and 300 tonnes, respectively. In order to provide access to Vemork for those who worked there, a suspension bridge was built across the river gorge in 1908. The bridge replaced an older bridge serving a rural settlement further downstream. With the switch to the Haber-Bosch method in 1929, the power plant at Vemork had to be modified to produce direct current.

Immediately after the completion of Vemork in 1911, work continued on the construction of ***Såheim Power Plant*** *(objects 4.1–4.5)*, which utilised the remaining 273.6 metre fall of the river. As many as 2 000 labourers were employed during the construction period, which lasted two years. In this case, a shaft was blasted through the rock for the penstock. The plant's nine generator sets had a maximum output of 167 000 hp. Såheim started producing in early 1916. Såheim Power Plant is among the most typical representatives of the imposing architecture that was so prominent in the early 20th century. The focus was on aesthetic interior and exterior design, as well as functionality. Såheim Power Plant is also known as the 'Rjukan Opera' and it is one of the most magnificent grand-scale industrial sites in Norway, with towers, columns, arches and building details inspired by historical styles. Two corner towers with angled and rounded roof profiles enhance the impression of heavy massiveness, a powerful stature that appears to have been created to manifest the enormous forces that were transformed here, at the same time as the building matches the dramatic nature that gives rise to these forces. At the same time, the building houses the plant that utilises the power, and the absence of a chimney, the most prominent feature of the classical factory, makes the building a symbol of how absolutely clean the new energy source is. The building has acquired a permanent, recognised place in Norway's recent architectural history. Såheim Power Plant is the town of Rjukan's most iconic feature.



"The water fall" by Theodor Kittelsen for Sam Eyde. Owned by Norsk Hydro.

Rjukanfossen today on a rare occasion when the water is led down its original course. The waterfall seen like this triggered Sam Eydes ideas about the future for the remote valley. Photo: Per Berntsen.

Regulating dams (5)

On account of the topography and climate conditions it is not necessary to construct large dams and artificial lakes in order to utilise the energy potential of the East Telemark watercourse. Regulation of the water flow to compensate for seasonal variations with flood peaks in spring and autumn and insufficient water in the winter, can be achieved by relatively modest damming of natural lakes. No water has to be transferred to the East Telemark watercourse from other catchment areas. The biggest and most important power plant dams are found in the mountain lakes on the edge of the Hardangervidda plateau. Møsvatn lake is the natural main regulating reservoir for the watercourse as a whole. ***Old Møsvatn Dam*** *(object 5.1)* raised the surface of the water by up to 10 metres. It was referred to as Europe's greatest dam structure, and it was Norway's first big concrete dam. With the regulation of Møsvatn, the country's biggest regulating reservoir was created. Møsvatn held this position until 1975. At present it is said to be Norway's fourth biggest reservoir. Tinnsjøen lake has been regulated at Tinnoset for timber floating purposes since 1889, when a log crib dam was built there. In 1907, a concrete dam was constructed for regulating the water flow to the power plants, primarily at Svelgfoss. When the new Tinnoset dam was completed in 2003, 20 metres upstream of the old one, the old dam was demolished and the river bed was dredged and sealed/lined with stone/concrete. Tinnsjøen lake is regulated to between 187 and 191 masl.

On the left: The Svælgfos dam by Theodor Kittelsen for Sam Eyde. Owned by Norsk Hydro.
On the right: Tinnfossen with dam as portrayed by Hans Finne-Grønn.

Power transmission (6)

Transmission lines were built from the power plants at Svelgfoss and Lienfoss down to AS Notodden Salpeterfabrikker's factories by the Heddalsvatnet lake. Power from Svelgfoss was transmitted through 18 copper cables, each with a cross-section of 120 mm, suspended from five rows of pylons, which, at Lienfoss, were joined by another two rows holding cables of the same dimension. A voltage of 10 kV was transmitted directly from the power plants' generator sets to the factory's furnace houses A and C. The lines have been demolished, but some of the pylon foundations are clearly visible. There are approximately 25 such pylon foundations in different locations, several of them inside the nominated area. The construction of the Bratsberg Line in 1919 clashed with the route of the suspended power cable and with a timber floating route down to Tinnesandbukta bay in Heddalsvatnet. The cables were therefore laid underground from the ***Cable House*** *(object 6.1)* that was erected on the Villamoen plateau at that time, and down to the furnace houses.

Large quantities of electric power were transmitted from the power plant at Vemork to the Rjukan I factory plant 4.5 km further down the valley. This was accomplished through an extensive network of overground cables that were suspended from tall pylons in 1911. An output of up to 120 MW from Vemork was transmitted through 60 cables, which were suspended from five rows of steel pylons and distributed via a ***Control Room in Furnace House I*** *(object 6.2)*. The cables for transmission of the 11 kV voltage were of unusual dimensions. As a result of high prices on the copper market, copper was only used for the upper third of the stretch, while aluminium cable was used for the first time for the remaining part of the stretch. These cables remained in use until 1928/29 when Hydro switched to the Haber-Bosch method. The electricity was then needed for the many electrolysers in the hydrogen plant that the company built in front of the power plant. Pipelines for hydrogen and oxygen were installed along the route that had previously held power cables. Today, both the cables and the gas pipes have been removed, but the route with its remaining pylon foundations is clearly visible. The road known as Kraftledningsveien (the 'power cable road') going west from Krosso runs along this route, bordering on the World Heritage Site as far as Våer, where the route crosses to the southern side of the valley. The pylons in the Vestfjorddalen valley were designed by one of Hydro's engineers, and became a prominent feature of the landscape on account of their size and number. Overground cable installations are modest today compared with then. ***Power line 16/17*** *(object 6.4)* from Såheim Power Plant to Furnace House I is representative of the network of overground lines that used to be a prominent element. In 1915, a ***Transformer and Distribution Station*** *(object 6.3)* was built on the site in order to supply the Rjukan II plant extension. The transformer station's architecture and decorative elements in the form of natural stone and iron anchors emphasise the essential role of power in the factory.

Power transmission from Vemork to the industry area in 1912. Photo: Anders B. Wilse.

Industry. Areas, buildings and industrial equipment (7–9)

The industry component consists mainly of buildings that have had a direct function in connection with the industrial process for manufacturing artificial fertilizer, Hydro's main product at the time. The buildings reflect stages in the development of the industrial processes until the time when Hydro closed down its activities and the industrial areas were sold to new owners and prepared for new industries in what became known as 'industrial parks'. The interior of the buildings have been refurbished. Seen as a whole, the component illustrates the production of artificial fertilizer using the electric-arc and ammonia (Haber-Bosch) methods. In the two industrial areas, the functional sequence in the industrial processes is documented through the position of the buildings in relation to each other. The factories in Notodden and Rjukan complement each other with preserved buildings from the various steps in the two processes. The production lines are decipherable and complemented by preserved production equipment.

The first step of the electric-arc process took place in Birkeland/Eyde furnaces. The **electric-arc process** as an invention is described in more detail under 2.b on page 244-250. The principles on which the furnaces worked are described in more detail in the section on *The electric arc furnace, the most important ivention ever made in Norway* under 2.b on page 247-249. Three furnaces of this type have been preserved out of what was probably a total of around 100 constructed during the period when it was in industrial use, from 1905 to 1940.

With the exception of the Schönherr furnaces, all production methods used in Norsk Hydro's factories can be documented by means of preserved objects. First and foremost, we have the Birkeland/Eyde furnaces, of which Notodden and Rjukan have each preserved a specimen, and a full-height acid tower in Rjukan. Only one other Birkeland/Eyde furnace is still in existence, located at the Norwegian Museum of Science and Technology in Oslo. The furnace in Notodden is of an earlier type, while the furnace in Rjukan is of the fully developed type that was used for large-scale production. Industrial machinery used in the process that replaced the Birkeland/Eyde furnaces also exists, but its preservation has not been so much in focus as the preservation of the almost iconic specimens from the age of the entrepreneurs. A full-scale German-built synthesis furnace for ammonia has been preserved. The few smaller-scale furnaces of this type that otherwise remain can be found in the Carl Bosch museum in Heidelberg in Germany. The large furnaces were most recently known to have been in operation in Leunawerke in Germany, which was closed down and demolished in the 1990s. Other equipment can be found in fragments in Rjukan, although these have not yet been assembled in one place.

Industrial activity that stems from Norsk Hydro takes place in the factory areas in both Notodden and Rjukan, notably the production of industrial gases by Yara Praxair in Rjukan, and the manufacture of electrolysers by NEL Hydrogen in Notodden.

Yara Praxair occupies the western part of the industrial park on the Hydro plot. The buildings were erected by Hydro to manufacture artificial fertilizer when it switched to using the Haber-Bosch process in 1928. The company was organised into different divisions in the 1990s and Hydro Agri took over the production of artificial fertilizer. After several rounds of restructuring and sales, the majority owner is now the US company Praxair and the company that produces gas in Rjukan is now named Yara Praxair. This company is thus a partial owner of the history that constitutes the central content of the nomination.

The company **NEL Hydrogen** manufactures and maintains hydrogen electrolysers in the Nickeling Plant *(object 7.14),* thus contuing Hydro's same activity. The company was hived off from Norsk Hydro in 1993 when Hydro chose to focus on aluminium production, but is directly connected to the company's original core activity after it switched to using the Haber-Bosch process in the late 1920s. Today, electrolysers based on patents developed by Hydro during that period are being marketed by NEL Hydrogen, a world leader in the manufacture of hydrogen fabrication equipment on the basis of electrolysis technology with atmospheric pressure.

Other than air and water, the raw material for the production of calcium nitrate was limestone. The railway that transported the finished products from Rjukan to the port at Porsgrunn, were loaded with limestone before they returned. During the first two decades, the need for limestone was satisfied by various open-cast mines along the Langesundsfjord. Hydro's first limestone quarry was established in 1905 on Store Arøya island. From there, limestone was shipped on barges to Notodden in the period from 1905 till around 1910. The quarry is well preserved and the remains of a trolley track still exist. The lime from this quarry was light, which gave the very first 'Norway saltpetre' a light, yellowish brown colour.

It was when the new quarries at Sundby, on the mainland between Langesund and Stathelle, were taken into use from around 1910 that the 'Norway saltpetre' got the grey colour that it has retained ever since. The limestone from these quarries was grey and contained approximately 0.5% organic matter. Three closely-spaced quarries were op-

Sanden quarry at Sundby today, partly filled with water. Photo: Eystein M. Andersen.

erated simultaneously here during the period from around 1910 until 1929. The limestone was transported by cableway to the fjord at Ekstrand. The cableway no longer exists, but the quarries remain and have been filled with water. Transport to the factories was carried out using tug-boats and reloading onto railway wagons. The Rjukan Line carried the raw materials in to and the finished goods out from Rjukan.

In 1929, a new open-cast mine started up at Kjørholt, which was also in the Grenland area. The annual production from that mine reached 700 000 tonnes, making Kjørholt the second biggest mining enterprise in Norway after Syd-Varanger. A 5.5-km-long cableway carried the limestone from Kjørholt to Herøya. It had the capacity to transport 200 tonnes of limestone per hour. It was in operation until 1982, when it was demolished. A couple of masts and buckets have been preserved as cultural heritage. The mines have been taken over from Hydro by the cement industry that currently operates in the area.

Hydro Industrial Park in Notodden (7)

Hydro Industrial Park in Notodden contains the buildings that saw the first successful industrial production of artificial fertilizer from the nitrogen in the air. A unique feature of Hydro Industrial Park in Notodden is that there are intact buildings for two production lines based on two different production methods from two different periods. The position of these buildings in relation to each other provides documentation of the functional sequence in the industrial processes.

Norsk Hydro's industrial activity in Notodden went through **three phases** up until the 1930s:

- Test activities
- Consolidation and large-scale operation
- Switching to new technology

Buildings from all these phases still exist today. Some buildings have been demolished, however, and many have been altered or extended.

The furnace house in the first 'Test Factory' was destroyed by fire in 1908, but it was soon replaced by new, bigger and more permanent factory buildings (production line A) when upscaled production in the Birkeland/Eyde furnaces proved a success. The industrial plant, machinery and pipelines that were inside and between the buildings have been removed, however, and it is the exterior and structure of the building stock that is important in relation to the nomination proposal.

Hydro's Test Factory was put into operation in 1905 with Birkeland/Eyde furnaces and electric power transmitted through a separate cable from the Tinfos I power plant. Under a contract with Tinfos, the factory had 2 500 hp available. AS Notodden Salpeterfabrikker had been formed in the previous year with an equity of NOK 500 000 after Sam Eyde had successfully raised the funds through his Swedish and French contacts. At the time, the factory consisted of wooden buildings producing calcium nitrate and sodium nitrite using quite primitive and manually operated equipment. The product was called ‘cast saltpetre’ or ‘chemical saltpetre’ and was exported to Germany and England for the production of potassium nitrate and ammonium nitrate.

Calcium nitrate dried in flat trays later became the main product. It had to be removed using a sledge hammer and then crushed. Each of the furnaces consumed 520 kW, but the expected production level per kW and year was not achieved. The reason for this was the absorption equipment, where the acid was added to two granite vats filled with limestone. The neutral calcium nitrate solution was then reduced by boiling in coal-fired iron pots until it contained 76% dry matter, corresponding to 13% nitrogen. This was later replaced by a process whereby the lye was reduced using steam from the boiler that used the heat in the gas from the electric-arc furnaces. In full operation, the Test Factory achieved a daily production of around 3 tonnes of calcium nitrate, which was sold under the name **Norway saltpetre**. In 1908, a fire in the furnace house put a stop to the Test Factory, which had constituted production line B. A new plant had then been in operation for three months, and the Test Factory’s tower house was connected to production line A in the new plant.

The construction of Furnace House A in june 1906 with the buildings of Hydro’s Test Factory behind.
Photo: Norwegian Industrial Workers Museum.

The plant that was put into operation in October 1907 was situated on the eastern side of the Test Factory. It was based on electricity supplied by Hydro’s own power plant in Svelgfoss. Production line A was Hydro’s first regular production plant for processing nitrogen to manufacture artificial fertilizer. The furnaces in ***Furnace House A*** *(object 7.1)* were constructed of cast steel and iron with a refractory brick combustion chamber in the middle and was supplied with air through a pipe from the basement. The nitrous gases from the furnace were routed to a fireproof manifold, from which the gases were piped through the cellar to a steam boiler house (demolished). On passing the steam boilers, the temperature was reduced from approximately 1 000 to 200 °C. The heat emitted by the gases was used for hydro-extraction of the factory's products. The gases were then sent to the cooling plant, where the temperature was further reduced so that they would undergo the oxidation that was necessary to achieve the desired absorption. The cooling plant was made of aluminium and consisted of a large number of pipes that were cooled with cold running water. From the cooling plant, the gases passed through oxidation vessels in the form of vertically positioned cylindrical iron tanks lined with acid-proof stone. Each tank could hold approximately 300 m^3. The next step in the process involved the absorption towers in ***Tower House A*** *(object 7.2).* They were 20 metres high and filled with crushed quartz, which is resistant to both nitrous gases and nitric acid. The towers stood in a row, and fans ensured that the gas that was fed into the first tower would continue into the second tower from above, then into the third tower from below etc. At the same time, water was percolated through the towers, absorbing some of the gas to form a dilute nitric acid solution. Each row of absorption towers included two wooden towers, through which a sodium carbonate solution was percolated to form the absorption fluid sodium nitrite. The task of the wooden towers was to absorb the dilute residual gases from the granite towers which could not be absorbed by water. As neither sodium carbonate solution nor nitrite solution is corrosive, both wood and iron could be used in the construction. The nitric acid solution from the granite towers flowed on into a granite vat and from there to what are known as monte-juses that use compressed air at four times atmospheric pressure to push the acid approximately 30 metres up into some *ceramic pots*, each holding approximately 1 500 l. ***Ceramic Pots*** *(object 9.1)* from the test factory represent equivalent equipment. From there the acid was recirculated through the absorption towers from above, and it finally emerged as finished strong acid into the granite vats in the lime dissolution plant. The vats were filled with limestone with a natural content of carbon dioxide, which is driven away by the nitric acid under intense effervescence, leaving a solution of calcium nitrate, also called nitrate of lime, which was pumped into some vacuum evaporation units. They were supplied with vapour from the steam boilers that were heated by the nitrous gases from the Birkeland/Eyde furnaces. The calcium nitrate solution was reduced by evaporation until a concentration of 13% nitrogen was achieved. The solution could then be pumped into the solidification plant to a height of approximately 10 cm. The solidification plant consisted of large, flat iron trays, and fans that blew cold air onto the bottom of the trays to speed up the cooling process. The calcium nitrate solidified into an extremely hard, brittle and crystalline material, which was removed in lumps using levers and sledgehammers and then transported to the crushing plant. After crushing, finished grain-sized grit was fed into a silo, from the bottom of which it was filled into barrels holding a net weight of 100 kg.

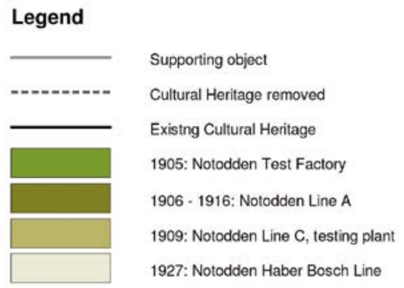
The nitrite solution from the wooden towers was refined in a separate building – it was first reduced by boiling and then crystallised. The crystals were then separated from the lye in a centrifuge and dried using hot air. When leaving the dryer, the finished sodium nitrite product was transferred into barrels holding a net weight of 300 kg. The product had a purity of approximately 97% and was used as a raw material in the production of certain aniline dyes

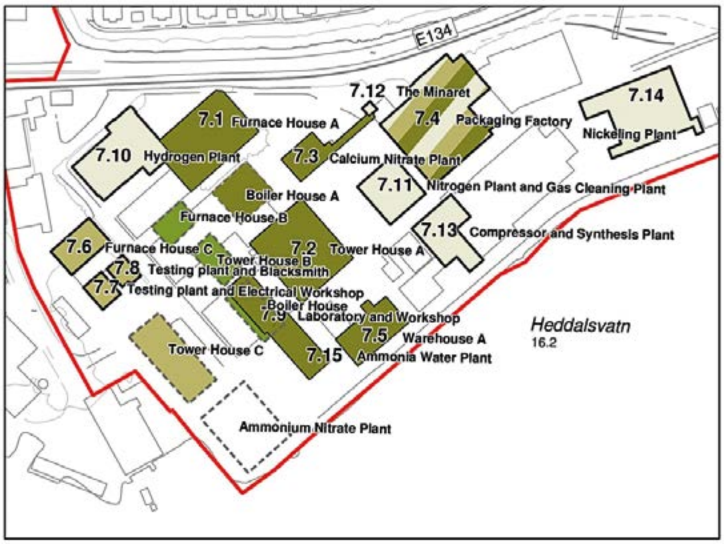
A further description of Professor Birkeland's patent is provided in section 2.b on page 244-250.

Norsk Hydro's calcium nitrate plant in Notodden in 1914. Drawing from Lysbuen Museum in Notodden.

In 1909, Hydro built a new ***Testing Plant*** *(objects 7.6–7.8),* this time to try out an alternative furnace technology. The efficiency of the German Schönherr furnaces was to be measured and compared with Birkeland/Eyde furnaces of a larger type that had been developed with a view to starting up in Rjukan. Yield measurements in 1910 showed that the German furnaces were not as efficient as the Birkeland/Eyde furnaces. The ten Schönherr furnaces in **Furnace House C** *(object 7.5)* were therefore replaced by Birkeland/Eyde furnaces. These belonged to the plant's production line C. The furnaces were supplied with electricity from Hydro's new power plant Lienfoss in the Tinnelva river, built in 1911. During that period, the finishing processes in the ***Calcium Nitrate Plant*** *(object 7.3)* used the electric-arc method for manufacturing Hydro's first product: **calcium nitrate**. In 1909, Hydro also built an ammonium nitrate plant (demolished) south of Tower House C, which supplied ammonium nitrate to the explosives industry and as a concentrate for the production of nitrogen fertilizer. In 1915, it was extended with the construction of an ***Ammonia Water Plant*** *(object 7.15).*

On the left: The factory area in 1933. On the right: The factory area today. Photo: Per Berntsen.





The building stages for the different production lines at Notodden.
(see also Annex 1)

The processing facilities for ammonia *(objects 7.6–7.14)* based on the Haber-Bosch method were set up in some new buildings from 1927. The processing facilities for ammonia consisted of buildings that were known as 'the New Production Facilities'. This generation of buildings was drawn by the architect Thorvald Astrup. The Birkeland/Eyde process was finally closed down by AS Notodden Salpeterfabrikker in 1934. All buildings used in the new process have been preserved on the industrial site.

Before the transition to the ammonia method, Hydro's facilities in Notodden appeared inefficient compared with Rjukan. Options for extending the electric-arc plant were limited. Until then, the acid from the absorption towers had been used in the production of ammonium nitrate. In 1906, the barrel factory with its stave mill and stave warehouse took up more than 4 000 m^2 of land, but when barrels were replaced by sacks, there was no future in this function either. With the construction of the Ammonia Synthesis Plant in 1927–28, there was renewed focus on Notodden, even though it was actually intended for test operations with a view to a future larger-scale establishment in Rjukan. New production buildings meant that the industrial area in Notodden was extended towards the east.

When hydrogen production started in the ***Hydrogen Plant*** *(object 7.10),* also called 'Vannstoffen' (antiquated Norwegian name for 'hydrogen'), Hydro was in a situation where there was competition between its own furnace type (Birkeland/Eyde) and the Haber-Bosch technology for the production of ammonia (NH3). Hydro imported technology from the American company NEC, which was to provide Hydro with an alternative option in its negotiations with the German company in connection with the switchover from the Birkeland/Eyde process. In the building that was therefore also known as 'the tactical factory', Hydro installed what were known as Pechkranz cells on the ground floor and Holmboe cells on the floor above. Both these technologies were used in the production of hydrogen, which was a step in the production of ammonia. Hydro improved the Swiss-designed Pechkranz electrolyser used for water electrolysis, and began to use their own patented method.

In ammonia synthesis, water is electrolytically split using direct current. High-voltage alternating current was transmitted to a switchgear station by Furnace House A, and then supplied to a transformer and converters inside the Hydrogen Plant. The direct current was then transmitted to the electrolysers on each floor of the building. Hydrogen gases were scrubbed to remove all traces of caustic potash solution in a gas cleaning tower in the same building. The caustic potash solution was then stored in separate tanks and used as an electrical conductor in the electrolysers. The gas was temporarily stored in a gasometer before it was transferred to the ***Gas Cleaning Plant*** *(object 7.11).* Nitrogen gas was produced in the eastern part of the same building, using air that was taken in 63 metres above the ground through an intake tower. The slender tower was known as the ***Minaret*** *(object 7.12)* and took in air for the processes in the calcium nitrate plant from a height, thereby avoiding the pollution in the lower atmosphere, including the smoke from the Tinfos ironworks, which contained small amounts of acetylene. This substance would have constituted an explosion hazard in the air-fractionation plant in Hydro's factories.

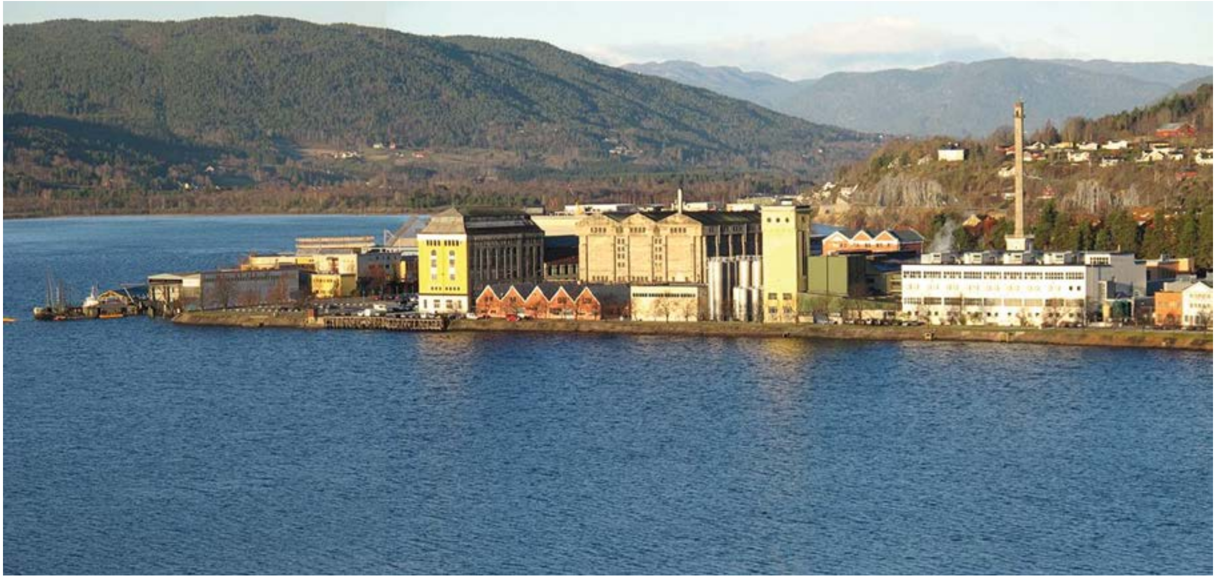
The N_2 gas produced was routed to a separate gasometer, and then fed to the gas cleaning plant where it was mixed with the H_2 gas from the first gasometer in the ratio 3:1 and cleaned to remove all oxygen. The gas was cleaned by heating the mixed gas and catalytically scrubbing it in a palladium catalysor. The clean gas mixture was then routed to another gasometer for intermediate storage. The ***Synthesis Plant*** *(object 7.13)* contained three compressors that drew in gas from the gasometer for mixed gas, compressed it to more than 300 bar and sent it through a filter to remove any oil before it was fed to the synthesis furnace. Three circulators were used to circulate the gas through the furnace, where H_2 and N_2 were catalytically combined to form gaseous ammonia (NH_3). The synthesis furnace was located in the tower that faces Heddalsvatnet lake. Outside the building there were storage tanks for liquid ammonia. Railway tankers transported the ammonia to Herøya for use in the production of fertilizer. Normally, 3 tank wagons were sent from Notodden on a daily basis, and approximately 30 from Rjukan. The ammonia production in Notodden was closed down in 1968.

Norsk Hydro produced its own packaging for the finished product. The sack factory in Notodden was Hydro's central ***Packaging Factory*** *(object 7.4)* from 1928. The barrel factory in Rjukan was closed down at that time, while the sack production, which up until then had taken place at Skøyen in Oslo, was transferred to Notodden. In 1939, the factory consumed 6 million metres of Indian sack jute, and ready-made impregnated sacks were also bought from factories in Calcutta.

Today, Hydroparken (Hydro Industrial Park) is a limited company owned by the property company Bryn Eiendom. The **plot covers a total of 80 000 m², and contains 35 buildings with a total floor space of approximately 40 000 m².** The space is leased out to more than 60 enterprises from diverse sectors, including industry, handicrafts, health services, artists, catering etc. Adjacent to the Hydro Park there is a slipway, the Notodden steamship quay and buildings that were erected by the industrial company Tinfos AS, including administration buildings, while the buildings holding the ironworks have been demolished.

The side of the industrial site that faces Heddalsvatnet is lined with blocks of granite from the acid absorption towers. The acid towers were located in Tower House C, which was demolished in 1958. Stone from the rock cavern for the new Svelgfoss power plant was used as backfill material. The 'Promenade' (Grüner Løkens Street, named after the factory manager) was completed and landscaped in 1965.

The buildings in the Hydro Industrial Park have steel frames that were initially infilled with brick and later with concrete (after 1910). Furnace House A has a steel frame roof, while steel



Hydro Industrial Park in Notodden seen from Brattrein. Photo: Trond Taugbøl.

frames were subsequently used for the whole shell in the later buildings. Originally, Furnace House A had traditional wooden windows, but all buildings of a later date had modern-style large windows with steel frames and glazing bars. The first buildings used concrete for certain elements, such as the foundations, but from 1915, the reinforced concrete used in modern architecture took over as the main material used in the industrial park. All the buildings had functional, open, light and spacious designs. The buildings are in the style of classical industrial architecture, a style that toned down the use of décor and had clear utilitarian features, and which formed the basis for 20th century modern architecture as seen in the progressive German industrial architecture from the first decades of that century. Several of the buildings in Hydro Industrial Park in Notodden, particularly from the time around World War I, display modern features with a limited use of décor and historicising details, and focus on form and function. These are mainly well-lit buildings with ridge turret skylights on the roof to let in light and provide ventilation, with one side dedicated to each of these functions. In 1926–1927, flat roofs also come into use, evidenced by the Hydrogen Plant and the Nickeling Plant. With its expressionist features, Tower House A is an example of another stylistic approach to modern architecture. When the building was renovated around 1920, it was given visible structural elements, raw and smooth concrete surfaces free of décor, and a unique expression adapted to its function. This was in line with the contemporary interna-

"The Growth of the Soil" by Theodor Kittelsen for Sam Eyde. The factory at Notodden in the background. Owned by Norsk Hydro.

tional trend and illustrates better than any other building in the industrial park in Notodden how industrial architecture was an entrance to modern architecture of the 20th century.

Hydro Industrial Park in Rjukan (8)

Hydro Industrial Park in Rjukan contains building stock used for the large-scale industrial production of artificial fertilizer from the nitrogen in the air. The large industrial area contains buildings erected for various functions, many of them with a high architectural value. There are buildings connected to both the electric-arc method and the ammonia method.

Norsk Hydro's industrial activity in Rjukan went through **three phases** up until the 1940s:

- **Rjukan I**: The first phase of development to accommodate the electric-arc method. Infrastructure development in steep and inaccessible terrain. Based on power from Vemork.
- **Rjukan II**: Expansion of operations based on the electric-arc method. Large-scale production using electric-arc furnaces and power from Såheim.
- **The New Production Facilities, Rjukan III**: Transition to operations based on new technology, the ammonia (Haber-Bosch) method and hydrogen electrolysis.

Buildings and other traces dating back to all these phases still exist today. Several buildings, gasometers, power lines, pipelines etc. have been demolished, however. Two production lines were based on the electric-arc technology; both the furnace houses are still in existence, while the two tower houses are gone. The most complete building stock held the plant that was based on ammonia synthesis in the New Production Facilities in the upper part of the area. The industrial plant, machinery and pipelines that were inside and between the buildings have been removed, however, and it is the exterior and structure of the building stock that is important in relation to the nomination proposal. There is documentation of both the construction and operating phases of all buildings, and of all demolitions (see chapter 7).

The factory area at Rjukan with all three phases completed in 1929. Photo: Norwegian Industrial Workers Museum.

Rjukan I was based on electric power from Vemork, transmitted through power lines over a distance of 4.5 km to the plant. Rjukan II was based on power from the plant at Såheim, which also contained Furnace House II on a separate floor. From there, nitrogenous gas was fed to the tower house through a 1 km long gas pipeline.

Hydro's factories in Rjukan were built on land belonging to Såheim farm on the southern side of the Måna river. There are no traces left of what were previously cultivated land and agricultural buildings. Some wooden houses were moved and used as accommodation for navvies/workers until they were demolished in the 1930s.

The Rjukan I plant started up in 1911, with two of the eight tower rows and a quarter of the lime dissolution plant having been completed when the first furnaces were put into operation. ***Furnace House I** (object 8.1)* contained 96 German Schönherr furnaces and 8 Birkeland/Eyde furnaces. The buildings were huge. The Furnace House covered an area of 6 000 m^2. The Tower House (demolished) took up 7 000 m^2 of land. With its lime dissolution and evaporation reduction plant, and a height of 35 metres, it was Scandinavia's biggest building. The ready-cut stone for the granite towers weighed 13 000 tonnes, while the iron structures weighed 800 tonnes. As much as 27 000 m^3 of quartz was needed to fill the towers. One ***acid tower** (object 9.4)* is still in place. There was a ***Boiler House** (object 8.2)* of 1 500 m^2, a ***Barrel Factory** (object 8.3)* with a boiler system and a stave drying plant of 4 000 m^2, and a solidification plant, crushing plant and packery in a separate building of 3 000 m^2. In addition, there were offices, workshops, warehouses etc. The first Norway saltpetre was sent to the packery and transferred to wooden 100 kg barrels from the Barrel Factory before the first railway load left Rjukan on 8 December 1911. In May 1912, all tower rows were in operation, comprising 32 granite towers and 14 iron towers, and the temporary plants for neutralisation and solidification had been replaced by permanent ones. As early as in 1913, the tower house was extended by 3 000 m^2 to make room for a total of 50 absorption towers. The ***Pump House** (object 8.4)* by the Måna river that supplied water to the production process is still standing.

To the left: Rjukan I in 1911 with Boiler House on the top right, Tower House, Laboratory and Pump House. To the right: The same area today. Photo: Eystein M. Andersen.

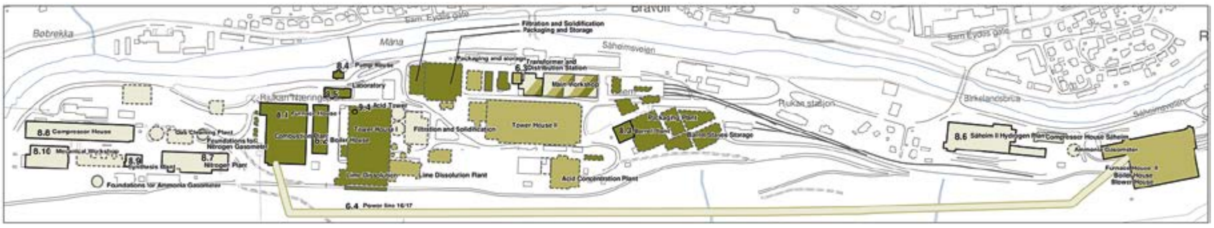
The construction of **Rjukan II** started at Såheim in the year that Rjukan I was completed. The work was completed in 1916 with 35 Birkeland/Eyde furnaces inside the power plant, an adjacent boiler house and ventilation house (demolished), 5 gas pipelines and a tower house containing 50 granite towers and 10 iron towers in 10 rows. The new tower house of 10 000 m^2 included an evaporation reduction plant for sodium nitrate. By building the furnace house right next to the power plant *(object 4.1)*, high-voltage transmission lines were avoided and fewer gas coolers and oxidisation vessels were needed. A new plant was constructed for the production of concentrated acid, while the lime dissolution plant, evaporation reduction plant, crushing plant and packery from Rjukan I were extended to handle the increase in production. A 1 km long corridor of aluminium pipelines transported gas from Såheim to the tower house at Rjukan II. In 1926, more Birkeland/Eyde furnaces were installed – two in Furnace House I and four new ones in Furnace House II.

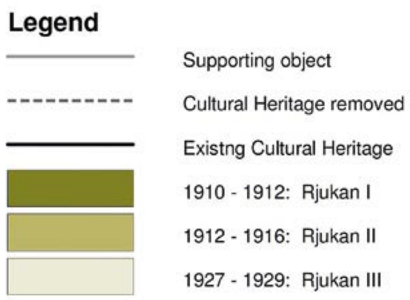
These plants were used for the production process in Rjukan until 1928. To the east of the Furnace House I *(object 8.1)* with the electricity distribution centre *(object 6.2)* the following lay in a row: the Boiler House *(object 8.2)*, Tower House I with solidification tower (demolished), the sifting plant (the lime dissolution plant), the filtration plant, the Nitrate Building (demolished), the Packery (demolished), Tower House II (demolished), the acid concentration plant and the acid filling plant. The products were calcium nitrate ('Norway saltpetre'), sodium nitrite (1928), sodium nitrate, ammonium nitrate, concentrated nitric acid, iron mordant, oxalic acid and sodium carbonate generation.

Large parts of the production took place in parallel with and using the same methods as in Notodden, but the plants that were established in the two towns also specialised and developed differently. One example is ammonia water from Notodden, which was delivered to Rjukan by railway tankers that returned filled with ammonium nitrate lye until Rjukan got its own production plant in 1916. Notodden was the site of much of the test activity that took place before the start of larger-scale production in Rjukan. Before the decision was made to switch to the Haber-Bosch method, trials were carried out to make the electric-arc method more efficient, increase the pressure in the Schönherr furnaces etc., but these trials were stopped in 1925. The experience of building and operating a separate testing plant for the new process in Notodden was extremely useful for the construction of the ammonia plant in Rjukan, which was approximately ten times bigger. When the Haber-Bosch method was introduced and the first ammonia synthesis furnace was started up in Rjukan in 1929, Birkeland/Eyde's electric-arc furnaces had been used in the production of approximately 360 000 tonnes of nitrogen in Rjukan, corresponding to 2.8 million tonnes of 'Norway saltpetre', and 110 000 tonnes in Notodden. The transition to the Haber-Bosch method in Rjukan changed the production lines. **Birkeland/Eyde furnaces were in operation until 1940 in Rjukan, and until 1934 in Notodden.**

Before the 'Norway saltpetre' was exported to the rest of the world, it was packed in the ***Barrel Factory*** *(object 8.3)*, which is said to have been the world's biggest. From 1912 to 1928, artificial fertilizer was filled into 100 litre barrels, which were manufactured close to the warehouse for reasons of efficiency. Barrels were manufactured and assembled at great speed by 150 coopers; as many as 9 911 314 barrels were manufactured in the course of those 16 years. The factory was closed down in 1928 when Hydro started using sacks made of Indian jute and centralised its sack production to Notodden.

The **New Production Facilities in Rjukan** (Rjukan III) were put into operation in 1929 and necessitated conversion of Vemork and Såheim power plants so that they could supply direct current, while continuing to produce power according to the old method. Herøya was chosen as the site for further processing of the ammonia into artificial fertilizer. Hydro had bought Herøya because the property was situated by the sea near Porsgrunn. Careful consideration was given to how the processing into the finished calcium nitrate product should be divided between Rjukan and Herøya, in relation to transport costs and consequences for the urban community in Rjukan. A 40/60 division was chosen, whereby 28 000 tonnes of the estimated ammonia production of 70 000 tonnes would continue to be processed in Rjukan. The Norwegian workshop industry became very busy with assignments for the New Production Facilities in Rjukan, which, among other things, included ammonia synthesis furnaces and ammonia storage facilities with a filling plant, and the conversion of the existing plant with steam boilers and new acid coolers with pumps by the absorption towers in Tower House I. The production of calcium nitrate required a new filtration plant, equipment for handling ammonia nitrate lye, fixtures for reduction by evaporation and a solidification tower with cooling and sifting systems. The plant was to be based on experience from IG Farben in Germany, but extensive trials had to be carried out in order to decide on the optimum equipment. Unlike in Germany, where coal was used for the production of hydrogen, *hydrogen electrolysis* was chosen in Norway where there was almost unlimited access to both water and electricity. The actual ammonia production process was otherwise identical to the one used in Germany.





The building stages for the different production lines at Rjukan. (see also Annex 1)

The most important buildings of the New Production Facilities were the ***Nitrogen Plant*** *(object 8.7)*, ***Compressor House*** *(object 8.8)*, ***Synthesis Plant*** *(object 8.9)* and ***Mechanical Workshop*** *(object 8.10).* In addition, there were three gasometers (demolished, but the imprint of the tanks can be seen on the ground). These buildings were arranged along a street (named 'Storgata' – the Main Street – and the square in front of the Nitrogen Plant was known as 'Market Square'). In addition, there were the electrolysis plants for hydrogen, which had to be located near the power plants to avoid significant power losses. *Hydrogen plants* were built in front of Vemork (demolished) and at Såheim in front of the power plant building (demolished), as direct current could not be transmitted over any distance without major power loss. However, the decision was made not to hide the power plant building behind a new tall building, as had been done in Vemork. The hydrogen plant building in front of Såheim was therefore designed with only a single storey, and the adjacent Såheim engine shed was used to expand the hydrogen production capacity. In the 1940s, the factory part of the former engine shed was extended with a new building *(object 8.6)*. At Vemork, the ten overground power cables for Rjukan had to be replaced by underground cables in order to clear the building site in front of the power plant. A total of 192 electrolysers of the Pechkranz type were delivered by Hydroxygéne SA in Switzerland. The electrolysers had to be assembled in Norway, and were nickel-plated in purpose-built nickeling plants in Notodden *(object 7.14)*, as well as Glomfjord. The hydrogen plant at Vemork was the world's biggest water electrolysis plant until the plant in Glomfjord in Nordland County was put into operation in 1946 (see the comparative analysis in section 3.2). The latter plant, which was also owned by Norsk Hydro, had room for almost 300 electrolysers.

Hydrogen gas and oxygen gas were transported in pipelines from the Vemork Hydrogen Plant to the factories in the town. The pipeline measured 4 750 metres, including 32 bends, with a total fall of 217.2 metres. There were two pipelines for hydrogen and one for oxygen, each with a diameter of 350 mm and 32 expansion loops. The pipelines were supported by 265 steel masts, except at the bridge over Krossobekken and at the Vemork, Våer and Rjukan suspension bridges, which were between 50 and 100 metres long. The pipeline was in continuous operation until 7 November 1971. It is possible to walk the route, which passes through very rugged terrain, and several of the mast foundations can be seen on the way.

The Vemork Hydrogen Plant produced heavy water as a by-product. In 1957, the plant and production were expanded, but it was closed down in 1971, and demolished and removed altogether in 1977. The Vemork Hydrogen Plant was the target of a successful sabotage campaign against the production equipment by Norwegian partisans during World War II, and subsequently also of an unsuccessful bombing raid by the allied forces in November 1943. 'D/F Hydro' *(object 11.15)*, one of the ferries across Tinnsjøen lake was sunk with a cargo of heavy water. The sabotage campaigns in Telemark may have had an impact on the war and its outcome.

The sites where Tower House I and Tower House II once stood. Photo: Per Berntsen.

Both the capacious tower houses, from Rjukan I and II, are gone today and have left a large unbuilt area centrally located within the factory area. Many of the buildings that had other functions remain intact and have new uses. The building stock in the central area of the Hydro Park is laid out with streets that, together with the intrinsic quality of the buildings from the different eras contribute to the character of the area. Building details and landscaping elements such as fences, gates and occasional lamp posts further emphasise the historical environment. In the uppermost area (the New Production Facilities) the company Yara Praxair is still producing industrial gases, and access to this part is prohibited for safety reasons.

In 2011, Hydro signed an agreement to sell the industrial park in Rjukan to Rjukan Næringspark KS. The agreement comprises **21 hectares of land and 34 buildings** with a total floor space of around 50 000 m^2. Hydro has also entered into an agreement with the municipally owned Tinn Energi, which is taking over the industrial park's electricity network. Rjukan Næringspark KS owns and manages most of the buildings and infrastructure. Approximately 90% of the buildings are leased out as industrial, storage and office premises. Today, 30 different enterprises/ business areas lease premises in the industrial park.

Production equipment (9)

Unique examples of industrial equipment have been preserved in Notodden and Rjukan, but are detached from their functional context in that the production has been phased out and the building stock used for new and largely non-industrial purposes.

Production equipment in this context is understood to mean plant and machinery that is fixed but replaceable. In the processing industry, old pieces of machinery are typically replaced by new ones, either because they are worn out or technologically outdated, or because of alternations made by the enterprises for various, often strategic, reasons. In Rjukan and Vemork, phased-out equipment is occasionally found outdoors, where it was dumped. The most essential machinery in Hydro's calcium nitrate plants consisted of the furnaces used to extract nitrogen from the air. Norsk Hydro was founded on the basis of Birkeland and Eyde's invention of the Birkeland/Eyde electric-arc furnace. The Birkeland/Eyde furnaces were developed in several steps, and different materials were tested out between 1903 and 1905 prior to the industrial phase. The production of the plant furnaces was a complex process: The shields were produced by some ironworks in Arendal, the interior was lined with refractory chamotte bricks from Borgestad Industrier at Skien, and some of the parts had to be assembled and put in place in the furnace house in Notodden. The furnaces that have been preserved are distributed between Notodden, Rjukan and the Norwegian Museum of Science and Technology in Oslo. The ***Birkeland/Eyde electric-arc furnace, Notodden*** *(object 9.2)* is of an early type, made for Vassmoen at Arendal and transferred from there to Notodden in 1907. The ***Electric-arc Furnace, Rjukan*** *(object 9.3)* represents the final version. The Birkeland/Eyde furnace competed with the German Schönherr furnace, which, by virtue of Hydro's sporadic collaboration with the Badische Anilin & Soda Fabrik (BASF), was also in use in Hydro's factories in Notodden and Rjukan. No furnaces of the Schönherr type are known to have been preserved.

Overview of nitrogen furnaces

Facility	Building	Type	Number	Capacity	Period in operation	Preserved
Notodden Testing Plant	Furnace House B, *demolished*	Birkeland/Eyde	?	520 kW	1905–1908	-
Notodden calcium nitrate plant	Furnace House A	Birkeland/Eyde	36	?	1907–1934	1*
	Furnace House C	Schönherr	10		1909–1911	-
		Birkeland/Eyde	1**	3 300 kW	1909–1934	-
		Birkeland/Eyde	10		1911–1934	-

Facility	Building	Type	Num-ber	Capac-ity	Period in operation	Pre-served
Rjukan I	Furnace House I	Schönherr	96	1 000 kW	1911– ?	-
		Birkeland/ Eyde	8	3750 kW	1911–1940?	-
		Birkeland/ Eyde	2	?	1926–1940?	-
Rjukan II	Såheim Power Plant, first floor	Birkeland/ Eyde	36	3 750? kW	1915–1940	2
		Birkeland/ Eyde	4***	3 750? kW	1926–1940	-

This furnace was one of the very first 'complete electric-arc furnaces'. They were made in the Testing Plant at Vassmoen outside Arendal. When it closed down in 1907, the furnace was transferred to Notodden.

***This furnace, which was to be tested against the ten Schönherr-type furnaces, may have been placed in the 'Testing Plant and Electrical Workshop' (7.7) building at the time, and may have been incorporated as part of the ten B/E furnaces that took over the location when the Schönherr furnaces disappeared in 1911.*

****Transferred from the Soulom factory in France when it closed down.*

Electric arc furnace from Rjukan II in front of the Norwegian Museum of Science and Technology in Oslo. The furnace was a gift from Norsk Hydro in 1959. Photo: Trond Taugbøl

A lot of effort had to be put into the development phase in order to improve the system for absorption of gaseous nitrogen dioxide to form nitric acid, before Hydro arrived at its own design where the conversion was achieved in granite towers filled with limestone through which water was percolated from above. During the first phase (the Test Factory in Notodden), the absorption took place in glass vats containing a few litres. In the new plant (production line A, Notodden), this had been expanded to rows of absorption towers in granite, each containing 600 m^3, and large ceramic pots for intermediate storage of the acid during the concentration process. The ***Ceramic pots*** *(object 9.1)* consist of one large and one small pot, the latter of which is believed to be from the Test Factory. The granite towers were big, immobile structures with a total weight of approximately 2 000 tonnes. The use of granite towers for absorption was first tried out and built on a large scale in Notodden, and their function is described above in the section on Hydro Industrial Park in Notodden (page 44-50). It was the world's first construction of its type at the time, and experts from leading industrial countries expressed their admiration at this feat of engineering. According to Sam Eyde, when Geheimrat von Brunck, the head of BASF, first visited Notodden on the completion of the plant, he remained spellbound for a long time before he removed his hat and said that he had never thought that such a splendid solution was even possible. *'It was the greatest compliment that could be paid to Norwegian engineers, in that it came from the mouth of the head of the world's biggest industry, and this was moreover a man who was known to never acknowledge anything that had not been his own people's idea,'* wrote Sam Eyde.

No acid tower has been preserved in Notodden, but one ***Acid Tower from Tower House I*** *(object 9.4)* in Rjukan has, as the only one, been preserved in full height. The acid tower was used in production for 70 years, and thus represents an extraordinarily long epoch in the history of the electrochemical industry. A new acid factory that replaced the acid towers in Rjukan lasted for about ten years before it was closed down. Altogether, the Rjukan plants had around 82 such granite towers in Tower House I and II, in addition to 24 towers of iron and wood.

Overview of all acid towers in the Notodden and Rjukan plants:

Facility	Building	ID no	Type	Number	Period in operation	Preserved
Notodden Calcium Nitrate Plant	Tower House A	10.2	Granite	9	1907–1934	-
			Wood	6	1907–1934	-
			Granite	3	1916–1934	-
	Tower House C	-		?	1909? - ?	-
Rjukan I	Tower House I	-	Granite	32	1911–1940?	1
			Iron/wood	14	1911–1940?	-
	Tower House I, extension	-	Granite/wood?	4	1913–1940?	-
Rjukan II	Tower House II	-	Granite	50	1916–1940	-
			Iron/wood	10	1916–1940	-

Granite blocks from the other, demolished acid towers can be found, *inter alia*, in supporting walls and monuments within the factory area, and they are also said to have been reused for landscaping in Kongsberg and around Tinn, where they are found as stone barriers along the roads etc. The preserved top of an acid tower can be found at Herøya outside Porsgrunn. It has been rebuilt by the waterfront, which is lined with stone blocks from the 46 towers that were used at Hydro's calcium nitrate plant here . The pump house by the Måna river *(object 8.4)* contains an original ***Pump*** *(object 9.5)* that delivered water for the production processes.

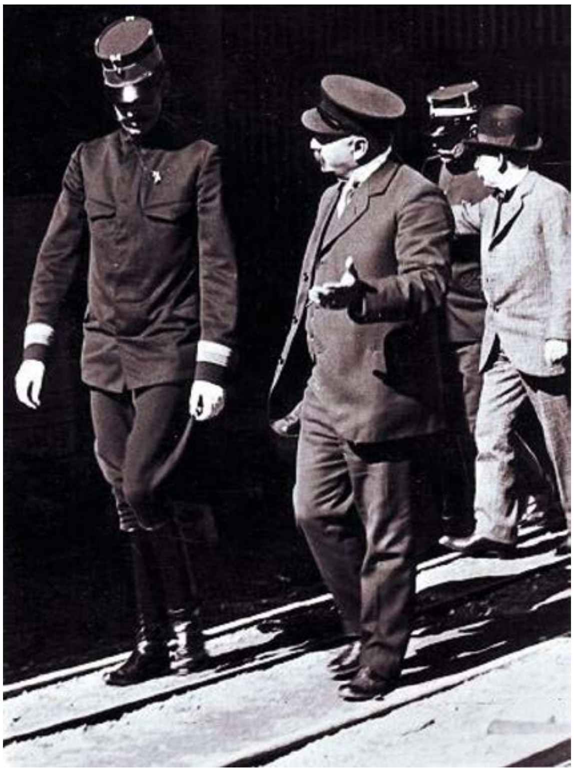
The absorption tower also worked with the **Haber-Bosch synthesis** process that took over from the Birkeland/Eyde process. The Haber-Bosch process used synthesis furnaces for ammonia production, in which the hydrogen was combined with nitrogen under high pressure and high temperature. One ***Synthesis Furnace*** *(object 9.7)* from Rjukan has been preserved. The Hydrogen Plant in Notodden has some large ***Tanks*** *(object 9.6)* that stem from the ammonia process. This is the only production equipment that remains in situ. In

Hydro's plants, the hydrogen for the ammonia synthesis was produced by electrolysing water, a raw material of which the company had plenty, along with the hydroelectric power for the furnaces. A large number of electrolysers were installed in dedicated hydrogen plants in Notodden *(object 7.10),* Rjukan *(object 8.6)* and at Vemork. The unassembled parts of an almost complete Pechkranz electrolyser have been preserved. Heavy water, which can be used for the production of nuclear weapons, was a by-product of the hydrogen electrolysis in Rjukan, and was therefore the object of resistance campaigns during World War II. One heavy water column remains intact *(supporting value).*

Based on preserved production equipment, the history of the various production methods used by Hydro can be shown by means of objects. In addition, a sufficient number of the buildings that contained these objects have been preserved to be able show how the production processes were organised in relation to each other in production lines.

The transport system (10–12)

Norsk Hydro's industrial development in Telemark was contingent on an efficient transport system. The distance from Notodden to the sea at Menstad by the Skienselva river was covered using barges along a system of canals. The company Norsk Transportaktieselskab, later Norsk Transport AS, was established to build and operate the transport system between Notodden and Rjukan. The company was established in 1907 by Hydro and the German BASF, which at that time were working together on developing the Vestfjorddalen valley. The system consisted of two railway sections linked by a ferry crossing across Tinnsjøen lake. The system had a total length of approximately 80 km. As many as 1 400 labourers were employed in the construction work at one time, most of them travelling construction workers known as navvies, or as 'honest vagrants', a title of honour describing men who were industrious with their hands and heads, willing to take risks, thrifty and at the same time proud and freedom-seeking. The construction period was intensive and lasted for 1½ years. Up until the time when the railway connection had been established, construction plant was moved by horse from Notodden, and by barge across Tinnsjøen as long as the lake was free of ice. In spring 1908, the icebreaker 'D/S Skarsfos' was put into service. The ferry quays at Tinnsjøen were completed in January 1909, and the first railway wagon arrived in Såheim in February that year. The scope and complexity of the work and the short construction period were remarkable feats of organisation. The official opening of the Rjukan Line took place in August 1909 and was attended by the King and representatives of the Government. The development had cost NOK 6 million, a sizeable amount in the currency



Sam Eyde accompanies King Haakon at the opening of the Rjukan Line in 1909.

value of the time (corresponding to approximately NOK 360 million or approximately USD 60.9 million in 2012 currency).

In autumn that year, 'D/F Rjukanfos', the first permanent steam-powered railway ferry, was put into operation on Tinnsjøen. The ferry crossing at Tinnsjø with the Rjukanfos 'Steam Ferry' was the first of its kind in Norway. Barge transport from Notodden required expensive reloading. The Germans (BASF) had plans to widen the channels, but when they were no longer in the picture, Norsk Hydro opted to extend the railway to Porsgrunn in collaboration with NSB, the state-owned Norwegian railway company. In 1917, transport by ship along the Telemark Canal was replaced by the Bratsberg Line between Notodden and Porsgrunn/Herøya. The Rjukan Line, the ferries crossing Tinnsjøen, the Tinnoset Line to Notodden and the railway section that continued down to Herøya were the cornerstones on which the whole new system for industrial production that Norsk Hydro had developed since 1905 relied.

Transport by river from Notodden to Skien was carried out by two tugs, two tankers, one motorboat and 54 barges, each with a capacity of between 110–245 tonnes. No traces of these remain in the area of the World Heritage Site or buffer zone, though there are some remains outside the area, the full extent of which is unknown.

The construction phase in Rjukan with its steep and inaccessible terrain, winter conditions and transport of big and heavy equipment for building the factory and what was then the biggest ever power plant, makes the railway system with ferries and the track to Vemork a unique testament to the level of contemporary engineering. The extensive transport system is a manifestation of financial, organisational and strategic calculations that were made during the planning and execution of this solution to the transport needs that were a consequence of the location of the factories in Rjukan. This location was partly chosen because the power lines of the time were unable to transmit voltages of more than 10 kV over any distance. The technological barriers were assessed in relation to the profitability of the investments. The costs were easier to handle when they related to challenges that could be met using known technology.-

In the early 20th century, many plans were being worked at to bind the country together by means of railways, a major national investment that would replace many of the most important shipping routes and provide seamless transport without reloading. The intention was for the new trunk route to cross the fjords of Western Norway using railway ferries of the type that had been used to good avail on Tinnsjøen lake. Actual developments took a different direction, however, based on road transport and car ferries. It was only the stretch between Moss and Horten that was developed for railway transport in accordance with these plans. The ferries that were ordered were purely car ferries, however, and the railway connection to Horten no longer exists today. The Tinnsjø ferries therefore represent a unique investment in railways as the means of transport.

The whole transport system built by Hydro is intact. The Rjukan Line was closed down in 1991 when production in Rjukan was cut back and then closed down completely. The track, rolling stock and vessels are intact and have museum value. Their ownership has been transferred from a foundation to the Norwegian Industrial Workers Museum at Vemork.

Both stretches of railway were originally known as the **Rjukan Line**. After the construction of the Bratsberg Line connecting Notodden and Skien in 1917, and the transfer of ownership of the stretch between Notodden and Tinnoset, this sub-section of the railway is known as the **Tinnoset Line**. The Bratsberg Line provided a connection to the new state railway network via the Vestfold Line at Skien, but the Vestfold Line was a narrow-gauge section at the time (1 063 mm). Contact with the normal-gauge railway network was established when the Sørlandet Line via Kongsberg was partially completed to connect with the Bratsberg Line at Hjuksebø in 1920. At the same time, the private railway section between Skien and Tinnoset was transferred to a state-owned company, in which Norsk Transportaktieselskab also had holdings. In 1955, the Bratsberg and Tinnoset lines were merged and became part of the NSB state-owned railways.

Name	Section	Length	Period used by Hydro
The Rjukan Line	Rjukan – Mæl	16 km	1909–1991
The Tinnsjø ferries	Mæl – Tinnoset	31 km	1909–1991
The Tinnoset Line	Tinnoset – Notodden	31 km	1909–1991
The Telemark Canal	Notodden – Skien/Menstad	59 km	1909–1917
The Bratsberg Line	Notodden – Porsgrunn/ Herøya	70 km	1917–1991

The station buildings that were built for the railway system are of value in that they contribute to the overall picture of Hydro's use of the architect Thorvald Astrup (1876–1940) in order to ensure architectural quality in the construction of the industrial communities in Notodden and Rjukan. All the station buildings were drawn by Thorvald Astrup, who was one of the most skilled and prolific architects in Norway in the early 20th century. (For more details on Astrup, see section 2.b on p. 284.) Astrup was employed by Sam Eyde, Hydro's founder, who had an interest in architecture and was construction manager for the Rjukan Line. Hydro used Astrup more than any other architect during the first decades. The station buildings illustrate some of the breadth of Astrup's architectural expression, and his focus on regionally inspired buildings that were uniquely suited to their sites.

The railway network included a separate transport line from Såheim to Vemork. Vemork Power Plant could not have been built without this line. It was also used during the building of the Hydrogen Plant at Vemork, and the route with the tracks removed is still used today when the power plant needs to be upgraded. A track system with a total length of approximately 20 km is also said to have existed within the factory area in Rjukan.

At its peak, rail transport of goods to and from Rjukan accounted for one sixth of Norway's total rail transport. (The statistics do not include rail transport of ore on the Ofot Line from Sweden to the port of Narvik.) From the time it was opened until it closed, the line transported a total of 30 million tonnes of goods. In 1930, it carried 550 000 tonnes and, in the peak year 1962, 722 000 tonnes.

Passenger transport by train and ferry continued until 1985, when these were transferred to transport by bus via Hovinheia. Norsk Hydro stopped using the system for goods transport in 1991. By then, a road connection had been completed between Tinnoset and Mæl on the western shore of Tinnsjøen lake, a so-called 'replacement road' which, due to the steep terrain, ran through several long tunnels.

Electrification of the railway line

The Rjukan Line was electrified in 1911 to become **Norway's first electrified, normal-gauge railway**. This was the second line to be electrified, following the metre-gauge Thamshavn Line outside Trondheim in 1908, which was also built to serve industry, and eleven years before the first section of railway was electrified by the state railway company NSB. There were plans for electrification from the very beginning in 1909, but electrification of the line was not completed until 11 July 1911. Licences had been granted for both steam and electrical operation, and steam was initially used to operate it. The electrification can be seen as an example of the breakthrough of the Second Industrial Revolution in Norway with the use of electric power.

The electrification was carried out by the German company AEG and received international attention. The electrification using 10 kV, 16 ⅔ Hertz alternating current was a real pioneering project, as trials with high-voltage electrification of main lines in Europe did not start until 1911 in Prussia. It was the background to an agreement on the use of 15kV, 16 ⅔ Hz electricity that Austria, Germany, Norway, Sweden and Switzerland entered into one year afterwards. The Rjukan Line operated as an isolated system until 1920, when it was connected to the state-owned railway network. The line between Notodden and Tinnoset was taken over by the state-owned railways and upgraded to a standard voltage of 15 000 V in 1936. The voltage was not changed on the Rjukan Line between Mæl and Rjukan until 1966. The first electric locomotive, RjB no 1, has been preserved in the Norwegian Railway Museum in Hamar.

A train with the Rjukan Line's electric locomotiv nr. 1 leaves Rjukan station in 1930. Photo: Norwegian Industrial Workers Museum.

From 1911 to 1958, the electric power for the Tinnoset Line was taken from the northern extension to Svælgfos I power plant, which had been built for that purpose in 1908. It contained three converters. The converters for the Rjukan Line were placed in an extension to Furnace House I, just west of Rjukan Station. To be on the safe side, it was decided to use two converters of the same type as at Svelgfoss. A third converter was put into place in 1913. Såheim Power Plant, which later supplied power to the Rjukan Line, was not put into operation until 1915. In 1958, Line Converter 2 from Svelgfoss was moved to the entrance to the turbine hall at Såheim Power Plant in Rjukan, where it still remains. The current overhead line equipment comprises components from all phases between 1911 and 1966. The masts and beams on the Rjukan Line date back to 1911.

The Tinnoset Line – stations and building stock (10)

The Tinnoset Line *(object 10.1)* covers a 30 km stretch from Notodden to Tinnoset. The terminal stations have very different buildings, both drawn by Astrup. Brick was chosen for the central station in ***Notodden*** *(object 10.2)*. From there, a branch line carried Hydro's freight to the ***Railway Quay*** *(object 10.3),* also known as the Rjukan Quay, while passengers were transported to and from the canal ferries via *Notodden Quay (supporting* *value)*. ***Tinnoset Railway Station*** *(object 10.5)* with its cog-jointed timber building alludes to Telemark's rural architecture. The station building at Tinnoset is a unique piece of railway architecture and can be seen as a salute to the areas steeped in tradition that were opened by the railway.

Originally there were two stations en route, both equipped with buildings that had served as workers' huts during the construction period. Lisleherad railway station building *(supporting value)* is from the 1920s, while the stationmaster's house at Gransherad *(supporting value)* is a converted workers' hut from 1909.

Place, name	Type	Building stock	Year built	ID no	Architect
Notodden Old	Station	Station building	1909	10.3	Architect Thorvald Astrup
Notodden New	Station	Station building	1917	10.5	NSB's architectural department, G Hoel
		Freight house	1917	10.5	NSB's architectural department, G Hoel
		Transformer station	1920	10.5	NSB's architectural department, G Hoel
		Workshop, smithy	1960		NSB's architectural department, A Sundby
		Engine shed	1963		NSB's architectural department, A Sundby
Lisleherad	Station/ unmanned stop	Station building outhouse	1930		NSB's architectural department,
Storemo	Unmanned stop	Shelter	1945		
Grønvollfoss	Manned stop		1909?		
Årlifoss	Manned stop		1914?		
Rugholt	Unmanned stop	Shelter	1947		
Gransherad	Station/ unmanned stop	Stationmaster's house	1909	10.6	Originally a workers' hut
Tinnoset	Station	Station building	1909	10.7	Architect Thorvald Astrup
		Outhouse/Privy	1909	10.7	Architect Thorvald Astrup
		Freight house	1909	10.7	Architect Thorvald Astrup

The buildings without an ID no are not included as central values in the nomination proposal.

The Rjukan Line's ferry crossing over Tinnsjøen lake (11)

Today, ***Tinnoset Ferry Quay*** *(object 11.2)* with building stock and ***Tinnoset Slipway*** *(object 11.3)* are a part of the Rjukan Line. The waters of Tinnsjøen lake, together with what were originally ***11 lighthouses*** *(object 11.4)* on strategic promontories connected the sections of railway to the ferry quays at Mæl and Tinnoset. Hydro's transport company had six vessels crossing Tinnsjøen. The first was the ferry barge 'Tinnsjø', constructed of wood in Tinn Austbygd and launched as early as in 1908. Railway tracks with room for eight wagons were installed on board 'Tinnsjø' at Tinnoset. The barge did not have its own propulsion system, but was towed by the icebreaker 'D/S Skarsfos', launched in the same year. So that the ferry would withstand the impacts of the ice, the skin of the hull was fitted with iron plates. The tug ferry was used until 1929 for the transportation of freight such as quartz from the quarry at Busnes, and it was finally condemned in 1938. What is left of it is buried under the material used for the breakwater outside the small-craft marina at Mæl. It was visible on the shore until the small-craft marina was built in the 1990s. 'D/S Skarsfos' was in service as an icebreaker until 1983; following modifications, it is now used for passenger transport from Skien. The wooden ferry was followed successively by 'D/F Rjukanfos' in 1909, ***'D/F Hydro'*** *(object 11.15)* in 1914 and ***'D/F Ammonia'*** *(object 11.13)*, the last steam ferry, in 1929. 'D/F Ammonia' was built at the same time as the transition to the Haber-Bosch method took place in the factories. Following the loss of 'D/F Hydro' during the War, the capacity of the fleet was not adequate for Hydro's production. 'Rjukanfos' was lengthened, but the result did not live up to expectations. The ship was broken up in 1969, after having served as a back-up ferry since the diesel ferry ***'M/F Storegut'*** *(object 11.14)* was delivered in 1956. 'M/F Storegut' was completed on the slipway at Tinnoset.

M/F Storegut at Tinnoset in 2009. Photo: Alexander Ytteborg.

The railway ferries ‘D/F Ammonia’ and ‘M/F Storegut’ are both protected and in working order. ‘D/F Hydro’ stands at the bottom of Tinnsjøen lake in a known location. She was sunk in a sabotage operation during World War II, in February 1944. A total of 21 vessels were built to transport passengers and goods across Tinnsjøen. ‘D/F Ammonia’ and ‘M/F Storegut’ are the only ones to have survived and, together with the ferry quays, slipways, lighthouses, railway stock, tracks and building stock, they were transferred from Norsk Hydro to ‘Stiftelsen Rjukanbanen’ (the Rjukan Line foundation) in 1997. The foundation has used the vessels as a stationary museum on Tinnsjøen. In 2012, the entire collection was transferred the Norwegian Industrial Workers Museum at Vemork and it is now part of a regular, publicly managed museum.

Contact with the upper railway line segment was at ***Mæl Ferry Quay*** *(object 11.5).* There, Hydro built a number of houses for the transport system employees; in addition to small single-family houses, a group of five larger houses was built in ***Mælssvingen 10–15*** *(object 11.7).*

The Rjukan Line’s stations and building stock (11)

The ***Rjukan Line*** *(object 11.1)* covered a distance of 16 km from Mæl to Rjukan, from where a 5 km branch line – the ***Vemork railway track*** *(object 11.11)* – ran up to the power plant. The terminals had identical station buildings, drawn by Thorvald Astrup. ***Mæl Railway Station*** *(object 11.6)* includes several buildings that formed a dense cluster around the ferry quay. ***Rjukan Railway Station*** *(object 11.9)* includes a freight house and the line’s engine shed. When it was opened, the line had no intermediate stations, but there were unmanned stops at Miland and Øverland, both of which had buildings drawn by Architect Thvorvald Astrup. The buildings at Miland were demolished in 1989, while the buildings at Øverland have been sold and moved. Local trains brought the workers to the factories from the housing areas on the east side of town as they were developed. The train departed from Ingolfsland in 1913, and was extended to Tveito in 1916. It was known as the ‘Shift Tram’ and was closed down in 1957. At Ingolfsland, a manned stop was built in 1913, which was later upgraded to a station in 1919. ***Ingolfsland railway station building*** *(object 11.8)* was also drawn by Astrup, replacing a ticket booth from 1915.

The line was busy with local traffic for many years. At its peak before the war, the line carried 200 000 passengers a year. During several periods in the 1960s, up to eleven train pairs were operating between Rjukan and Mæl on a daily basis, consisting of one goods train, five mixed passenger/goods trains and five passenger trains. Many pieces of ***rolling stock*** *(object 11.12)* used by Hydro have been preserved. The Rjukan Line was closed for passenger transport in 1970. Rjukan Station handled 100 wagons with an aggregate cargo of 800 tonnes of calcium nitrate and 400 tonnes of ammonia every day, or a total of 622 953 tonnes for the year 1957 as a whole. That was also when the railway workforce was at its greatest, comprising 186 employees. The line and ferry were closed down in 1991.

A table showing stations and building stock follows on the next page.

Place, name	Type	Building stock	Year built	ID no	Comments	Architect
Mæl	Railway station	Station building	1917	11.7		Thorvald Astrup
		Stationmaster's house	1909	11.7	1 gate	Thorvald Astrup
		Privy	1950 ap-prox.	11.7		
		Freight house	1909/1943	11.7		
		Carpenters' workshop, storage space	1950 ap-prox.			
		Smithy, tractor depot	Unknown/ 1964			
Ingolfsland	Railway station	Station building	1919	11.9		
Såheim	Engine shed	incl./Wagon Repair Workshop	1918	11.11		Thorvald Astrup
Rjukan	Rail-way-station	Station building	1909	11.10		Thorvald Astrup
		Engine shed/storage	1927/1963	11.10	4 gates, 2 with track	
		Freight house	1915/1939 /1963	11.10		
		Workshop/offices/ storage space	1930/1962			

The buildings without an ID no are not included as significant objects in the nomination proposal

Company town – urban community (12–13)

Hydro built and operated housing as well as administrative and societal infrastructure for the families that were connected to the company's hydroelectric, industrial and transport activities. The first houses that were built by the company were erected at Svelgfoss, which was followed by Notodden on a somewhat larger scale, and finally Rjukan, which took the form of a complete urban community of the 'company town' type.

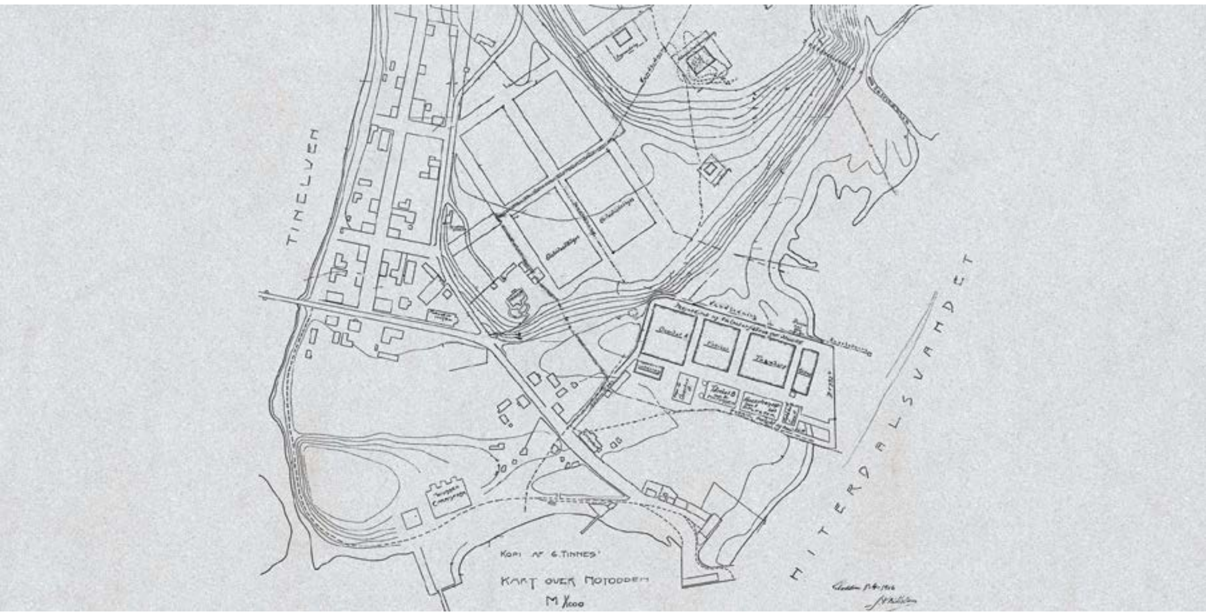
The industry was developed in previously undeveloped areas with few or no houses, in which urban communities were therefore created by the companies that were behind the industrial development, or by associations formed by the workforce that was employed by these companies. The functions that were met included housing for the various categories of personnel that were employed, in addition to assembly buildings, schools and a hospital, welfare buildings, buildings for supplying groceries and administration buildings, not only for the company, but also for representatives of the local community – in other words, everything that was needed in a complete urban community.

Notodden and Rjukan are inextricably linked to parts of Norsk Hydro's history, but the location of the industrial developments and the company's intervention did not have the same impact on the two industrial communities, and they therefore display both resemblances and differences. When Hydro was established in 1905, a small industrial community had already been established in Notodden around the company Tinfos AS. Tinfos AS started up as a paper manufacturer, tried its hand at carbide production and later became an ironworks company. The urban community can be ascribed to two industrial enterprises, each with its own characteristics, as reflected in those parts of the town that were developed by each of the companies. Hydro started up during the interval between the failure of the carbide factory and the establishment of the ironworks, which is why Notodden developed with both Hydro and Tinfos as driving forces in shaping the town. Notodden is situated in an established rural area of large farms and landowners. It was awarded town status in 1913, and the town centre is dominated by independent business interests. The town was based on two unofficial zoning plans – the first one drawn by Hydro's people and the second one by the landowner Tinnes, until an official zoning plan was adopted in 1920. In 1915, a Scandinavian competition on the zoning of Skien and Notodden was won by the Swedish engineering company Allmänna Ingeniörsbyrån. It emphasised the importance of setting aside space for various development purposes and practical communication routes. Rjukan was designed and built from scratch after 1907, purely as a Hydro enterprise, with Hydro as owner and developer of both industrial and societal institutions. With exception for one area, Hydro had bought the whole land on which the town was built, and it had the role of urban planning office during the establishment phase. The area's simple and marginal farming was completely replaced by a newly developed town. Rjukan is thus unique in Norway in that the industrial community was planned to the last detail and built from scratch over a short period of time.

The term 'company town' refers to a settlement or community created by a single enterprise and run so as to attract, maintain and control a workforce (described in more detail in section 2.b on page 279-280). Such a definition can cover a certain type of settlements as international phenomena and can be accurately used to describe the environments that were created in Rjukan, even though the workforce there organised itself and participated in the design of the community on an independent basis. Notodden is a typical industrial town; but while two large industrial enterprises have left their imprint, it also has commercial and other independent businesses on account if its location and the surrounding area. Rjukan was the first town in Norway that was planned purely as a company town, and developed as a company undertaking for the company Norsk Hydro's own account. The design was idealistic, based on the British garden city concept with organic urban structures, front gardens and open urban spaces to provide good physical standards for the workers, as well as on German examples. Quality of life was also to be offered through a standard of housing that included hot water and electricity and a social infrastructure that included schools, sports grounds, public baths and public spaces. These features are less prominent in the overall urban structure of Notodden, but they can be clearly seen in the housing areas near the factories: examples are the Grønnebyen housing area, which was connected to Hydro, and the Kanalbyen and Hyttebyen housing areas, which were connected to Tinfos.

The design of Rjukan in particular, but also parts of Notodden, represents a unique architecture that is peculiar to the local landscape, and that, together with the factories, power plants and transport system, makes up structures that are decipherable today and clearly tell the history of an important period of development in Norway and globally.

The delineation of the nominated area is defined by the time of origin, i.e. from start-up to completion of the urban communities. This coincides with the start-up of industry and the first decades of large-scale production, during the period from about 1905 to about 1930. Local cultural history analyses have been carried out for the central areas of both towns (Norwegian Institute for Cultural Heritage Research (NIKU), 2012). The division into sub-areas and the description of these areas are based on those analyses.



Map of Notodden 1906, with Hydro's testing factory by the lake and the areas zoned for worker's housing (Grønnebyen). Also the carbide factory of Tinfos AS, the steamship quay, and the main street with its commercial blocks can be seen.

Notodden Hydro Town (12)

The centre of Notodden as it appears today is largely the result of the fact that Hydro and Tinfos established themselves in Notodden in the early 20th century. Before 1900, the feeble beginnings of a centre was emerging up at Tinnfoss, but when the road was rerouted and the steamship quay was built, a new area was developed down by the lake on land belonging to the Tinne, Hvåla, Sætre, Heibø, Tveiten and Tinnes farms. The farm houses are now encompassed by buildings, but with a certain distance to the built-up area, Tinne and the two Tinnes farms are still imposing with their prominent position in the landscape. The town is named after a cotter's farm that lay down by Heddalsvatnet lake. The town became a centre of trade, communication and the tourist industry for the surrounding villages, and it was linked to the corn mill and the timber industry until its development was boosted by the industrial expansion driven by Tinfos and Hydro.

Around 1900, before Hydro arrived on the scene, Notodden was a rural community with 849 inhabitants in the centre, offering trade and services to the surrounding area. Hydro could therefore concentrate on building housing, and did not have to make sure that there was a supply of goods, or provide healthcare and schools or address other societal needs. The urban centre and institutions were established by independent parties and public bodies. Hydro has nonetheless influenced the design of Notodden, not only in its own parts of the town. As early as in autumn 1904, those who were behind the company are said to have started work on a grid plan that became the basis for the Notodden's commercial centre *(supporting value)*, which was built in the Art Nouveau epoch. The overall plan shows the main street (Storgata) with its block layout next to blocks that were reserved for the workers' housing that in future would become Grønnebyen. The idea was based on the companies that Eyde was concurrently building and on negotiations with Tinfos AS. A new centre therefore developed further south, closer to Heddalsvatnet lake than the existing beginnings of a centre which was linked to old routes of communication across the Tinnelva river above the Tinnfossen waterfall. In 1912, Notodden was awarded status as a 'building community' (in accordance with the Norwegian Building Act of 1869), whereby it could prepare zoning plans, and in 1913, it was awarded town status.

The central part of Notodden in 1900 and 1912, clearly showing the rapid growth of the town, seen from Tinnes west of Tinnelva river. Right photo: Directorate for Cultural Heritage.

During the first period of Hydro's establishment in Notodden after 1905, there was a great housing shortage and, even in 1910, the census showed that families were living in outhouses, in houses previously used for brewing and in stable buildings. The company developed rapidly and was constantly recruiting more labour, so it had to build new housing itself. Hydro developed the housing areas ***Grønnebyen*** *(object 12.1)* from 1906 and ***Villamoen*** *(object 12.2)* from 1908 as separate, self-contained and delimited parts of Notodden. The two areas are situated on separate terraces in the moraine landscape, with the factory down by the lake, the workers' houses in Grønnebyen on the level above and housing for the white-collar workers furthest up, on the Villamoen plateau. The arrangement visualises the link with the industry and the social hierarchy. Grønnebyen is special both as an urban workers' community and as an early example of the adaptation of the *garden city ideal* in Norway, prior to a wave of garden city and own-home projects after 1910 and onward into the 1920s. Grønnebyen primarily served as a model for the housing that was built in Rjukan. Hydro's housing developments were regarded as high quality, based on the use of acclaimed architects such as Henning Kloumann, Helge Blix and Thorvald Astrup, and it was a continuation of the paternalistic philosophy from a century of industrialisation in the rest of Europe. Other housing projects initiated by Hydro in Notodden were Own Homes (1910-14) and Tinnebyen (1917-20) which started with 'Femrader'n' (the row of five) *(supporting value)* to the east of the existing built-up area. 'Femrader'n', which despite its name consists of a row of four identical multi-family houses along a curved street, is special in that it comprises the only brick buildings in Hydro's housing stock in Notodden. Hydro also built houses beside the power plants at Svelgfoss (from 1905) and Lienfos (from 1909), north of the urban centre. Altogether, Hydro administered 320 housing units during the time it was active in Notodden. In 1950, Hydro had 110 houses containing 233 apartments, of which 99 houses containing 193 apartments had been built by the company and 11 houses containing 40 apartments had been bought. In addition to housing, Hydro contributed to the construction of buildings for social welfare and other purposes:

- A festivity house for the workers, 1909, converted to a small infirmary (architect: Helge Blix, demolished).
- Notodden Municipal Baths, 1912 (Architect: Helge Blix, demolished).
- Notodden Primary School, 1912 (Architect: Helge Blix, demolished).
- Notodden Theatre, 1914 (Architect: Helge Blix, demolished).
- Notodden Hospital, 1919, after first having allowed the municipality to use one of the houses in Grønnebyen as a hospital.
- Brattrein, a children's home built in 1924 by the Notodden Tuberculosis Association, taken over by Hydro in 1955 and converted to the company's Institute of Education. Following its sale in 2009, the building now serves as a hotel.

For its own use, Norsk Hydro built ***Admini*** *(object 12.3),* an administration building used for offices, hospitality and accommodation. The building played an important role in the effort to raise funds for the industrial development from the international parties that became involved in it. Sam Eyde had a home and office in the building when he was in Notodden, and all important guests were received and lodged there. Buildings bearing the name of 'Admini' were also built in Rjukan and Herøya. The company built the ***Casino*** *(object 12.4)* for its engineers and white-collar staff that did not hold high enough offices to be given lodgings in Admini. The term 'Casino' originates in Italy, where it was used to describe places offering amusement and later included canteens that served good food; it came via Germany, where the term *Offizierskasino* was used to describe an officers' mess or officers' lodgings. Hydro took the term from German industry, which had in turn adopted it from the military to describe an eating and lodging establishment for persons of high rank.

Rjukan Hydro Town (13)

Rjukan is a genuine and self-contained company town created by Hydro. In those parts of the town that fall within the proposed boundaries of the World Heritage Site, delimited by the extent of the town when its development was completed in the late 1920s, the nomination focuses on the areas, buildings and relationships between them that are particularly representative or illustrative of what is typical about Rjukan.

Rjukan town is unique in Norway as the first totally planned town that was built under the auspices of a private enterprise. The grand-scale development has clear models abroad, and is a Norwegian parallel to, *inter alia*, the Swedish mining town of Kiruna where a prestigious housing programme was realised under the auspices of LKAB using 'a majority of Sweden's most prominent architects, artists, engineers etc...', and the Wallenberg family's funds. Sam Eyde stressed that he was inspired by Germany, where Alfred Krupp had built a model town as early as the 1860s, with good housing for his employees, based on the conviction that secure housing was an advantage in relation to other companies. Sam Eyde had a rare ability to bond with first-rate professionals, which in the case of the town development project, consisted of many of the most skilled young architects of the time. Most of them were educated in Germany or had degrees from Swedish academies, but some had their education from technical colleges in Norway.

The companies formed to utilise the energy in the waterfalls and build the calcium nitrate plant systematically bought land from the four farms (Måna, Såheim, Gryte and Mogen) along the southern bank of the Måna River and Bøen Farm on the northern side. Housing and infrastructure had to be in place before Hydro could establish its factories. In the course of a few decades, a town was built that increased the population from a few hundred to more than 10 000. Despite being built in a hurry, the town is characterised by good-quality workmanship, both in terms of town planning and the execution of the individual buildings.

To the left: Old meets modern. The very first stages in developing the Vestfjorddalen vally from farming to industry. Photo: Anders B. Wilse. To the right: The building of Sing Sing, a new and modern type of housing. Photo: Norwegian Induistrial Workers Museum

Rjukan was Norway's most modern town, and the only one to have been planned from scratch. At the same time, the town was a closed community of people who were mostly connected to one and the same company, which meant that their position in the internal hierarchy became painfully obvious.

In 1907, the company decided to build the first workers' housing of a type (the 'J' type) that was almost identical to the type that had previously been built in Grønnebyen in Notodden, in addition to a bakery, commercial building and administration building. The first urban centre and the start of an industrial community was then established at the westernmost side with the workers' housing in Flekkebyen, houses for the white-collar staff and the Admini building along Villaveien road and the storage facilities, bakery, chemist etc. at Bøen, at the same time as the factory was being built on the Såheim side south of the river. Following the first developments in Bøhagen, Flekkebyen and Villaveien, the town expanded rapidly towards the east to what would eventually become Torget, Ingolfsland and Tveito during the period up until 1920.

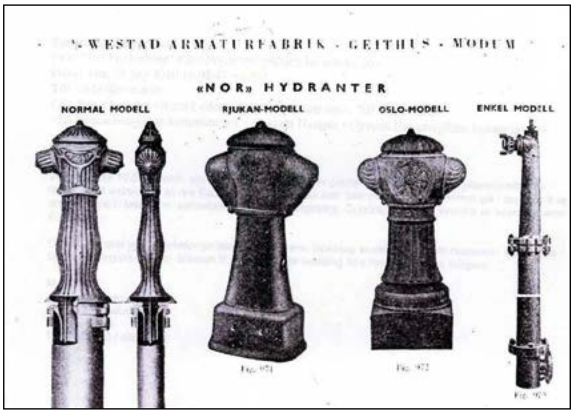
In 1912, Rjukan was chosen as the official name of the town, which during the first building phase had been known by the name Såheim urban area. The name Rjukan is derived from the Norwegian word meaning 'the smoke', referring to the significant amount of mist and spray produced by the Rjukanfossen waterfall. The climax was reached around 1920, when Rjukan became Norway's biggest industrial community, and the town of approximately 12 000 inhabitants had largely been completed. In the 1920s, the town entered its first period of recession following the international recession that came in the wake of World War I. The number of people leaving culminated in 1927 when more than

700 persons moved out. It is the extent of the town at that time which forms the basis for the nomination proposal's delimitation of the urban community component in Rjukan.

Houses and industry in Rjukan before 1920. Photo: Directorate for Cultural Heritage.

In order to manage the development of the town, Norsk Hydro set up a separate department in 1909 under the name of **Rjukan Byanlæg** (Rjukan town development), employing the skilled architects Bernt Keyser-Frølich, Joh. E Nielsen, Helge E Blix, Bjarne Blom and Ove Bang. Thorvald Astrup, Harald Aars, Magnus Poulsson and Christian Morgenstierne were other architects who were also given assignments for Hydro in Rjukan. The town development office functioned as a town planning office, which, in addition to housing, also attended to tasks that normally belong to local and central government authorities. It put in place schools, a children's home, hospital, library, post office, parks, sports grounds and assembly halls. Significant practical and financial contributions were made to church buildings. Based on the drawings, it is sometimes difficult to determine what was drawn by whom, as they often bear a number of signatures. A building was often a collaboration in which plan and façade drawings were produced by different architects, while yet others were responsible for modifications and corrections. *The houses that were built until around 1925 comprised 140 different types,* lettered from A to Ø (the next to last letter in the Norwegian alphabet), 1 to 39 and 101 to 140, in addition to variants such as 11, 11a, 11b etc. From then on, the town development office became a maintenance department that, in addition to maintaining the housing stock, undertook municipal tasks such as road maintenance right up until 1970. In its capacity as town developer and owner, Hydro had direct control of 80% of the Rjukan community. By 1925, the company had spent NOK 22 million (corresponding to NOK 460 million in 2012 currency) on building up the area and had 1 230 dwellings at its disposal.

Rjukan Byanlæg also saw to the development of infrastructure such as streets and roads, water and sewage systems, street lighting and the electricity supply in general. The drawings that were produced for the town development department included drawings of transformer buildings, a pumping station, kiosks, toilets, bridges, lampposts, garden benches and dovecotes. Attention was given to form and details as exemplified by urban equipment like the fire hydrants. The latter were developed and manufactured by Westad Armaturfabrik under the joint trade name Nor-hydrant. A customised model for Rjukan was more robust than those that were manufactured for Kristiania (now Oslo), and bore the engraved initials RS for Rjukan Salpeterfabrikker. Approximately 120 such fire hydrants were installed in Rjukan between 1910 and 1920. Several of these have been preserved, as have a number of racks for fire ladders in strategic locations within the housing developments, lamp posts, some dustbin enclosures and other equipment. Rjukan is built on electricity, and, in contrast to many other Norwegian towns, the town as a whole was developed after the arrival of electricity. All the houses in Rjukan were designed and built to use electricity for lighting and heating. Hydro produced the electricity and supplied it through a distribution network that included pylons, cables and transformer kiosks. The town has preserved some examples of the transformer kiosks and pylons. Some of the town's waterworks buildings also remain, including the pressure reservoir and pumping station.



Far left: Catalogue from Westad Armaturfabrikk, with the Rjukan model in the middle.

Left: The Rjukan model is preserved in several places in Rjukan. Photo: Trond Taugbøl.

Hydro also took responsibility for the distribution of food and tobacco to the town's inhabitants. This took place via 'Rjukan Salpeterverkers landhandleri' (Rjukan calcium nitrate works' general store), eventually abbreviated to 'Rjukan varelager' (the Rjukan store). The store was opened in order to prevent private merchants from charging excessive prices and, more generally, to provide the workforce with sufficient goods. When it opened, the store had four employees, but at one time it was the biggest retail store in Norway, with 86 employees. Hydro sold the store in the mid-1920s. By then, the business included a patisserie, shoe department, textiles department and a separate butcher's shop. Agriculture in Vestfjorddalen was marginal and much of the land had been devoured by the industrial town. The few and small farms were not capable of supplying enough milk to the new urban communities. Hydro had to take on this task, and built and ran farm buildings for milk production for almost 30 years.

A small infirmary was built very early on in the development period, at the bottom of Villaveien (no 5) and, in 1919, it was replaced by a fully equipped hospital located further east in the town. In order to attract qualified labour, Norsk Hydro built and operated the first schools in the community, including a vocational school, and, in 1922, an upper secondary school, in collaboration with the municipality. In the early days, it was low-church movements that dominated religious life in Rjukan. After pressure from the Church of Norway, Norsk Hydro prepared the ground for a large church building in the eastern part of the town. Unlike in other Norwegian towns, the church, which was opened in 1915, was not situated in the town centre.

Town plan

In the narrow east-west valley, the topography set clear limits for urban planning and urban growth. At the same time, the topography was exploited to manifest social order in the Hydro structure. The town was developed from the west, in step with the development of the power plants in the watercourse and the pertaining factories and plants. One main street (Sam Eydes street, 6.3 km long) runs the length of the town. Only where there were plains along the valley floor, was there room for parallel streets and the beginnings of a block structure. A **zone-division principle** was used. The factories were built on old agricultural land on the southern side of the river, while the town with its dwellings was planned on the northern side where there was more sun. The mountain to the south

Rjukan viewed from the Krosso Aerial Cableway. Photo: Trond Taugbøl.

kept the sun away for up to six months of the year. The housing was designed to make the outlying community below the Gaustatoppen mountain more attractive, in particular to skilled workers. The more important the position with Norsk Hydro, the better the housing that was offered. This lead to a clear social stratification of the Rjukan community, which was reflected in the saying: 'Tell me what position you have with Hydro and I will tell you where you live'. Furthest up, in Villaveien and Fjellveien, where there was most sunshine, lived the higher-ranking white-collar staff, the company doctor, the chief local judge, the chief of police and the senior manager. The parts of the town in which the workers lived were on the floor of the valley. Firemen and engineers who had to be mobilised fast in the event of an accident, lived near the factories, which led to a certain social and architectural softening of the typical workers' district of Flekkebyen. In the late 1920s, the Krosso Aerial Cableway was built on Norsk Hydro's initiative as a welfare measure for the town's inhabitants. Northern Europe's first cable cars with two suspension cables were an ingenious initiative designed to bring people into the sun, in a place where it was extremely difficult to bring the sun to the people. With a ticket price of only 0.1 Norwegian kroner, the idea was that everybody should be able to afford the trip.

The idea of '**Own homes**' for the workers had been around since the turn of the century and model drawings had been produced of small, detached workers' homes with a garden and outhouse. The idea was based on self-building on allotted parcels of land. In Rjukan, there was a departure from this principle, as the workers did not have the opportunity to build their own homes but were offered ready-built housing if they took up a loan with the company. The addition of new housing areas to the east started with 20 Own Homes on Ingolfsland in 1912, but the company decided to continue the development by arranging a competition among the architects mentioned above. It covered most of Norsk

Hydro's subsequent housing stock in Rjukan, and in addition to small wooden houses, it included a belt of brick buildings to provide a fire division across the town. House drawings and an overall plan for the arrangement of the buildings was to be provided within the framework of a zoning plan. Space was to be set aside for a church, school, baths, a library, a general stores building and administrative staff quarters, and for a colony of 12 housing units for administrative staff, with an area of 80–100 m^2 each and sharing a park and playground. The rest of the land was to be developed with Own Homes on parcels of land of 350 m^2 for detached houses and 500 m^2 for semi-detached houses. With the passage of time, separate housing was built for pensioners, so that the family housing could be allocated to active employees. After 1920, Hydro built 12 houses containing 102 pensioners' flats in Rjukan.

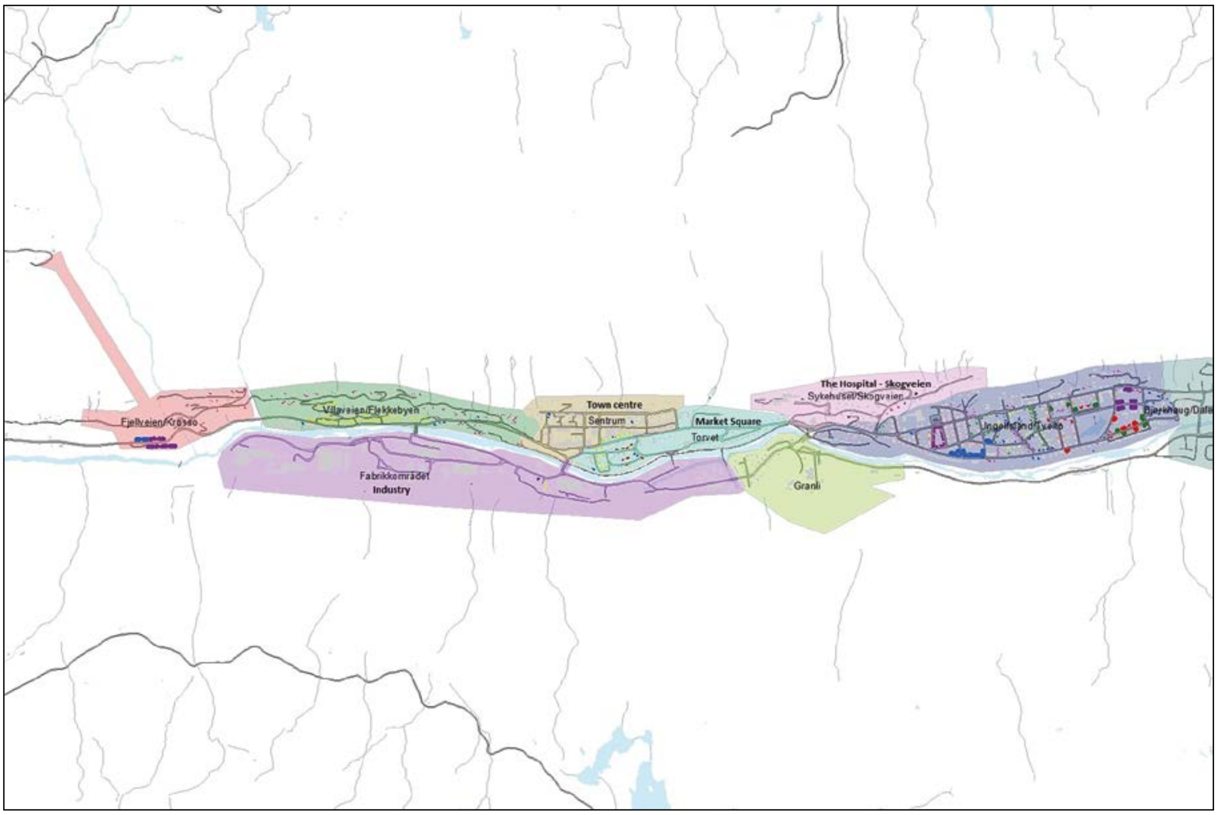
British urban planning ideals based on the organic structures of the **garden city concept**, which had been promoted by Ebenezer Howard in particular, and the corresponding recommendations of the Austrian Camillo Sittes, were clear influences on the architects' work when they designed Rjukan. These contemporary ideals were reflected in the variation in the shape of the houses, curved streets, open squares and front gardens. **Rjukan is thus a testimony of the time of its creation – an example of planned physical fabrics and urban forms, social structures and the organisation of people's working lives and leisure time, at the same time as it illustrates the technological and industrial breakthrough known as the Second Industrial Revolution.**

The town of Rjukan was admired by contemporaries. One example is when the chair of 'Kristiania Sundhedskommission' (public health commission) visited the town accompanied by a delegation from England. The British delegation was amazed and asked where the workers lived when they saw the 'Own Home' colony which they thought were the homes of Hydro's engineers and high-ranking administrative staff.

Norsk Hydro's acquisition of building land did not include all the land on the Bøen farms. An area known as 'Private Bøen' was developed by other parties into commercial buildings along the town's two main streets, Sam Eydes street and Storgata. Sam Eydes street is the thoroughfare that runs the length of the town. The string of urban houses from Krosso to Bjørkhaug is a ribbon town extending approximately 5.5 km along the length of the valley. Opposite Private Bøen, Hydro established the town's market place, flanked by the library and post office/chemist. There were plans to build a town hall/assembly hall that would form a backdrop and city wall on the southern side of Market Square, but the plans were never developed beyond the drawing board and the proposals put forward during the architects' competition.

Artificial fertilizer was produced using limestone dissolved in nitric acid. The lime was included in the finished product which was called 'Kalksalpeter' (calcium nitrate). The process created a waste product known as 'dregs' or 'black quarry dust', a black substance with a grit-like consistency. Dumps of this waste were used for landscaping in Rjukan. Such waste material was used as backfill material for, *inter alia*, Rallarparken (the 'Navvy Park'). Dumps along the Måna river were also used as building land after the war. Many local garden owners have collected 'quarry dust' for their garden paths, slopes and lawns.

The various parts of Rjukan Hydro Town, described from the west



Map showing the various sub-areas of Rjukan. NIKU 2010.

Våer – Vemork

The sub-area Våer – Vemork is a satellite of Rjukan, a separate small community linked to Vemork Power Plant further west, at the head of the valley. The Våer housing area comprises the director's residence, workers' housing and a farm building for milk production. The housing consists mainly of Hydro houses. Though they are not specified as Hydro-type buildings, Våer 3, 4, 5 and 6 are similar to the J type that we find in Grønnebyen in Notodden, and in Rødbyen and Flekkebyen in Rjukan. The row of houses at the fringe, Våer 18–22, is probably a version of the series of 4H types, various variants of which are found near the Rjukan store at Bråvoll, Musikkhuset (the music house) in the centre, Lasarettet (the infirmary) in the hospital area and the pensioners' housing in Tinngata 63–69 and Sam Eydes street 248–252.

The area Våer – Vemork is by its overall and clearly defined structure an important component in deciphering the Rjukan community and the connection between power production, the factory area and urbanisation. Some of the buildings at Våer have been renovated or extended, but are still recognisable as Hydro houses.

Krosso – Fjellveien (the 'mountain road')

This sub-area includes the built-up area along Fossoveien, the brick buildings at Krosso *(object 13.1)*, the Krosso Aerial Cableway *(object 13.2)* with pertaining buildings and the villas in Fjellveien and the upper part of Villaveien. The buildings in Fjellveien were individually designed as single-family and two-family houses. The earliest buildings from 1918 with access roads, front gardens, stone walls etc. clearly illustrate that the area was a residential area for Rjukan's upper social class. Later buildings along Fjellveien and Villaveien are partially modified in volume and location, and the area appears to be planned and shaped as a whole with the newer buildings having been well-integrated.

Villaveien – Flekkebyen housing area

This sub-area represents the early development of the industrial town of Rjukan and comprises Hydro's Admini *(object 13.6)*, the housing in Villaveien and Flekkebyen *(object 13.4)*, and the urban functions that were established during the initial development of the town, including the Fjøset farm buildings with housing *(object 13.3)* built by Hydro to secure food supplies to the new town. The old town centre *(object 13.5)* with a chemist, bakery, butcher, shops and a storehouse for groceries, clothing and shoes was situated on the main road. The area lies opposite the factory area to which it is connected by the Fabrikkbrua bridge across Måna *(object 13.23)* leading straight to the factory's gatehouse and fire station *(object 13.7)* and the company's construction office and office building *(objects 13.8–13.9)*. Municipal street furniture such as fire hydrants, fences and drying racks have been preserved in the area.

The town centre

This sub-area comprises a block layout from the Admini park and eastwards on the northern side of Sam Eydes street (with the exception of the row of houses included in the Market Square sub-area). The central area was developed at the same time as Hydro's industrial town was being built, but mainly by private landowners and businessmen. This is parallel to the way in which the private centre in Notodden arose, but has not had the same impact on the character of the townscape. In relation to Norsk Hydro's ambitious town-building project, the layout seems dull and the architecture is that of anonymous master builders. It makes the qualities that Hydro was able to create in its urban community all the more outstanding.

The centre was divided into 80 plots in accordance with a grid-pattern street layout, as opposed to Hydro's areas, which were partly modelled on the garden city ideal. The area 'Private Bøen' was largely developed around 1920 and has elements of Swiss chalet style architecture, Art Nouveau style and other contemporary styles. Most of the houses are made of wood, but there are also some brick buildings. Some of the buildings such as the Music House and the Methodist Church represent important functions in the urban community. The Music House was originally the Labour movement's People's House from 1910, and was used until a new People's House was completed in 1930 as one of the finest assembly buildings in Scandinavia. It was fully financed by loans from Hydro and Frydenlunds Bryggeri (brewery). In 1935, the Worker's Association had to surrender the building to Hydro, which renamed it the ***Rjukan House*** *(object 13.10).* Together with the park that fronts the building towards Sam Eydes street, the Rjukan House constitutes the area's most central individual element.

Market Square

This sub-area extends from Birkeland's Bridge to the Måna River and Sam Eydes street in the east, and includes individual houses and areas on the northern side of Sam Eydes street. It includes what used to be Såheim Private School *(object 13.11)* and the Baths, the housing areas Rødbyen and Tyskerbyen *(object 13.12)*, Market Square *(object 13.13)*, the Primary School at Bøen, the sports ground and New Town with its row of O-type houses *(object 13.14)* on both sides of Sam Eydes street. The area represents an important town planning initiative from the early development period with societal and administrative functions. The housing areas were gradually expanded to the east as the town grew. With Hydro's assistance, a congregation of Baptists were able to build the Baptist Church *(object 13.15)* in this area, whose architecture stands out as very different to that of the rest of the company town.

The Hospital – Skogveien

This sub-area comprises the housing in Skogveien, in addition to Rjukan Church *(object 13.16)* and Rjukan Hospital *(object 13.17)* which were built concurrently during the period before 1920, and which formed the background to why housing was built in the area. Skogveien was a parallel to the development in Villaveien and Fjellveien, with detached houses for the upper social class, including the pastor, bank manager, chief engineer, chief physician and other hospital employees. The detached houses were drawn by prominent architects and display qualities that reflect the contemporary building styles. Further developments have taken place along Skogveien in several phases, and the 1950s are among the periods that are represented in the area.

Ingolfsland – Tveito

The Ingolfsland-Tveito sub-area seen from the east. Photo: Per Berntsen.

This sub-area includes the buildings with which the industrial town of Rjukan was extended in the 1920s. The house types and planning measures were largely a result of the special 'Own Homes' architects' competition that was held in 1912 and evaluated in 1913. The jury included one representative of the workers. Magnus Poulsson won the architects' competition in 1913 (second prize; no first prize was awarded) and in the course of a few years, 64 of his house types were erected, variants of which were easy to devise. Type-11 houses, for which Bernt Keyser-Frølich was responsible, were built in an even greater number. The sale of 'Own Homes' was slow, however. This can be explained by the workers' fear of becoming bourgeois, and the risk associated with being a house owner in an outlying place like Rjukan should the industrial boom come to an abrupt end. Many workers were also unable to meet their financial commitments, so that Hydro ended up exercising its pre-emptive rights to 38 dwellings during the period 1916–1919.

The area was largely developed between 1913 and 1920, starting with Own Homes. The buildings at Ingolfsland and Tveito constitute a comprehensive catalogue of many of the building types delivered by the architects and which became Hydro's standard houses. Living arrangements and planning measures were part of the programme for the architects' competition, the terms of which were 'Own Homes' based on the garden city ideal and a fire division in the form of a brick belt. The area has ***parks and avenues*** *(object 13.19),* two schools, including the massive ***Tveito School and teachers' housing*** *(object 13.18)*, a railway station etc. The public services buildings are built in brick. The area's mixed building stock of brick buildings and wooden houses reflects different living arrangements in tenement buildings and small houses. Wooden houses dominate, but in addition to the housing quadrant of ***Sing-Sing*** *(object 13.21)* it includes multi-family brick housing along Jernbanegata (the 'railway street') and Tveito Avenue, and in the housing complexes known as Mexico, ***Mannheimen and Paradiset*** *(object 13.20),* where Mannheimen (the 'Men's Home') was planned to house unmarried workers. ***Triangelen housing complex in Ligata*** *(object 13.22)* is a group of wooden multi-family houses.

Vestfjorddalsgata no 23 is a workman's dwelling in Vestfjorddalsgata at Ingolfsland that was protected by the Cultural Heritage Act in 2003. The house is one of Magnus Poulsson's single-family house types for the Own Homes competition in 1913 (described above), type A II. The house has 1½ storeys, a pitched roof, and horizontal wooden cladding, and is arranged in a rectangle around the fire place and chimney in the middle. It is one of the few workers' dwellings in Rjukan that has been left virtually unchanged through the years.

When the town had been extended a little way beyond the Tveitoparken Park in the east, the vigorous urban growth of the past two decades came to a halt. The Bjørkhaug area further east had been zoned and a plan existed for its development, but there was uncertainty in the economy both at home and abroad at the same time as Hydro's transition to the Haber-Bosch method after 1928 led to rationalisation of production processes and a decline in the demand for new labour. Some of the houses in the Tveito – Ingolfsland area have been considerably modernised and have been renovated after they were sold by Hydro from the 1970s and onwards. Despite some reduction in the authenticity of individual buildings, the area as a whole is unique in character, with clear and decipherable overall structures and planning initiatives for functional contexts. The area also includes examples of kiosks and other smaller elements.

Catalogue with detailed description of objects

Tabular overview of nomination proposal attributes and pertaining significant objects:

ID no	World Heritage attribute	Significant objects/parts	Municipality
	Hydro electric power		
1	**Tinfos power plants**		
1.1		Tinfos I with Myrens Dam	Notodden
1.2		Tinfos II and the Holta Canal	Notodden
2	**Hydro's power plants in the Tinnelva river**		
2.1		Svælgfos lightning arrester house and workshop	Notodden
3	**Vemork Power Plant**		
3.1		Power station building	Tinn
3.2		Penstock	Tinn
3.3		Penstock valve house	Tinn
3.4		Skarsfos Dam I with intake gate house	Tinn
3.5		Tunnel system with six waste rock dumps	Tinn
4	**Såheim Power Plant**		
4.1		Power station building	Tinn
4.2		Underground turbine generator hall	Tinn
4.3		Underground penstock	Tinn
4.4		Tunnel system with seven waste rock dumps	Tinn
4.5		Workshop building	Tinn
5	**Regulating dams**		
5.1		Old Møsvatn Dam	Tinn and Vinje
6	**Power transmission**		
6.1		Cable House	Notodden
6.2		Control room in Furnace House I	Tinn
6.3		Transformer and distribution station	Tinn
6.4		Power line 16/17	Tinn
	Industry		
7	**Hydro Industrial Park in Notodden**		
7.1		Furnace House A	Notodden

ID no	World Heritage attribute	Significant objects/parts	Municipality
7.2		Tower House A	Notodden
7.3		Calcium Nitrate Plant	Notodden
7.4		Packaging Factory	Notodden
7.5		Warehouse A	Notodden
7.6		Furnace House C	Notodden
7.7		Testing Plant and Electrical Workshop	Notodden
7.8		Testing Plant and Blacksmith	Notodden
7.9		Laboratory and Workshop	Notodden
7.10		Hydrogen Plant	Notodden
7.11		Nitrogen Plant and Gas Cleaning Plant	Notodden
7.12		The Minaret	Notodden
7.13		Compressor and Synthesis Plant	Notodden
7.14		Nickeling Plant	Notodden
7.15		Ammonia Water (ammonium hydroxide) Plant	Notodden
8	**Hydro Industrial Park in Rjukan**		
8.1		Furnace House I	Tinn
8.2		Boiler House	Tinn
8.3		Barrel Plant	Tinn
8.4		Pump House	Tinn
8.5		Laboratory	Tinn
8.6		Såheim II Hydrogen Plant	Tinn
8.7		Nitrogen Plant	Tinn
8.8		Compressor House	Tinn
8.9		Synthesis Plant	Tinn
8.10		Mechanical Workshop	Tinn
9	**Production equipment**		
9.1		Ceramic pots	Notodden
9.2		Electric Arc Furnace, Notodden	Notodden
9.3		Electric Arc Furnace, Rjukan	Tinn
9.4		Acid Tower	Tinn
9.5		AEG pump	Tinn
9.6		Tanks in the Hydrogen Plant	Notodden
9.7		Synthesis Furnace, Rjukan	Tinn

ID no	World Heritage attribute	Significant objects/parts	Municipality
	Transport system		
10	**The Tinnoset Line**		
10.1		Railway track with signalling system and overhead line equipment	Notodden
10.2		Notodden old railway station building	Notodden
10.3		The Railway Quay/Rjukan Quay	Notodden
10.4		Notodden Railway Station with eight buildings	Notodden
10.5		Tinnoset Railway Station with three buildings	Notodden
11	**The Rjukan Line**		
11.1		Railway track with signalling system and overhead line equipment	Notodden and Tinn
11.2		Tinnoset Ferry Quay with six buildings	Notodden
11.3		Tinnoset Slipway with winch house	Notodden
11.4		Lighthouses along Tinnsjøen lake	Notodden and Tinn
11.5		Mæl Ferry Quay	Tinn
11.6		Mæl Railway Station with four buildings	Tinn
11.7		Mælsvingen 10–15 with five houses	Tinn
11.8		Ingolfsland railway station building	Tinn
11.9		Rjukan railway station building, freight house and engine shed	Tinn
11.10		Såheim engine shed	Tinn
11.11		Vemork railway track	Tinn
11.12		Rolling stock with 16 units	Tinn
11.13		'D/F Ammonia'	Tinn and Notodden
11.14		'M/F Storegut'	Tinn and Notodden
11.15		'D/F Hydro' – shipwreck	Tinn
	Company town		
12	**Notodden Hydro Town**		
12.1		Grønnebyen (the 'Green Town') housing area	Notodden
12.2		Villamoen housing area	Notodden

ID no	World Heritage attribute	Significant objects/parts	Municipality
12.3		The Admini (administration) building in Notodden	Notodden
12.4		The Casino with four buildings	Notodden
13	**Rjukan Hydro Town**		
13.1		Krosso housing area	Tinn
13.2		Krosso Aerial Cableway	Tinn
13.3		Fjøset farm building with housing	Tinn
13.4		Villaveien – Flekkebyen housing area	Tinn
13.5		The old town centre	Tinn
13.6		The Admini (administration) building in Rjukan	Tinn
13.7		Gatehouse and fire station	Tinn
13.8		Construction office in Hydro Industrial Park	Tinn
13.9		Office building in Hydro Industrial Park	Tinn
13.10		The Rjukan House (the People's House)	Tinn
13.11		Såheim private school with teacher's residence	Tinn
13.12		Rødbyen (the 'Red Town') and Tyskerbyen (the 'German Town') housing areas	Tinn
13.13		Market Square	Tinn
13.14		New Town (house type O)	Tinn
13.15		Baptist Church	Tinn
13.16		Rjukan Church	Tinn
13.17		Rjukan Hospital with Chief Physician's residence	Tinn
13.18		Tveito School with five teachers' houses	Tinn
13.19		Tveito Park and Tveito Avenue	Tinn
13.20		Mannheimen single men's home and Paradiset housing complex	Tinn
13.21		Sing Sing housing quadrant	Tinn
13.22		Triangelen housing complex in Ligata	Tinn
13.23		Fabrikkbrua Bridge, Birkeland Bridge and Mæland Bridge	Tinn

Hydroelectric power. Detailed description of buildings and plant

1. Tinfos power plants

The power plant that the company Tinfos AS had already built at Tinnfossen played a historic role in the establishment of Hydro's industrial success story in Telemark.

1.1 Tinfos I with Myrens Dam

Tinfos I in 1910 and today. Photo to the right: Trond Taugbøl.

Built: Put into operation in 1901.

Architect: Unknown.

Original function: River power plant.

Description: Tinfos I was a small first-generation power plant and a typical example of traditional, plain industrial architecture. The power plant on the western side of the waterfall with Myrens Dam as the water reservoir was among the first river power plants in Norway. The building was erected in plastered brick with bare-brick details and ornamentation. The only decorative element also marks the building's function: two bolts of lightning – symbolising electricity – shoot symmetrically out from the gable windows. The station belongs to the first generation of power plants in Norway, when there was little understanding of the potential represented by electricity production. At maximum water flow, the power plant had an output of 9 000 hp, or approximately 6.6 MW.

Myrens Dam was constructed of natural stone and concrete; in 1900 it replaced the waterfall's first dam, a timber dam from 1843. The dam's water intake reservoir for the power plant is intact, but dry.

Myrens Dam today. Photo: Telemark County Council.

Changes: Tinfos I was expanded twice during the first nine years, the first time in 1904 to increase capacity. The second expansion was not completed until the decision regarding a new power plant, Tinfos II, had been made. When the third power plant, New Tinfos I, was completed in 1955, Myrens Dam and the old Tinfos I were phased out. The generator set was removed and reused in Helleren power plant in Troms from 1958. By that time, a new Tinnfoss dam was in place. The pipeline from Myrens Dam to Tinfos I has been removed. It consisted of a riveted iron pipe, 4 metres in diameter, laid in a curve around the old mill. Two ventilation hoods in the form of small ridge turrets with spires had been removed some time before.

Function today: Today the building is just a shell of a building without any plant. It is now used as a workshop, but the cable that transmitted the power that Hydro contracted for its testing plant still spans the river to the eastern side. Myrens Dam is still intact, but dry. The reservoir has been renovated and is used for cultural events.

A small office building of bare brick was built in 1898 at the same time as the power plant, between the power plant and the river wall. The negotiations between Tinfos and Hydro concerning the purchase of power took place in this building, which served as the paper mill's office building until a new administration building was completed in 1908. The building is intact and currently houses a pottery.

1.2 Tinfos II and the Holta Canal

The area with Tinfos I and II with the Holta Canal seen from the air before 1955. Photo: Notodden Municipality.

Built: Put into operation in 1912.

Architect: Finn and Sverre Knudsen.

Function: The power plant was established by the company Tinfos AS in order to meet the increased need for electric power when the ironworks were built beside Heddalsvatnet lake. Tinfos II supplied power to Norsk Hydro's factories in Notodden during World War I.

Description: The plant consists of the power plant and a penstock of four riveted iron pipelines running from the valve house by the intake dam at the end of the Holta Canal.

Today the station facilities represent a unique set of intact exteriors and interiors.

The architects must have been inspired by medieval fortresses in their design. The buildings are of plastered and painted brickwork with bare brick and granite ornamentation.

To the left: Tinfos I and II. Photo: Trond Taugbøl. To the right: Tinfos II. Photo: Telemark County Council.

The actual power plant has decorated interiors, in areas such as the turbine hall, which uses the full height of the building, and a bathroom in the southern wing, which has a recessed bathtub. The interior is rich in detail, with its balcony with a view of the turbine hall, wrought iron railings, stone ornamentation, reliefs, tiling, colour scheme and decorative painting. The interior is largely intact and includes original cabinets, shelves, workbenches, special-purpose tools, light fixtures, bathtubs, washbasins and toilets. The wrought iron railings have a motif with symbolic bolts of lightning, a motif that is also found in Notodden's coat of arms.

When it opened, the station had three generator sets. A fourth generator set was added in 1926, increasing the capacity by almost 100%. All four generator sets remain in place inside the power plant. The three oldest units consist of horizontal Francis turbines manufactured by J.M. Voith in Heidenheim and German Siemens & Schuckert generators with an output of 7 000 kVA. The fourth unit consists of a vertical Francis turbine manufactured by J.M. Voith and a NEBB generator with an output of 5 000 kVA.

The 900-metre-long Holta Canal was built to supply water to the Tinfos II power plant. The canal bypassed Sagafossen waterfall, so that the head provided by two waterfalls could be utilised by a single power plant. At the upper end of the canal there is a water intake structure with an intake gate house that is preserved but not in use. The canal runs to an intake dam with a valve house, where the water is distributed to the penstock for Tinfos II. At the valve house end and on the side closest to Sagafossen, the canal was constructed of concrete. The rest of it was dug out from the terrain east of the river, and the excavated material was used for the embankment on the western side. There were major water leaks through the embankment, and the entire length of the canal had to be lined with concrete in order to seal it. The expertise needed for this type of canal construction came from Germany. However, due to the amount of sludge carried by the rivers in Germany, their canals become naturally sealed without having to be lined with concrete. The Holta Canal was a feat of engineering that attracted international attention in its time. It is the only intake canal of its kind in Norway. The canal is typical of its time, in that it represents technical innovations, based on knowledge taken from wherever it could be found. The canal is named after Ole H. Holta, the managing director of Tinfos AS. Hydro's power plant, built at Svelgfossen a few years previously, also had an excavated open headrace canal. It was not as audacious in that it followed the bottom of the downslope, so that there was no danger of a leakage to the adjacent terrain.

Changes: The biggest change to the power plant's interior was the disassembly and removal of the control centre and installations in the high-voltage rooms in the southern wing. The valve house has undergone changes in that the supply for the three original generator sets has been blocked off with concrete, but the original installations have otherwise been left in place. The penstock is intact with all four riveted iron pipelines.

In 1976, Tinfos II was, in principle, replaced by generator set no 2 in New Tinfos I. Since then, only the fourth generator set has been in operation; in principle, it provides redundancy for New Tinfos I but, in practice, it is in daily operation.

The new Sagafoss dam was built in 1955 for the New Tinfos I power plant and brought the Tinnelva river at Tinnfossen up to the same level as the Holta Canal, swallowing up the above-lying Sagafossen waterfall. Today, the Holta Canal is a rockfill dam of approximately 380 metres, whose function is to supply water to the single generator set that is still in operation in Tinfos II. It is a concrete slab dam with flood gates of timber, steel and concrete. Towards the east, the concrete slab dam transitions into a rockfill dam of natural stone, which also has a new water intake for the Holta Canal.

Function today: The plant is still in operation as a power plant and back-up generator set for New Tinfos I.

2. Hydro's power plants in the Tinnelva river

Hydro's first hydroelectric power plants were located in the Tinnelva river below the Svelgfossen waterfall. All that is left of these are ruins. One building – the lightning arrester house and workshop – is the only important object remaining from Hydro's first hydroelectric power plant. The cultural environment, including the ruins, is described under *Supporting values*.

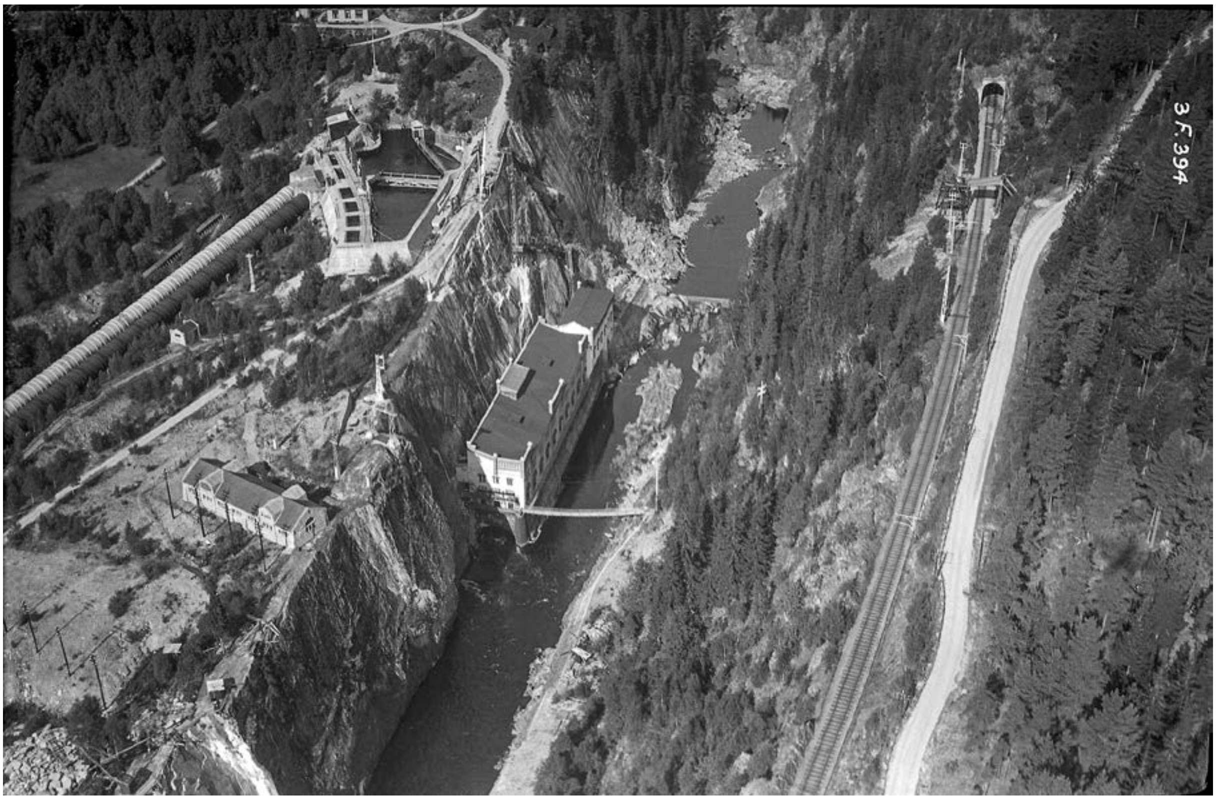
2.1 Svælgfos lightning arrester house and workshop

Built: 1906–1907

Architect: Unknown

Function: Lightning arrester building

Description: A lightning arrester house and workshop was built in connection with the power plant in Svelgfossen (Svælgfos I). It is an elongated low building with carved natural-stone façades, situated on the edge of the cliff by Svælgfos I. Iron anchors on the end walls, window columns and stone cladding convey the impression that a lot of money went into its construction. The building is testimony to the experimental pioneering that went into what was in its time the world's second biggest power plant, when the power was transmitted straight from the generators to the furnaces in the calcium nitrate factories without any form of modification. The building included workshop space and heavy machinery equipment intended to enhance the stability of the power plant. Today, the lightning arrester house is important in that it is representative of Hydro's first power plants, which were built here. The building is owned by Hydro.



Svælgfos mid 20th century with the power station in the gorge and the ligthning arrester house on the cliff. The Tinnoset line to the right.

Changes: The lightning arrester equipment was removed in the early 1950s, at the same time as new exciters were installed next to the generators in Svælgfos II.

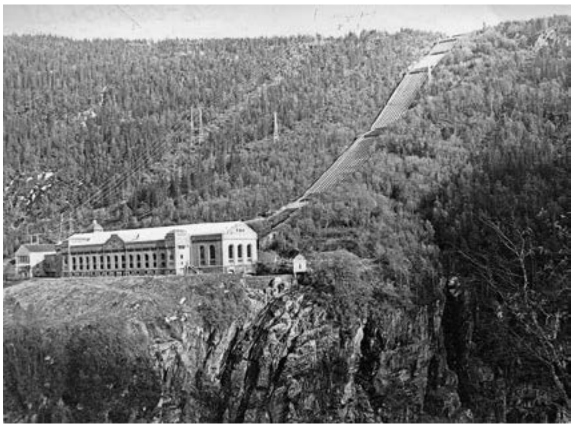
Function today: None

The lightning arrester house today. Photos: Trond Taugbøl.

3. Vemork Power Plant, buildings and plant

The station is fed from the Skardfoss Dam intake. An open penstock runs from the distribution reservoir and valve house at Vemorktopp and down to the station. The distribution reservoir is made of cast concrete walls and has been partially filled in/covered in concrete. The open part is today filled with rock and earth. The reservoir's water level was at contour line 846.50. It had a discharge gate and fed a penstock of eleven pipelines. The spillway is still working and the water is routed through a separate bypass tunnel from Måna river above Rjukanfossen directly to Såheim Power Plant. With generator set axes at contour line 556.00, a total head of 299.5 metres was achieved. The power plant was the biggest in the world when it opened.

3.1 Power station building



Vemork Power Station before 1928 and today. Photo to the left: Norwegian Industrial Workers Museum. Photo to the right: Trond Taugbøl.

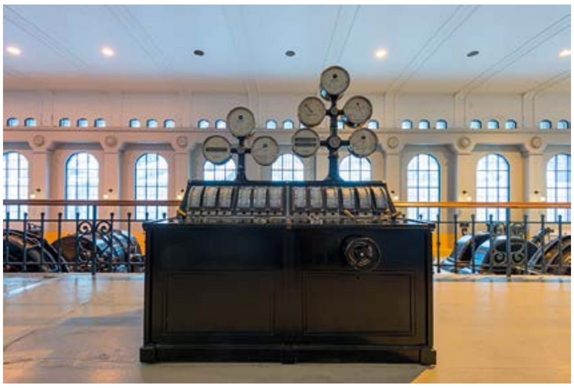
Built: 1907–1911

Architect: Olaf Nordhagen

Function: Power plant

Description: This is an imposing building, with a length of 110 metres and a width of 21.75 metres. The building is made of concrete and is clad in natural stone. The use of carved stone for the façades can probably be ascribed to Nordhagen's knowledge of older Norwegian architecture, not least church architecture, and conforms with the contemporary perception that architecture should have a national stamp. At the same time, the station conforms with the international architectural tradition in which rustic natural stone was used for buildings inspired by the Middle Ages and the Renaissance. The carved stone architecture is used with medieval motifs as décor. According to the stories that have been passed down, Sam Eyde refused to approve the original drawings when the construction work started, because the station had not been given the imposing design warranted by its position in the landscape, and he therefore sent an urgent message to the young architect Nordhagen, who was then 24 years old. After having seen the drawings and accepted the assignment to produce a more imposing design by the following afternoon, Nordhagen drew the station. He has clearly reused motifs from the winning design for the library in Bergen, for which he had been acclaimed a few years previously.

The power plant was equipped with two 45-tonne travelling cranes and ten horizontal-axis Pelton turbines, each with an efficiency of 76% at the maximum output of 14 500 hp. Five of the turbines were delivered by I. M. Voith in Heidenheim, and five by Escher Wyss in Zurich. Tests showed a maximum efficiency of approximately 80%. During the years 1918–1919, the turbines were fitted with new runners and blades, increasing the efficiency to approximately 88%.



Interior of Vemork Power Station. Turbines and switch board. Photos: Per Berntsen.

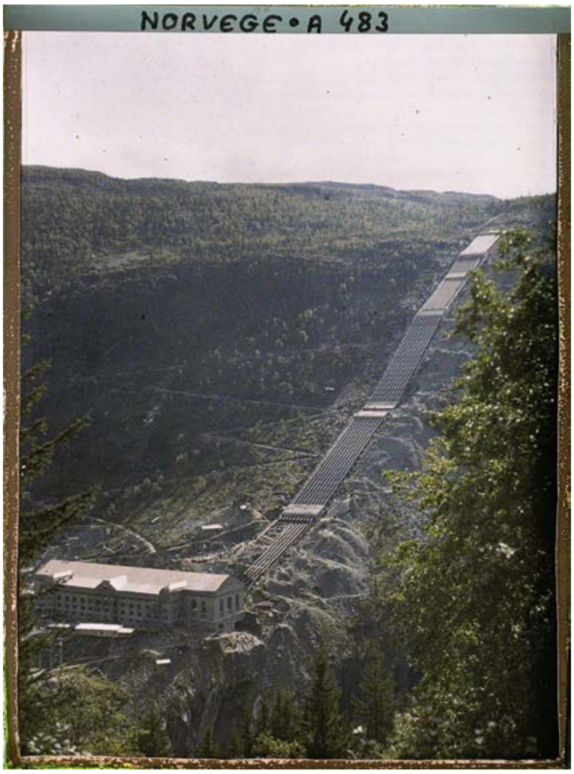
The turbines are directly connected to three-phase generators with an output of 17.00 kVA at 10–11 kV. Nine of the generators are dual generator sets with two generators mounted on the same axis. Five of them were delivered by ASEA (Allmänna Svenska Elektriska Aktiebolaget) in Västerås, Sweden, and the rest were delivered by Brown Bovery & Cie in Switzerland, together with a single generator. In addition, a 1 000 hp house turbine, delivered by Kværner Brug in Oslo, was connected to a three-phase generator and supplied electricity for lighting and electric power to Vemork and the surrounding area. The power plant's instrumentation was supplied by Sté Anonyme Westinghouse in Le Havre in France.

Hydrological surveys carried out during the construction of the plant suggested that the water flow was greater than first estimated. An outlet for an eleventh water pipe was therefore installed in the distribution reservoir with a view to a possible expansion of the plant. Because the turbines when tested proved to be more efficient than expected, thereby reducing the operating reserve that could be produced by overloading the generator sets, it was decided to expand the plant. The pipeline was increased in dimension so that it could supply water to two generator sets, and the annex was designed accordingly. The annex for what was popularly called the 'reserve station' was designed as an extension to the eastern end of the generator hall, terminating in a transverse gable wall. The eleventh turbine was delivered by Escher Wyss, the type and output being the same as had previously been delivered by the same company. The generator was delivered by Maschinenfabrik Oerlikon in Switzerland and the data were the same as for the other generator sets. A 12th generator set was installed in the 1920s, with a vertical-axis Francis turbine with an output of 15 000 hp. The instrumentation for the generator sets was placed in an annex in the form of a tower with a square base, from which the power transmission cables could be routed.

Changes: The power plant closed down in 1971, when it was replaced by New Vemork power plant, which was located in a rock cavern behind the old station (for details, see the section Cultural conditions in general – Hydroelectric power production on page 227).

The old Vemork Power Plant now houses the Norwegian Industrial Workers Museum, with exhibition space, offices, archives, cafeteria and shop. Some minor modifications have been made to the building, including the installation of a ramp for universal access. In the generator hall, the original generator sets remain in their original position and are part of the museum's permanent exhibition.

Function today: Industrial workers museum.



The Penstock in 1910. Photo: Auguste Léon.

3.2 Penstock

Description: The penstock comprises eleven pipelines, each with a length of approximately 720 metres and lies above ground. The pipelines have now been replaced by a pressure shaft for the new underground turbine generator hall, but they have not been removed. The pipes have an external diameter of 1 450 mm, which is reduced to 1 250 mm down by the station. The ten first pipelines to be installed were riveted for the upper third of their length, and otherwise welded. The eleventh pipe with a diameter of 2 000 mm was welded along its whole length. The pipes are held together by riveted collars. A cable car is mounted on top of the penstock.

3.3 Penstock valve house

To the left: Penstock and valve house when finished 1912. Photo: Anders B. Wilse.
To the right: The valve house today. Photo: Trond Taugbøl.

Description: Automatic throttle valves supplied by I. M. Voith of Heidenheim in Germany were installed in a separate building, where the pipe dimension of ten pipes was reduced to 1 250 mm and of the eleventh pipe to 1 600 mm before the intake for the station. The valves closed automatically if the water in the pipe increased beyond a set limit, but they could also be controlled manually or using the instruments inside the station. The building was built using carved stone of the same type as for the power plant.

Changes: During the war, the Germans encased the valve house in concrete to protect it against aircraft bombs. This was mainly driven by their fear that the building would be the target of raids or sabotage attacks. The building was taken out of operation in 1971, but it remains standing as it was when it closed down.

3.4 Skarsfos Dam I with intake gate house

Skarsfos Dam I in 1930 and today. Photo to the left: Norwegian Industrial Workers Museum. Photo to the right: Bjørn Iversen.

Description: The dam forms a 5.5 km long lake as a result of damming up the Måna river. The first Skarsfos Dam was built of concrete and natural stone between 1905 and 1908. It was 120 metres long and 14 metres high, with its crown at contour line 855.50. It is usually submerged in its position upstream of the new concrete dam. The original intake gate house on the southern side of the dam, with trash racks and gates, was built of carved natural stone as an appendage to the power plant at Vemork, to which it would supply water. The house no longer serves this function, but it will be preserved. The dam house by Skardfoss and the valve house below the distribution reservoir on Vemorktopp both have an architecture that is reminiscent of medieval watchtowers.

The old intake gate house. Photo: Per Berntsen.

Changes: The present dam is a concrete dam built in the 1950s. Work is in progress to build another dam, approximately 10 metres further down. A new tunnel intake was built in 1970. It was drawn by the architect Geir Grung, and will also be retained in the ongoing upgrading work.

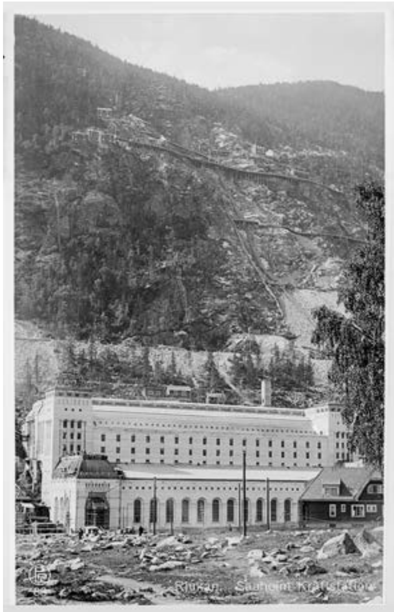
The Rjukanfossen gorge in 1929 with Vemork Power Plant, penstock, rock dumps and the Hydrogen Plant on the southern side, Våer housing, Maristigen road and Krokan on the northern side. Photo: Norwegian Industrial Workers Museum.
Below: Rock dumps between Skardfoss and Vemork today. Photo: Per Berntsen.

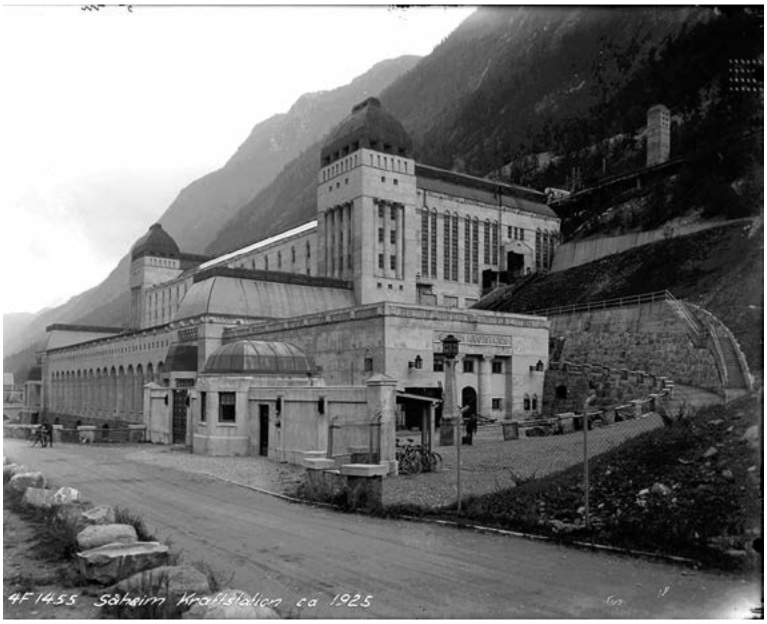
Description: The power plant is supplied with water through a 4 242-metre-long tunnel running from the intake at the Skarsfoss Dam to a distribution reservoir. The tunnel to Vemorktopp has a cross-section of 26 m² and an average fall of 1:465. It was drilled manually and blasted. The work was divided between ten sections, each with an adit for removing the debris. These adits have subsequently been closed up. Six of a total of nine rock dumps remain almost untouched and are included in the nomination proposal as characteristic landscape features on the hillside. The pressure reservoir at Vemorktopp has been phased out (1971). Separate family housing was provided on Vemorktopp for those who worked there. When the tunnel was being blasted, there were huts for the work teams beside each adit.

4. Såheim Power Plant

Såheim Power Plant comprises a system of tunnels, adits and spillways between the water intake at Vemork's underfloor level and the actual power plant with its distribution reservoir, penstock valve house and penstock. A free-standing building on the eastern side of the power plant contained an electrical workshop. The station was the biggest in the world when it was completed in 1915. The first preparations for the Rjukan II development, which was the name used to describe the whole plant, and the second construction phase for the factories in the valley started in January 1912 with the blasting of a tunnel from the Vemork Power Plant.

4.1 Power station building





Såheim Power Plant under construction in 1915 to the left and in 1925 to the right.
Left photo: Directorate for Cultural Heritage. Right photo: Norwegian Industrial Workers Museum.

Built: 1912–1916

Architects: Thorvald Astrup and Olaf Nordhagen

Function: Power station building

Description: The power plant is an imposing concrete building, and a principal work in Norwegian industrial architecture. The volume of the building was decided by the fact that it originally contained a plant with 35 Birkeland/Eyde-type electric arc furnaces for calcium nitrate production. This was what was known as 'Furnace House II' and was situated behind and above the turbine hall. The ground plan of the power plant itself measures 110 x 23 metres, including an annex of 24.5 x 20.5 metres for the steam plant. There is a height difference of 59 metres from the tailrace channel below the station to the top of the towers.

With a normal water level in the distribution reservoir at contour line 546.00, the generator axes at contour line 289.00 and the water level in the underwater channel below the station at 282.40, a total head of 273.60 metres could be utilised. Inside the power plant itself, there were nine main turbines and one house turbine.

The power plant was equipped with horizontal-axis main turbines which were perma-

Såheim Power Plant today. Photos: Eystein M. Andersen.

nently connected to three-phase generators in a star circuit. The generators had an output of 18.99 kVA at 9.5 kV. The three main generators were delivered by Brown Bovery & Cie in Baden in Switzerland, while six were delivered by ASEA in Västerås in Sweden. The total generator capacity was 167 000 hp. Power was to be supplied to a new furnace house that was being erected on the factory site. In order to avoid any problems with the government concession, Furnace House II was placed inside the power station building instead, and the gas that was produced in the furnaces was transported by pipeline to the plant's tower house, just over one kilometre away. A concession was not required for piping gas, as was the case for the transmission of electricity. Såheim (Rjukan II) was officially put into operation on 15 January 1916.

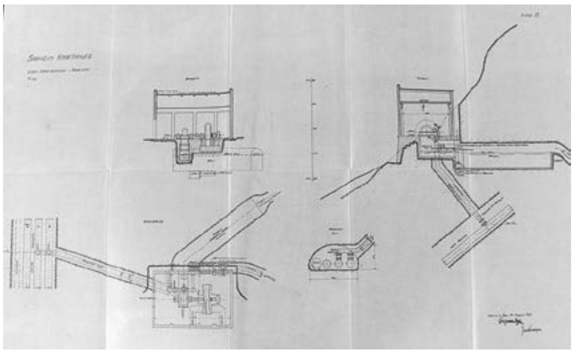
Interior of Såheim power Plant. Photo: Trond Taugbøl.

Changes: The Furnace House that contained the Birkeland/Eyde furnaces is now a gym. The three penstock tunnels with a total of nine pipelines have been replaced by a pressure shaft extending down to the main station. The nine original main turbines have been replaced by three modern Francis turbines, which take up less room, and some changes have been made to the water inlet on the basement floor. The three new generator sets were put into operation in 1959, 1961 and 1973, respectively. The installed capacity totals 185 MW and the average annual production amounts to 1033 GWh. The interior of the turbine hall has not undergone any significant changes. The generator hall contains the original generator sets no 9, manufactured by Oerlikon and no 10, manufactured by ASEA, as well as the control desk. The room containing the converter for supplying power to the Rjukan Line is intact with all pertaining technical equipment. Some minor changes have been made to the exterior of the building, on the western façade, around the entrance to the power plant and with a new entrance to the gym on the fourth floor. A guardhouse, built in the same style as the power plant, was originally built into the fence on the street side. It was demolished in the 1990s to provide access for transport to the construction sites in the mountains.

There have only been minor encroachments on the plant's surroundings. The building's main function remains unchanged, and technical upgrades have only slightly affected the building structure. The power plant has been well maintained.

Function today: Power plant and gym. Hydro Energi's local power entity in Telemark is administered from Såheim and the joint control centre for all Hydro's 17 power plants in Norway is located here. The joint control centre controls and monitors the plants remotely.

4.2 Underground turbine generator hall



Drawing of the Unerground turbine generator hall from 1912 to the left. Owned by Norwegian Industrial Workers Museum. Interior of the hall to the right. Photo: Eystein M. Andersen.

Description: Next to the penstock shaft, approximately 85 metres above the floor of the power plant, a rock cavern was blasted out to hold the reservoir for the plant's water supply. The water was supplied through branch pipelines from each of the two largest pipes that singly or in combination operated a 6 750 hp turbine before the water ran into the reservoir. The turbine's water consumption was regulated by a float in the reservoir, where the water level was thus kept constant. One of the station's two house generator sets, known as generator set 12, was located inside this cavern. Another house generator set was located in the power plant's generator hall. Both these generators had a maximum output of 6 250 kVA at 10 kV and were delivered by Maschinenfabrik Oerlikon near Zurich. They were operated in parallel, with the lower of the two generator set automatically taking over the load that could not be provided by the upper one. The arrangement of the uppermost generator set from 1914 is a very early example of an entire power plant located inside a rock cavern, and it may have been the world's first of its kind. It continued to produce electricity until it was replaced in late 2010–early 2011, long after the station's main generator arrangement had been upgraded with new plant. The underground power plant with generator set, travelling crane etc. is completely intact. The water reservoir has been dry since generator set 12 was phased out. The underground power plant will be preserved as a museum.

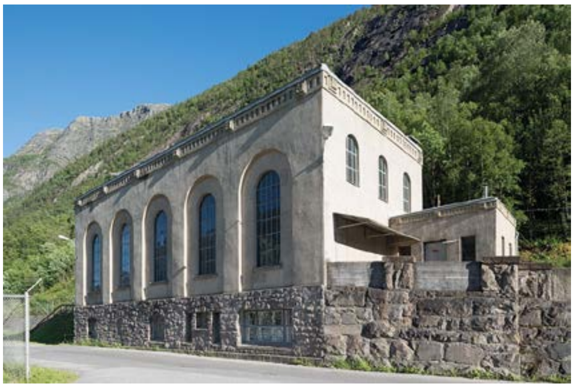
4.3 Underground penstocks

Description: From the distribution reservoir, the water was fed to the power plant through nine pipelines equally divided between three shafts. The pipes are continuously welded and held together by riveted collars. Seven of the pipelines have a diameter at the top of 1 600 mm, reduced to 1295 mm down at the plant, while two have a diameter at the top of 1 790 mm, reduced to 1 425 mm at the lower end. The two biggest-sized pipelines each fed water to one main turbine and to an auxiliary generator set for the factory's operating plant, in addition providing the factory's water supply. Below the underground distribution reservoir there were throttle valves of the same type and make as at Vemork. The penstock has a gradient of 33° up to the water supply reservoir/generator set 12, followed by a gradient of 44° up to the distribution reservoir. Six of the pipelines were phased out in 1993, while the last three were phased out in 2011. The shaft for the penstock on which the cable car is mounted will be closed with concrete, but remains intact.

4.4 Tunnel system with seven waste rock dumps

Description: The tunnel from Vemork Power Plant has a cross section of 32 m² and is 5 660 metres long with an average gradient of 1:708 down to the distribution reservoir. Seven large stone dumps on the mountainside along the route of the main tunnel stand out and form distinctive and decipherable landscape elements. A separate bypass tunnel with an intake house and gate arrangement in the Måna river at the top of Kvernhusfossen waterfall just above Rjukanfossen can transport water past Vemork and directly to Såheimtopp. This tunnel can feed operations at Såheim in the event that Vemork is inoperative or temporarily closed. The bypass tunnel with intake was built in 1918.

4.5 Workshop building



Workshop building in 1940 to the left and to day to the right.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: Just after the completion of Såheim in 1916.

Architects: Probably Thorvald Astrup and/or Olaf Nordhagen.

Function: The building was erected as a mechanical and electrical workshop for the repair and maintenance of plant and equipment. The building has three floors. The basement floor contained storage space and a changing room, while the ground floor contained the workshop with lathe and workbenches, and also a tool shed. On the first floor were the offices for the works manager and chief engineer. The building is adjacent to the railway track.

Description: The use of materials and the design associates the building directly with the power plant in Såheim.

Present-day use: The basement floor is currently used by the woodcarvers in Rjukan. The building is otherwise used to store miscellaneous materials and equipment.

5. Regulating dams

Møsvatn as it appears today was formed by building the Møsvatn Dam and the Torvehovd Dam (towards Rauland in the west), whereby three different lakes became one. It was the first big concrete dam in Norway and created the country's biggest regulating reservoir. Møsvatn Dam is the most elevated arrangement in what is known as the 'Rjukan string' of five power plants, and it is the only dam built purely for regulating purposes, of which the essential parts of the original structure have been preserved. The remaining part of the old dam is the most elevated object included in the World Heritage proposal. The Skarsfos dam is an intake dam, while the regulating dam at Tinnoset has been completely renovated.

5.1 Old Møsvatn Dam

Old Møsvatn Dam in 1930 and to day. Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1904–1944

Description: Skiens Brugseierforening (owners' association) started building the old Møsvatn Dam in 1904, aiming to secure a more stable water flow to the mills etc. downriver and for timber floating. The dam raised the water level by 10 metres from its natural elevation of 902 masl. The concrete face rockfill dam was built using coarse aggregate and natural stone cladding and completed in 1906. Stone for the dam was quarried in Bjørnurdi at the head of the inner fjord arm of the lake. When Norsk Hydro came into the picture, the dam was extended in several steps: in 1908–1909 in the form of a gravity dam raising the water level from 912.0 to 914.5 masl, and in 1942–1944 in the form of a concrete buttress dam, which raised the level to 918.5 metres. At the same time as the water level was raised in 1908, the Torvehovd Dam was build as an earthfill dam to prevent runoff to Rauland. Concurrently with the extension of the dam in 1908, the outlet was blasted out so that the water level could be lowered by 2 metres. A regulating height of 14.5 metres made a water reservoir of 768 mill. m^3 available, whereby the flow rate in Måna river could be adjusted between 45 and 54 m^3 per second. The concrete dam is 180 metres long and had a height of 25 metres.

Changes: In 1951–53, an earthfill dam was built as a security dam downstream of the concrete dam; it was the first big earthfill/rockfill dam in Norway. The dam was reinforced in 1994–1995. The gates are controlled remotely from the control centre in Rjukan. The upper part of the old concrete dam was demolished to contour line 910.65 in 2004.

Present-day use: The remains of the old dam have been preserved for water retention during technical inspections and as a cultural heritage monument.

6. Power transmission

Power transmission is a function that has undergone considerable technological development since the days when the power plants and factories in Notodden and Rjukan were completed. There is therefore little left of the first pioneering plant and equipment. A number of pylon foundations from the overground power lines remain, but they are spread around the terrain and are a poor testament in comparison with buildings and erect pylons with cables.

6.1 The Cable House

The Cable House in function in 1918 to the left and to day to the right.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen

Built: 1915

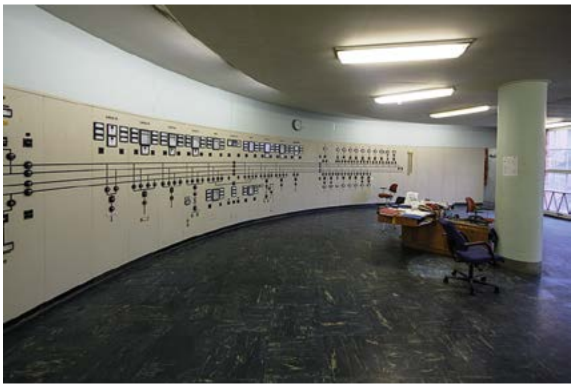
Architect: Unknown

Function: Distribution station for the power lines down to Hydro Industrial Park, so that the overground cables could be moved and the area cleared for the construction of Notodden's new railway station.

Description: The Cable House is a concrete building with a fortress-like appearance that towers above the site of Notodden's new railway station. The cast-iron yokes which formerly carried the overground cables are still in place on the eastern façade. Some of the insulators are also in place. From the western side of the Cable House, the cables were laid in an underground culvert to the factory. Along the slope leading down to Grønnebyen, some parts of the culvert were open. It is easy to spot in the terrain.

Changes: The exterior remains unchanged, with the exception of a new entrance and emergency exits with a spiral staircase from the upper floor.

Present-day use: Offices



The Control room in the 1950's to the left and to day to the right.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1956 (1911)

Architect: Unknown

Function: From 1911, the eastern part of Furnace House I served as the distribution station for electricity to the whole factory area in Rjukan. The distribution station fills three floors in the three first halls in Furnace House I *(object 8.1).*

Description: The power line from Vemork entered the building through the western façade. The lines are gone, but porcelain insulators and entry gates are still visible on the façade. Power lines from Såheim enter through the southern wall of the building. From 1929, the distribution station in Furnace House I fed power from Såheim to the new factories that were built for the ammonia method. Såheim also delivered electricity to a distribution station closer to the power plant.

Changes: The distribution station in Furnace House I was improved several times during the period that the ammonia method was used. A five-step total renovation was started in 1954 and completed in 1956, to remove the remains from 1911 and create a new system adapted to the factory operations. Pneumatic control was established for the whole system, and it was possible to control all the switches remotely from the control room. The control room from 1956 on the second floor of the building is well preserved and still in use. The main switchboard includes a graphic display and remote control equipment for the main switchboard system. The secondary switchboard has measuring instruments for the distribution station's 500 and 220 V systems, and remote control instruments for all distribution and transformer stations in the factory. Parts of the distribution system outside the control room have been removed or modified.

Present-day use: Control room.

6.3 Transformer and distribution station (Building no 273)

The Transformer and distribution station as new in 1915 to the left and to day to the right.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1915

Architect: Unknown

Function: The building contained both transformers and a distribution station that supplemented the one in Furnace House I. From here, electricity was distributed to the plant and to the town. The building was built as a result of the increased need for power when the factory was extended and Rjukan II was put into production.

Description: The building with three floors and 600 m^2 of floorspace is made of rendered concrete and has a steel roof structure. The transformers were located on the ground floor, while the distribution cells were on all floors. The building still functions as a trans-

Interior of the station in 1915 to the left and today. Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

former station, as half the ground floor is still used as a transformer and distribution station. Twelve distribution cells are preserved and in use, along with the aisle with room for transformers on both sides. Trolley tracks for moving transformers are still in place in the aisle. The rest of the building is now used for storage. Distribution cells have been partially preserved on several floors. The elegantly designed stairs between the floors have also been preserved.

Changes: The exterior remains unchanged, with the exception of a storage shed that has been added to the southern end wall. The exterior of the building was renovated and painted in a new colour around 2005.

Function today: Transformer and distribution station, storage space.

6.4 Power line 16/17

Power line 16/17. Left photo: Eystein M. Andersen. Right photo: Per Berntsen.

Built: 1928–1929

Description: Power line 16/17 runs from Såheim Power Plant to Furnace House I. The 11 kV power line consists of a 1 418-metre-long overground section with nine riveted steel pylons on concrete foundations, six conductors and one earth wire, porcelain insulators and a tensioning frame where the lines feed into in Furnace House I. Two of the pylons are tension angle towers while the rest are suspension towers carrying suspended cables. The line was built with a double circuit and a line cross-section of 506/600mm^2 aluminium. It was constructed at the time of the transition to the ammonia method and the need for a greater electricity supply. The electricity was transmitted directly from Såheim Power Plant to the distribution station in the furnace house, from which it was fed to the various parts of the production plant. The lines were in use right up until the end of 2011 when they were replaced by underground lines. The section is among Norway's oldest preserved power lines that are still standing.

There are nine pylons between the tower in Såheim Power Plant and the frame on the roof of the Furnace House building, and all the conductors with top wires and porcelain insulators, as well as the roof supports in the industrial park have been preserved.

7. Hydro Industrial Park in Notodden

7.1 Furnace House A (Building no 60)

7.1-1 og 7.1-2: Furnace House A in 1920 to the left and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1906

Architect: Unknown

Function: Furnace house with 32 Birkeland/Eyde electric arc furnaces, each with a power consumption of 750 kW, installed in four rows. The first step of the production process in production line A in Notodden Calcium Nitrate Plant. The furnace house was in operation from 2 October 1907 until 17:00 on 6 April 1934, when the last Birkeland/Eyde furnaces were extinguished, marking the end of the period of the electric arc method in Notodden. After that, the furnace house was used as a paper store for the sack factory, and, in 1959, the interior was refurbished in order to manufacture laminate in the form of Respatex products.

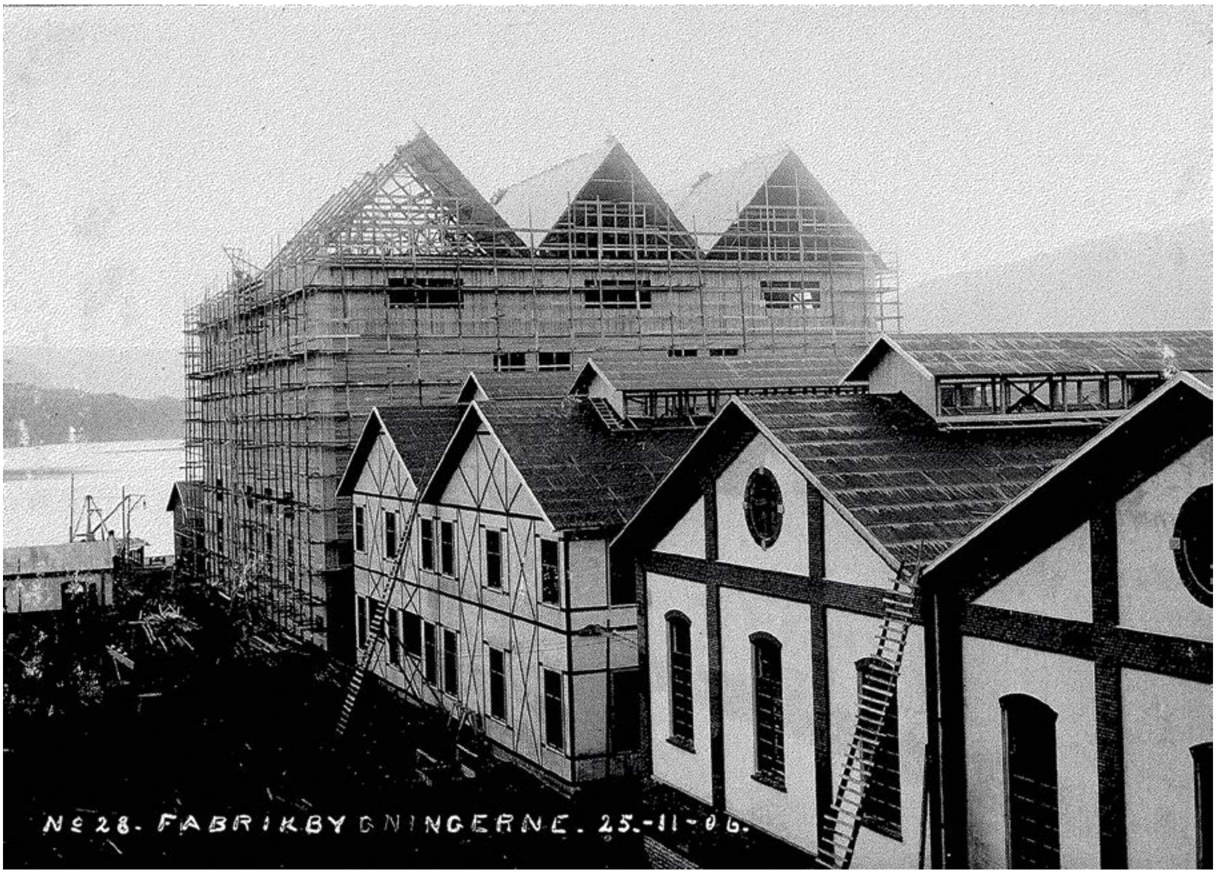
Interior of Furnace House A in 1908. New electric arc furnaces under construction. Photo: Norsk Hydro.

Description: The furnaces were arranged in two rows in each of two connected halls. The halls have separate pitched roofs and are only separated by load-bearing steel columns. The furnace house has a traditional industrial architectural design. At the same time, it embodies the principles of single-surface factory buildings, steel roof framework structures, turret skylights on the ridge of the roof for light and ventilation and large windows in the walls. It is functionally designed with a constructive and decorative use of brick to divide up the rendered façades. The building is otherwise minimally decorated with few historicising details.

Changes: The windows facing north have iron glazing bars and are of a more recent date, but the windows facing south have original wooden jambs and muntins. The ridge turrets have been removed and the ground has been raised so that the basement windows are now below ground level. An annex was added to the north-eastern gable and used as a switchgear station during the Haber-Bosch period. The halls have largely been preserved with their open structures.

Function today: Norsk Hydro used the building for its local archives, and the eastern part of the building housed Hydro's Industrial Museum in Notodden from 1992. In 2012 the collection moved premises to the Tinnfoss area. The building is currently not in use.

7.2 Tower House A (Building no 70)



Tower House A under construction in 1906. Photo: Norwegian Industrial Workers Museum.

Built: 1907/1916/1921

Architect: Unknown

Function: The tower house contained the absorption plant for nitrogen used in production line A during the period of the electric arc method, in the form of rows of granite towers filled with limestone. The towers were built of granite blocks of 2.24 x 1 metres and were 23 metres high with a ten-sided cross-section. The building functioned as a tower house until 1934. One acid tower of this type has been preserved in Rjukan *(object 9.4).* Tower House A was used as a steel warehouse from the 1950s.

Description: The building is a concrete structure and, in material technology terms, it represents pioneering construction work in ferroconcrete. It is a rough, industrial-style, unpainted building. The tower house was the biggest building on the site, with a base of 52 x 42 metres and a height of 28 metres. Until 1916, it was a 36 metre high steel framework structure with timber walls. It contained three rows of towers, each with five acid towers for nitrogen absorption, extended to rows of six towers in 1916. The shape of the roof reflects the three rows of towers. Three pitched roofs followed the rows of towers, and five windows under the cornice marked the position of the towers.

The original timber building from 1907 was a dangerous fire hazard after being affected by acid vapour, nitrate lye and nitrous gases, and, when the plant was expanded in 1916 or in 1920–1921, it was therefore modified to become the reinforced concrete building that we see today. The walls and steel framework were probably used as formwork. The width of the building was increased to 45 metres, at the same time as the height was reduced and it was given a new roof structure in steel with three pitched roofs of concrete with an overhang supported by columns. The columns divide the side walls into six and the end walls into three to mark the rows and towers. There are windows with iron glazing bars along the interior walkway at the top, and at the bottom above the rendered section with entrances and gates. The doors and gates are original Art Nouveau-style wooden gates. The building as a whole has features of contemporary Expressionist German architecture, with its rawness, visible structural elements, lack of décor and a sculptural form that is determined by what the building contained.

Tower House A today. Photos: Eystein M. Andersen.

Changes: The acid towers have been removed from the interior of the building along with the gas coolers and oxidation vessels. The open space under the ceiling has been preserved, as have the crane tracks and inspection corridor under the ceiling, while the lower corridors are no longer there. In 1954/55, a boiler house with one oil-fired boiler and one electric boiler was erected inside the building.

Function today: Today, the building is leased out to the company Thermokraft, which produces district heating using a wood chip boiler. Granite elements from the demolished acid tower have been used to line the factory area's shoreline along Heddalsvatnet lake.

7.3 The calcium nitrate factory (Building no 105)

The calcium nitrate factory at stage one in 1915 to the left and stage two in 1917 to the right.
Photos: Norwegian Industrial Workers Museum.

Built: 1915–1916. The building was built in two stages. The western part was built around 1915 as an extension to the former boiler house (demolished) between Furnace House A and Tower House A, while the eastern part with two new pitched roofs was added in 1916.

Architect: Unknown.

Function: The building was part of the factory's production line A. During World War I, when Norsk Hydro saw a golden opportunity for the profitable production of ingredients for the arms industry, the eastern part of the building was built as a makeshift ammonium nitrate factory to supplement the established ammonium nitrate factory which was situated south of Tower House C (demolished). After the war, this part of the building was incorporated in the rest of the calcium nitrate factory. Here, limestone was dissolved in nitric acid, and cooling, solidification and screening was carried out before the calcium nitrate was packed. In 1919, a new method was adopted, whereby dissolution towers with a base of 1 m^2 and a height of 3 metres were used to dissolve the limestone instead of large vessels in the boiler house attic. There was room for 15 of these towers in the calcium nitrate plant when the temporary ammonium nitrate plant was closed down. The building functioned as a calcium nitrate factory until 1934, when the Birkeland/Eyde process was phased out in Notodden.

The factory today. Photo: Per Berntsen.

Description: The calcium nitrate factory is built of rendered brick and concrete with three pitched roofs. The building has features indicative of modern 20th century architecture. The use of reinforced concrete, smooth surfaces, asymmetrical forms and few historicising details are illustrative of industrial architecture as an entrance to modern architecture.

Changes: Many of the technical installations in the building, such as the limestone silo from 1919, have been demolished and the façades have been partially altered several times. Doors have been replaced, while the original windows with iron glazing bars have been retained. In 1952, major alterations were made to the interior of the building as it was converted into a welfare building with a medical centre, changing rooms for the sack factory's employees, a canteen etc., and thus became known as the Welfare Building. The building that connected it to the 'Minaret', which formerly had probably consisted of a 35-metre-long passageway for transporting goods to and from the sack factory, was converted into a pedestrian passageway for the sack factory's employees.

Function today: Canteen, offices. Two floors are available for lease.

The Packaging factory around 1940. Photo: Norwegian Industrial Workers Museum.

Built: 1920s/1936. Built in several stages.

Architect: Unknown.

Function: The building was part of the factory's production line A. Barrels for Hydro's primary product, calcium nitrate, were manufactured here. In the 1930s, Hydro's sack production was moved from Lillo in Oslo to Notodden. The sack production, which included sewing rooms for paper and jute sacks, was located on the first floor, while a limited number of barrels were still being produced on the ground floor. In 1954, the Packaging Factory was replaced by the 'New Sack Factory' at the same time as operations in the old premises continued. Barrel production in the old plant was gradually reduced until it was finally closed down in 1958. The production dropped from a peak production of 350 000 barrels to 45 000 in 1950 and 7 000 in 1957. From 1958 onwards, the ground-floor premises were used as storage space for paper sacks. The annual production increased to as many as 25 million impregnated sacks. The Packaging Factory continued to operate until 1991, and a part of it has continued to operate as an independent company in the premises from 1954.

Description: The Packaging Factory is now part of a larger building complex, consisting of three parts. The oldest part consists of two long halls with pitched roofs, which are

The factory today. The impregnation factory from 1936 on photo to the right.
Left photo: Trond Taugbøl. Right photo: Eystein M. Andersen.

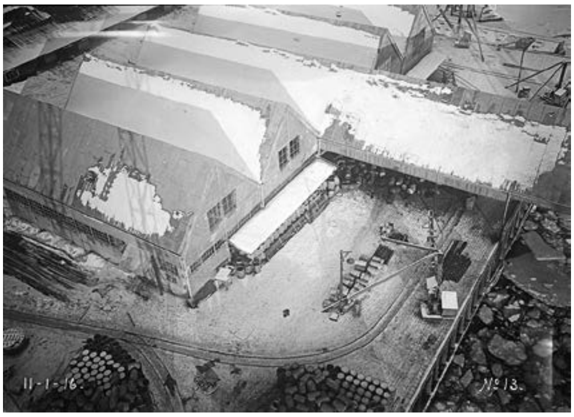
adjoined, and have a total base of 54 x 23 metres. This part was built in the 1920s in the classical style of hall architecture, replacing the first barrel plant. The building is of rendered concrete and has windows with iron glazing bars. The materials used, and the windows and façades that are free of décor and historicising details, points towards modern 20th-century architecture.

The second part of the complex consists of the extension that was built to increase sack production. The third part of the complex comprises the impregnation factory from 1936, a separate building extending to the north east from the older halls. It was used for boiling impregnation agent. The building is of rendered reinforced concrete, has windows with iron glazing bars and a flat roof. This was where the sacks were impregnated. Hydro required its sacks to be both watertight and airtight, and after years of experimenting, Hydro had found a method whereby the same impregnation compound was used for both jute sacks and paper sacks. The factory is in the contemporary Functionalist style and has a characteristic high middle section with tall, narrow windows. There was an elegant entrance in the middle of the eastern façade, but, in recent times, it has disappeared behind new surrounding buildings, like much of the building itself. Remnants of production equipment have been preserved on the top floor. A water mark remains showing the level reached by the water during the great flood in 1928.

Changes: Between 1934 and 1936, an annex was added on the south-eastern side of the building in order to expand sack production. The annex is of concrete with a flat roof measuring 24 x 24 metres. The impregnation factory was built on the north-eastern side in 1936 as another annex.

Function today: Today, many tenants lease space in the oldest part of the building complex, which consists mainly of storage space and offices.

7.5 Warehouse A (Building no 95)



Warehouse A in 1916 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: www.hydroparken.no

Built: 1915–1916

Architect: Unknown.

Function: The building was built as a storage and warehouse for Notodden Calcium Nitrate Plant's production line A for the storage and shipping of artificial fertilizer, when the volume was up-scaled after a period of trial operations. It was built to replace an older wooden building.

Description: The gables facing Heddalsvatnet lake are in the classical form of boathouses, made up of five adjoined buildings with pitched roofs. The warehouse is constructed of rendered concrete and steel. It is quite decipherable even though changes have been made to the façades.

Changes: The ground floor was originally open on the side facing the lake, but was later rebuilt. In the middle section, the goods crane from the loft and the loft gate have been preserved. The gates and doors are of more recent origin. The iron window frames are mostly original. There are new windows on the eastern side. The quayfront has subsequently been moved further out and lined with stone.

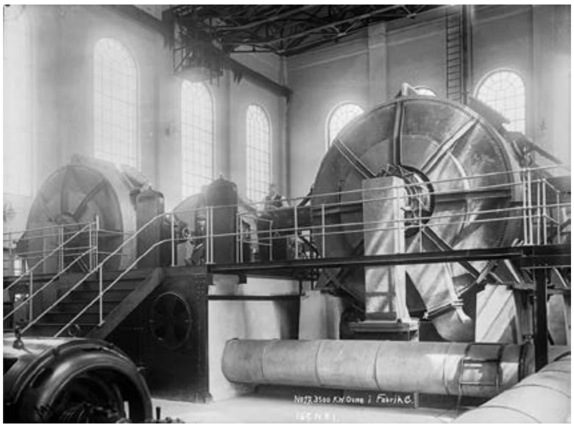
Function today: The building has been used for various purposes through the years. Today it is leased out as a garage, studios, offices and storage space.

7.6 Furnace House C (Building no 20)

Built: 1907–1909

Architect: Unknown, but possibly Helge E. Blix, who at the time drew the ammonium nitrate factory (demolished) in the same style.

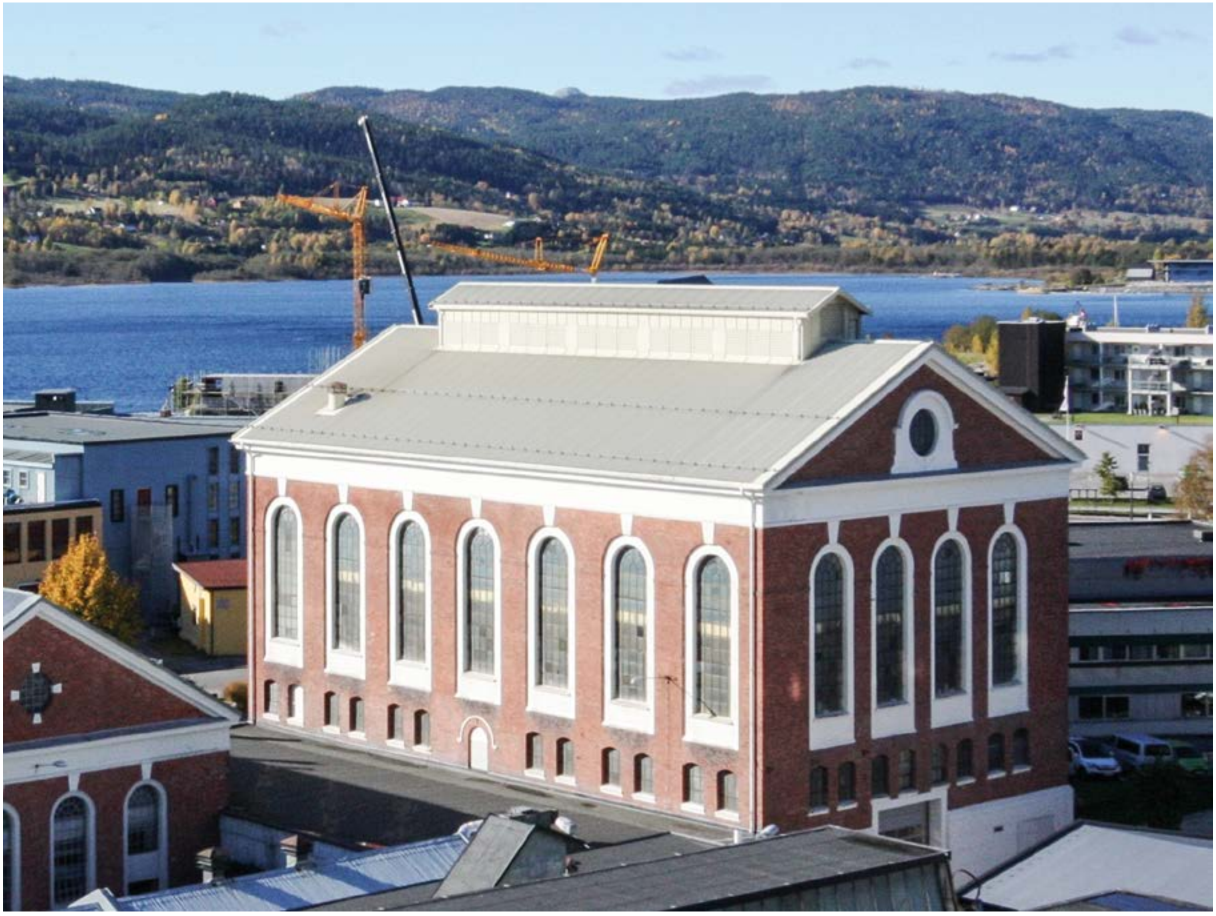
Function: The furnace house was used for testing out BASF's Schönherr furnaces, with a view to deciding whether to use the German or the improved Norwegian furnace in the fertilizer factory that was being built in Rjukan. The yield measurements carried out during the tests proved to be in favour of the Norwegian furnace. The Schönherr furnaces were replaced by ten Birkeland/Eyde furnaces of the improved type. They were put into operation in July 1911and were used there until 1934. Furnace House C was subsequently used for the production of ammonium nitrate (NH_4NO_3), which can be used in fertilizer



Furnace House C just finished in 1909 with the workers in front to the left, and the interior with Birkeland-Eyde furnaces after 1911 to the right. Photos: Norwegian Industrial Workers Museum.

and as an ingredient in several types of explosive, as well as in various types of production and testing. The building has also been used as a workshop for the manufacture of incinerators.

Description: The building was part of a testing plant that was built under an agreement entered into with the German company BASF in December 1906, which included furnace houses, tower houses, steam boilers etc. The facilities were completed and put into operation in November 1909. During the period 1909–1911, the building housed ten Schönherr furnaces: The tall, majestic structure was defined by the shape of these furnaces which



Furnace House C today. Photo: Eystein M. Andersen.

had tall, cylindrical combustion chambers where the electric arc was deflected to form a five-metre-long string. In the Birkeland/Eyde furnaces, the arc was electromagnetically deflected to form a circular disc.

The gas that was produced was routed to Tower House C (demolished in 1958) where various absorption methods were tested out. The Testing Plant buildings went under the name of 'the Acid Factory' because it was intended for the production of nitric acid. When the tests had been completed, the collaboration with BASF came to an end, at least for a period. The factory known as 'Factory C' was taken over by AS Notodden Salpeterfabrikker as a new production line based on the electric arc method.

Furnace House C was built in 1909, inspired by the Classicist tradition in industrial architecture. It has a more decorated and historicising appearance than most of the buildings on the site. The building with a base of 20x34 metres has façades of exposed brickwork with rendered and painted ornamentation around the tall arched windows, plinth and cornices. The foundations are concrete. The building has a steel framework. The tall windows with the iron glazing bars give character to the façades. The building has a plate roof and a ridge turret for light and ventilation. Inside the hall, which has a ceiling height of approximately ten metres, is a 30-tonne travelling crane. In the south-western end of the building are the preserved remains of an electricity distribution system from the first half of the 20th century.

Changes: Apart from the installation of a new vehicle access door in the plinth, the exterior remains largely unchanged. The interior vertical space has been divided by the installation of a new floor.

Function today: In more recent times, the building has been used for storage.

7.7 Testing Plant and Electrical Workshop (Building no 25)

Testing plant in 1918 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1909

Architect: Unknown, but possibly Helge E. Blix, who drew the contemporary ammonium nitrate plant (demolished) in the same style.

Function: The building was part of the testing plant known as the 'Acid Factory', used for testing out different furnace technologies during the years 1909–1910. The building may have been home to the large and improved Birkeland-Eyde furnace of 3 300 kW that was to be tested in relation to the Schönherr furnaces in Furnace House C. The gas from the furnace was routed to a separate steam boiler in Tower House B (demolished), where the yield was measured and determined. The aim was to surpass the results that were achieved using Lovejoy and Bradley's method in the factory beside Niagara (described in 2.b in the section *Niagara Falls, from tourism to industry*), and this was successfully accomplished through the efforts of Hydro's engineers and Birkeland himself to improve the Norwegian furnace. The furnace was put into operation in February 1910. Since then, the building has been used for various purposes, including as a workshop for electrical equipment. As in the case of many of the other buildings, railway tracks went right up to the building to enable the transportation of large components. During the 1970s and 1980s, the building was used as a carpenter's workshop.

Description: The building belongs to the earliest generation of Hydro buildings in Notodden. The materials used and the details replicate the architecture in Furnace House C, which was built at the same time. The base is smaller, but this building also had a ridge turret for light and ventilation.

Changes: The exterior remains largely unchanged.

Function today: In more recent years, the building has been used as a centre for energy efficiency and training. Today, the building houses offices and a dry-cleaning business.

7.8 Testing Plant and Blacksmith (Building no 30)

Testing plant and Blacksmith today.
Photo: Eystein M. Andersen.

Built: 1909

Architect: Unknown.

Function: The original function of the building is not clear, but the year it was built and its location right next to the Testing Plant suggest that its function was linked to that plant, perhaps as a boiler house for the Birkeland/Eyde furnaces. Later on, it is said to have functioned as a privy for white-collar workers and as a blacksmith's workshop.

Description: The building measures 18x10 metres and was constructed using brick and timber with brick veneer side walls. It has one storey and a newer plate roof. The building is distinctive in terms of the building method used, and seems to be more akin to the first building stock belonging to the Test Factory that was demolished. The simple appearance suggests that it had a subordinate function.

Changes: The exterior remains largely unchanged, while the interior has been refurbished for various functions.

Function today: Today the building is used as a restaurant.

7.9 Laboratory and workshop (Building no 80)

Laboratory in 1917 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1915

Architect: Probably drawn by Helge Blix and Carl Borch, the architects behind the Ammonia Water Plant *(object 7.15)* that was built at the same time.

Function: Built for Hydro's laboratory services and as a workshop. The laboratory was used for analyses to check the process control in the factory. This was important in order to ensure that the production was carried out correctly at all times. The new building was erected to provide more space for the laboratory, which up until then was confined to Tower House C. The Test Factory's boiler house from 1905 was then used as a workshop. The building was erected on the plot where the boiler house had stood. The workshop was able to continue in new premises on the ground floor, while the laboratory was given new premises in the rest of the building. Hydro's laboratory at Skøyen in Oslo was moved to Notodden in the 1920s.

Description: The building reflects the Classicist tradition in industrial architecture. Hydro demanded that the same 'construction method and style' should be used for the Ammonia Water Plant and laboratory. The building is in reinforced steel-framed concrete, with a plate roof and windows with iron glazing bars. It has a Swedish-style mansion roof, with an attic storey above the other three storeys, dividing the roof into an upper and a lower part. The ground floor is marked by horizontal building blocks. The building is surrounded by and adjoined to the surrounding building stock.

Changes: The exterior remains largely unchanged, but several of the facades have been covered by newer buildings.

Function today: Over time, the building complex has also been used as a mechanical workshop and for the assembly of equipment for the oil industry. Today, the complex contains a mechanical workshop, artists' studios and offices.

7.10 Hydrogen Factory (Building no 55)


Hydrogen Factory in 1928 and today.
Left photo: Norwegian Industrial Workers Museum. right photo. Eystein M. Andersen.

Built: 1927

Architect: Thorvald Astrup.

Function: The Hydrogen Factory was the first step in the production line based on the ammonia method. Here, hydrogen was extracted by electrolysis of water using Hydro's own method (as opposed to a coal-based process). The building was planned after an agreement on the building of an ammonia plant in Notodden had been entered into with the American company NEC in August 1926. It was part of the reorganisation and consolidation that followed from the decision to phase out the Birkeland/Eyde process in favour of the ammonia (Haber-Bosch) method. The factory was in operation until 1968.

Description: The building is constructed of un-rendered, reinforced concrete and has tall windows with iron glazing bars. Here, Thorvald Astrup created a building that epitomised the Classicist tradition in industrial architecture, with towers and a simple temple-like gable at the western end, but with features of 20^{th}-century modern architecture in the forms and materials used, and in the simplicity of the building. It is architecturally akin to the contemporary factory buildings in Rjukan, and to the margarine factory in Oslo that Astrup drew in the same year.

Changes: Electrolysers were placed in two halls on two levels. The hydrogen was scrubbed to remove all traces of caustic potash solution in a gas cleaning tower. All the production equipment is gone today, with the exception of three tanks *(object 9.6).* The building was refurbished as office premises and reopened in 1987. The blue sections on the façade are from that period. Some annexes have been added to the southern side of the building. The annex furthest east was probably added soon after the building was completed.

Function today: The building has been used for various purposes since 1968, including as storage space for Hydro's archives. The ground floor is used for storage, and the overlying floors are used as offices.

7.11 Nitrogen Plant and Gas Cleaning Plant (Building no 115)

Nitrogen Plant and Gas Cleaning Plant. Photo: Per Berntsen.

Built: 1927

Architect: Thorvald Astrup.

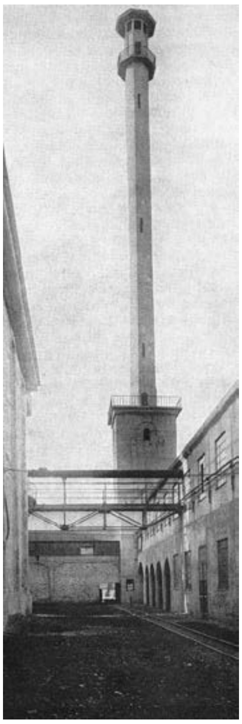
Function: Nitrogen gas was produced in the building's eastern hall, using air from the Minaret. The nitrogen gas was stored intermediately in a gasometer (1 500 m^3) on the northern side of the building. Next to it was another gasometer filled with hydrogen gas from the hydrogen factory (3 000m^3). Gas from these two gasometers (both demolished) was brought together and scrubbed of oxygen in the western part of the building. A third gasometer (5 000 m^3, demolished) was then used for intermediate storage of the gas mixture before it was sent to the compressor and synthesis plant where N and H were chemically combined to form liquid ammonia (NH3). The factory was in operation until 1968. Afterwards, the building was used as a plastic container factory for about 20 years.

Description: The building is constructed of rendered concrete as two adjoining halls with pitched roofs and ridge turrets for light and ventilation. It complies with the Classicist tradition in industrial architecture, with its temple-like façades and tall windows with iron glazing bars. The architectural style of the building creates a harmonious interplay with the Synthesis Plant. Both buildings housed important functions in the ammonia production.

Changes: Largely unchanged exterior, but the windows have been altered in the eastern hall. The interior has been renovated, including with a lower ceiling in one of the halls.

Function today: The building is currently used for storage.

7.12 The Minaret (Building no 135)



The Minaret in 1928 and today. Left photo: Norsk Hydro. Right photo: Per Berntsen.

Built: 1927

Architect: Thorvald Astrup.

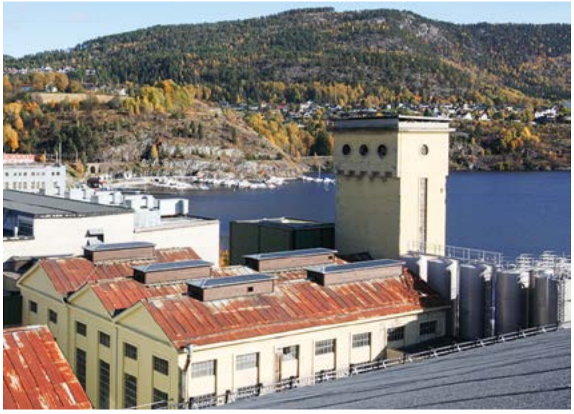
Function: The tower was used as air intake for the production of gaseous nitrogen in the ammonia production process, to avoid taking in polluted air, which would have constituted an explosion hazard. The air in the area was polluted by acetylene emissions from Tinfos AS's ironworks, which were not far away. Clean air was piped to the nitrogen plant. At one time, there were offices on the ground floor.

Description: The 63 metre high and slender tower is adjacent to the Packaging Factory (building no 140) and a pedestrian bridge connects it to the Calcium Nitrate Factory (building no 105). The tower is constructed of concrete, and the lower part has rendered surfaces. The concreting took place during winter. The Minaret is a landmark in Notodden.

Changes: Largely unchanged.

Function today: None.

7.13 Compressor and Synthesis Plant (Building no 130)



Compressor and Synthesis plant under construction in 1928 to the left and today to the right. Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1927

Architect: Thorvald Astrup.

Function: In this building, nitrogen (N) and hydrogen (H) from the Nitrogen Plant/Gas Cleaning Plant were brought together for the purpose of producing ammonia (NH3). Gas from the gasometer for mixed gas was drawn in by three compressors, compressed to 300 bar and sent through a filter to the synthesis furnace located inside the characteristic tower. Three circulators were in place that circulated the gas through the furnace where the H_2 and N_2 combined to form ammonia. The plant was in operation until 1968.

Description: The building is of rendered concrete and consists of three adjoining halls with pitched plate roofs and ridge turrets for light and ventilation. The halls are of different lengths, but the building has a base of approximately 34x33 metres, excluding the tower building for the synthesis furnace. The tower is shaped to hold a 12 metre tall synthesis furnace. The architectural style of the building creates a harmonious interplay with the nitrogen and gas cleaning plant.

Outside the building were tanks for liquid ammonia, which was transferred from the tanks to ammonia wagons and transported to Herøya.

Changes: The building is joined to the adjacent buildings (nos 151 and 132), and it is therefore difficult to discern.

Function today: The building is currently used for the production of plastic packaging.

7.14 Nickeling Plant (Building no 160)

Nickeling plant. Photos: Eystein M. Andersen.

Built: 1918/1928. The building complex consists of buildings from different periods.

Architect: Unknown.

Function: Here, Hydro conducted tests with lucite, a potassium aluminosilicate, with a view to extracting aluminium oxide and potassium nitrate. This was done in collaboration with an Italian financial consortium formed to exploit raw materials imported from Italy, where such materials are present in alkaline igneous rocks (mineral clay). The tests were abandoned in the early 1920s, probably because it was considered too risky to base production on a raw material that might be subject to export duty. When the ammonia method was introduced from 1928, the need arose for a nickeling plant for nickel-plating the material used in Hydro's hydrogen plants.

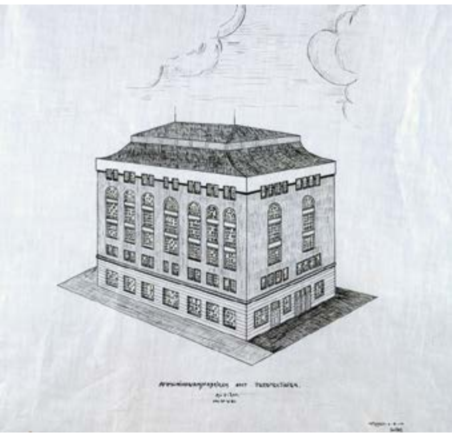
Description: The oldest part from 1918 is recognisable with its pitched roof, gable end and simple ornamentation. The extension from 1928 on the eastern side, built to accommodate the Nickeling Plant, is a tall, flat-roofed building crowned with iron ornamentation.

All nickeling in Hydro took place in Notodden and Glomfjord. An improved version of the electrolysers used in the hydrogen factories was introduced in the early 1950s, which required more space for nickel-plating. In 1953, it was therefore decided to build a completely new nickeling plant in Notodden. The new nickeling plant from 1953 is soberly functional with flat roofs. All parts of the building complex are of rendered concrete and have windows with iron glazing bars and felted roofs. The oldest part to the west has architectural features in common with the calcium nitrate plant from the same period. The annex furthest east is probably from the transition to the building's use as a workshop.

Changes: Extended towards the east in 1928, when the nickeling function was established in the old test building. New nickeling plant added in 1953. The new factory was built on the eastern side of the old factory so as not to interfere with production in the latter. The old factory was closed down and the building put to use for workshop functions. Further extensions have been added on the western side and, more recently, also on the northern side of the complex.

Function today: The building is still in use as a nickeling plant for electrolysis technology. The company NEL Hydrogen produces hydrogen electrolysers here.

7.15 Ammonia Water Plant (Building no 90)



The architects drawing from 1914 of the Ammonia Water Plant to the left and the construction of the building in 1915 to the right. Drawing and photo: Norwegian Industrial Workers Museum.

Built: 1914–1916.

Architect: Helge Blix and Carl Borch.

Function: This building was built for the production of ammonia water in order to use the by-product ammonium nitrate from the artificial fertilizer process as a component in explosives for the arms industry. Ammonia water was produced here during the period

Ammonia Water plant today. Photo. Trond Taugbøl.

1917–1919, and sporadically until 1927. The ammonia water was used in the ammonium nitrate plant (demolished), but also sent to Hydro's factories in Rjukan and Herøya until 1928, when it was no longer needed after the introduction of the Haber-Bosch method.

Description: The building is of reinforced concrete and complies with the Classicist tradition in industrial architecture. The building bears testimony to Hydro's international orientation and basis, as the company was quick to adapt to international economic fluctuations and offer products for which there was a demand on the world market and which were at the same time profitable. The plan was to import ammonium compounds from England or Germany to the ammonium nitrate plant, which during its first years imported ammonia water from England. After the outbreak of war in 1914, this became difficult, and Hydro built its own ammonia water plant on the site in 1914. During World War I, there was a strong growth in demand, and production reached 24 000 tonnes. A second supporting ammonium nitrate plant, which later was converted to the calcium nitrate factory *(object 7.3)*, was built to increase production and improve the process at the same time.

Changes: The exterior remains largely unchanged since the northern extension was built in 1916. Several doors and windows have been replaced. The building has recently been rendered and painted.

Function today: Mostly used as storage space and office premises by several enterprises.

8. Hydro Industrial Park in Rjukan

8.1 Furnace House I (Building no 242)

Furnace House I in 1910 to the left and part of its interior with Schönherr furnaces a few years later to the right. Photos: Norwegian Industrial Workers Museum.

Built: 1910–11

Architect: Christian Morgenstierne.

Function: Consisting of three adjoining furnace halls (I, II and III) for the first Birkeland/Eyde furnaces in Rjukan, and two storage halls (IV and V). The distribution station that

Furnace House I today. Photo: Per Berntsen.

supplied electricity to the whole factory area was located at the northern end of the eastern side of the building where it has three floors (see *object 6.2*). Power lines from Vemork entered the building through the western façade, while the power lines from Såheim entered through the southern façade. On the eastern side, adjacent to the distribution station, is an annex from 1910, which housed the transformer station for the Rjukan Line. Transformers were kept in the building until 1958.

When Hydro introduced the ammonia method, production using the electric arc method in Furnace House I came to an end. From 1929, the building was instead used for the new (Haber-Bosch) production method as a combustion plant for ammonia. The building was thus connected to the New Production Facilities on its western side. The combustion plant was located in the fifth hall, while the fourth hall was used as a steam boiler plant. A total of 25 combustion furnaces of five different types were installed for ammonium gas in Hall V. The gas was transferred from the synthesis plant via a gasometer and sent from Hall V to the steam boiler plant in Hall IV, before it was transferred to the absorption towers in the tower house. The plant was in operation until 1983.

Description: The furnace house was built as part of the Rjukan I factory facilities. It was designed to accommodate both German Schönherr furnaces and Norwegian Birkeland/ Eyde furnaces, depending on the results of the tests that were being carried out in

Furnace House I, west facade, today. Photo: Per Berntsen.

Notodden (see object 7.6). That is why the building has both ample floorspace and ample height. Regardless of the results of the tests in Notodden, the German company BASF gained acceptance for the installation of 96 German and only 8 Norwegian furnaces. Furnaces were thus only installed in the three halls to the north, while the two remaining ones were used for storage and the testing plant. The furnace house was put into operation in autumn 1911. Two new Birkeland-Eyde furnaces were added in 1926.

The halls are reflected in the five curved gables, of which the two on the sides have pitched roofs while the three in the middle have curved roofs. The building has a total floorspace of 10 500 m^2. The style of the building is classical industrial architecture, with features from traditional, continental gable architecture. It also illustrates the birth of 20th-century modern architecture, however, in that it also embodies the principles of single-surface factory buildings, steel framed structures, ridge turrets on the roof for light and ventilation and tall windows with iron glazing bars. The eastern side has a continuous ribbon of windows. The building is a bare brickwork building on concrete foundations. The décor is limited to the two side halls, which have simple classical window markings and blind niches. The power lines from Vemork are gone, but porcelain insulators and entry gates are still visible on the façade.

Changes: Refurbished for use as storage space for iron and other materials.

Function today: Today, the whole building is used as warehouse and business premises

8.2 Boiler House (Building no 246)

Boiler House under construction in 1911 to the left and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1911

Architect: Unknown.

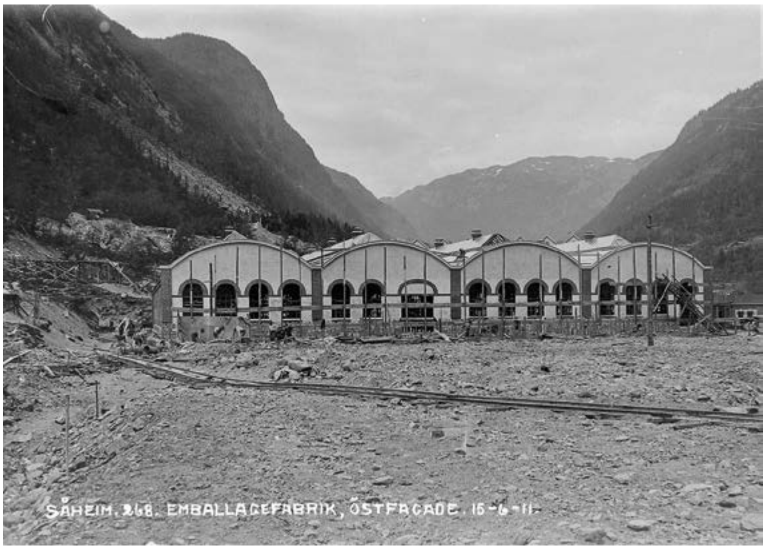
Function: Built as part of the first building phase (Rjukan I) in the development of the calcium nitrate factory. This was the building in which the gas from the furnace house was cooled down as it was passed through large steam boilers and then through gas coolers, which consisted of horizontal pipes cooled by running water. Here, the gas was transferred to an oxidation vessel before it was sent to the tower house for absorption. The boiler house functions were located in the higher-lying western part of the building, while the fans and compressors were located in the lower-lying eastern part. When operated at full capacity, the gas throughflow was approximately 500 000 m^3 per hour. There were also changing rooms in the building. The plant was operated as part of the electric arc process until 1929. The equivalent building in Hydro Industrial Park in Notodden has been demolished. From the late 1940s, the building was used as plumbing, electrical and instrumentation workshops.

Description: The building with a floorspace of 15 000 m² lies just east of the furnace house. The building reflects the Classicist tradition in industrial architecture. The style is clearly utilitarian with no decorative elements apart from the pilasters. It is a steel-framed brick structure with large square windows.

Changes: In the late 1940s the building was renovated. Interior ceilings have been installed. Towards the west, a previous canopy roof has been walled in to form an annex. The façades have undergone some changes, including a new entrance, which was built in the 1980s.

Function today: Today, the building is a technical centre with offices, workshops and production premises.

8.3 Barrel Factory (Building no 282)



Barrel Factory under construction in 1911 to the left and its interior in operation in 1912 to the right.
Photos: Norwegian Industrial Workers Museum.

Built: 1911.

Architect: Unknown.

Function: Build as a packaging factory with a workshop for maintenance of tools and equipment for the production of barrels. Approximately 5 500 barrels were produced here every day. Production was closed down in December 1928. From then on the need for barrels was to be met by the factory in Notodden, which also produced the sacks of Indian jute with which the barrels were largely being replaced. The empty premises were used for the famous 'sausage feast' arranged by Hydro in 1929 to mark the transition to the ammonia method and attended by more than 3 000 people. The building was subsequently also known as the 'Sausage Hall'. From 1937, the building was used as a carpenters' workshop for building maintenance and miscellaneous tasks in the factory area and the Hydro company Rjukan Bydrift's (city management) building stock in the town.

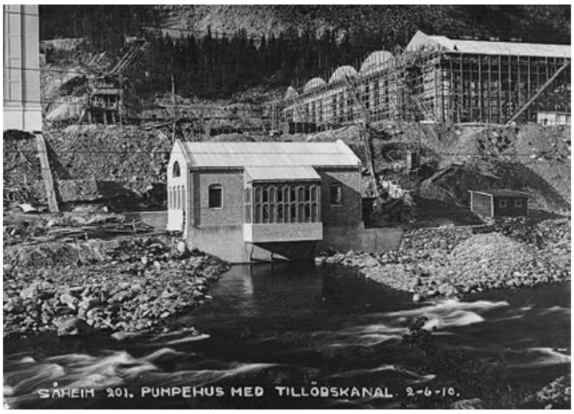
Today's rest of the complex. Photo: Per Berntsen

Description: It was built in brick and concrete with steel frames and has window with iron glazing bars. It originally consisted of four adjoining halls with arched roofs, with a floorspace of 2 500 m². Together with the stave warehouse, barrel plant and drying house, it covered an area of 1.2 hectares.

Changes: Following serious damage to the building during the World War II, it had been partially demolished by 1946. The two arched-roof halls furthest south were removed. Today, the building consists of two halls in the north-western corner of the site, and its length has been much reduced towards the east. Changing rooms were installed in the basement of the building in 1955. They were refurbished together with the northern façade in 1979, when the windows of that façade were also replaced. On the site of the demolished parts of the building, another building was erected which initially served as a timber warehouse until an aluminium forge was established there.

Function today: Today, the building is used for offices, and workshop and storage space.

8.4 Pump House (Building no 249)



Pump House in 1910 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1910

Architect: Christian Morgenstierne.

Function: The Pump House brought water from the Måna river to a reservoir behind Furnace House I. This water was used in many parts of the electric arc process as well as the ammonia production process, including the provision of running water for the acid towers in the Tower House, for cooling and for the production of steam in the Boiler House. The Pump House was the main source of water until Såheim Power Plant was built. After that, the facility provided redundancy, supplementing generator set 12 in Såheim's Underground turbine generator hall *(object 4.2).*

Description: The pump house was built on the bank of the Måna river. It is in the Classicist style with decorative blind niches in bare brick. It is a rendered-brick single-storey building of 175 m^2. The concrete dam in Måna as it stands today was built in 1916 and altered in 1922. The actual pump function is prosaic, and a simpler and less costly building would have sufficed. Water was essential to the Birkeland/Eyde process, however, and the house is an example of Sam Eyde's interest in architecture. Consumption reached 1 m^3 per second. By way of comparison, the city of Hamburg had a consumption of 1.5 m^3 per second in 1907. Of the interior, one original AEG pump with engine *(object 9.5)* remains, together with a tool board.

Changes: Remains largely unchanged.

Function today: Functions as emergency pump station for supplying production and consumption water to the industrial park.

8.5 Laboratory (Building no 248)

Laboratory in 1911 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1911

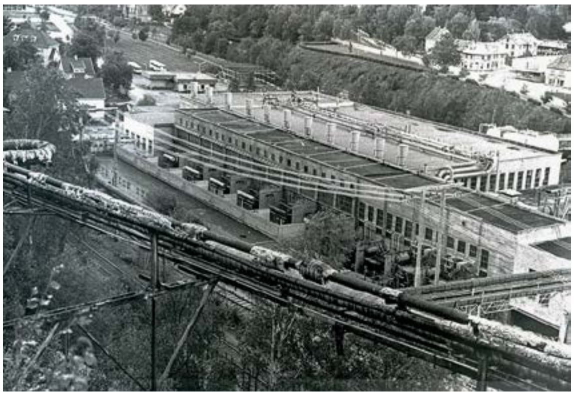
Architect: Christian Morgenstierne.

Function: Built as the main laboratory for the chemical production processes. All production and finished goods were checked here, from the first Norway saltpetre to the noble gas that was produced in the 1990s, i.e. during the periods of both the electric arc method and ammonia method. The building also represents the testing and pioneering activities that took place. It was here that the engineers tested out improved production methods. The company's physician also had his offices in the building.

Description: The building was erected in a simple Classicist style. It is of rendered concrete, measures 45x15 metres, has two floors and a floorspace of 1 300 m^2.

Changes: In recent times, the Laboratory has been extended with a flat-roofed extension on the eastern side, a dormer towards the west and a small porch towards the south. The old slate roof has been replaced by steel plates and the chimneys have been replaced. New windows were installed in 2003.

Function today: Parts of the building now serve as offices and laboratory space.



Såheim II Hydrogen Plant in the 1950's and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1941/1948

Architect: Unknown.

Function: Hydrogen Plant based on water electrolysis. Closed down in 1989.

Description: From 1929, Såheim engine shed *(object 11.10)* was part of Såheim I, but, in 1941, the first part of the building known as the ***313 building*** was built as an extension to Såheim engine shed and incorporated into the hydrogen plant to increase fertilizer production. From then on, this plant, consisting of the former engine shed and the 313 building, was known as Såheim II Hydrogen Plant. At that time, it consisted of ten Pechkranz electrolysers and two large electrolysers of German design (supplied by the company Bamag). These were taken out of operation in June 1954. Another extension was added to the 313 building in 1948, in which 60 electrolysers were installed. After production was expanded, the oldest part of the plant contained 56 bipolar Pechkranz electrolysers, while the 313 building and extension contained a total of 96 electrolysers.

The ***Compressor House*** was built in 1948 to serve the different parts of the Hydrogen Plant (I and II) in the building in front of the power plant and in the 313 building. A concrete wall that evens out height differences in the terrain by the Compressor House on the eastern side facing Såheim Power Plant is a segment of the hydrogen gasometer that was constructed in 1941.

To the left: Såheim II Hydrogen Plant seen from Såheim Power Station with the Compressor House in front.
Photo: Eystein M. Andersen. To the right: Interior with electrolysers. Photo: Norwegian Industrial Workers Museum.

Changes: Såheim I Hydrogen Plant was established in 1929, in a low building in front of the Såheim Power Plant and in the former Såheim engine shed, where the water distillation plant and compressors were installed. It initially consisted of 36 bipolar Pechkranz electrolysers of the same type as those used at Vemork. In 1940, the plant was extended to include another 20 electrolysers. From 1941, the former engine shed became part of Såheim II. The building in front of the power plant (Såheim I) was demolished when production was closed down in 1989.

An extension has been added to the 313 building. The interior of the Compressor House has been changed as a consequence of its changed function, while the exterior remains virtually unchanged.

When the heavy water production plant was moved from the hydrogen plant at Vemork to Såheim in 1971, a tower-like extension in concrete was added to the Compressor House to make room for a water/hydrogen exchange column for heavy water *(supporting value).*

Function today: Today, the Compressor House has been refurbished and contains offices and workshop space.

8.7 Nitrogen Plant (Building no 226)

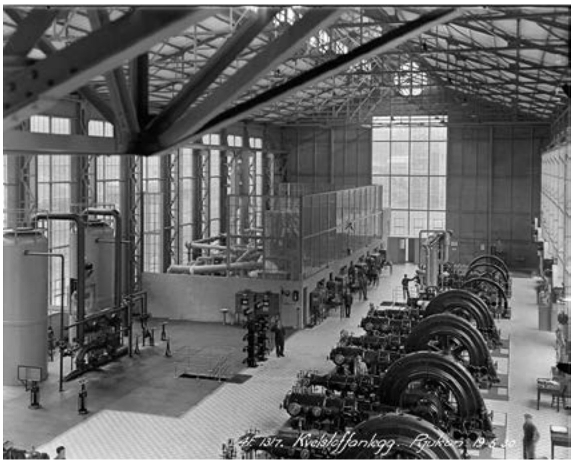
Nitrogen Plant in the 1950's and today.
Left photo: Norwegian Industrial Workers Museum.
Right photo: Eystein M. Andersen

Built: 1928

Architect: Thorvald Astrup.

Function: The Nitrogen Plant was built in collaboration with the German company I G Farben as part of the 'New Production Facilities' that was built in connection with the transition to the ammonia method. This building was used for the production of nitrogen, which was mixed with hydrogen and sent to the gas cleaning plant and then on to the Compressor and Synthesis Plant. The latter was also known as the 'Linde Plant', named after the German compressor manufacturer. Initially, in 1929, four nitrogen units, two turbo-compressors for air, two gas cleaning towers, five high-pressure air compressors and three ammonia compressors and pertaining equipment were installed. During the first years of operation, there were major problems due to the entrainment of nitrose and ammonia with the air that was drawn in. The plant continued to operate until 1989.

Description: The building is basilica-shaped in the style of traditional industrial architecture, but other features are illustrative of early 20th-century modern architecture. The building has smooth surfaces without décor and lacks historicising elements. The pro-



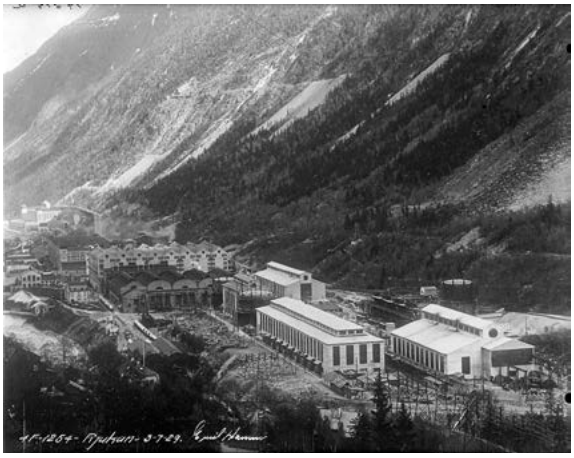
Interior of the Nitrogen Plant in 1930.
Photo: Norwegian Industrial Workers Museum.

duction hall was open, light and airy. It is a rendered concrete structure with steel frames, and has tall, wide windows with steel glazing bars mounted flush with the exterior wall. The building is 105 x 25 metres with 2 800 m² floorspace.

Changes: The plant was extended in the 1940s, and again in the 1950s. The façades are intact, but some new doors and gates have been installed and some of the windows on the southern façade have been blinded. An extension on the eastern side was added in 1948. In the interior, the original floor has been removed and Hydro's production equipment removed.

Function today: Yara Praxair uses the building as a warehouse for gas cylinders and an operations centre for its gas production.

8.8 Compressor House (Building no 228)



Compressor House in 1929 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Helge Songe.

Built: 1928

Architect: Thorvald Astrup.

Function: Compression of mixed gas in the 'New Production Facilities'. The building contained compressors for nitrogen and carbon dioxide, and storage tanks and a cleaning plant to remove oil. The plant was in operation until 1989.

Description: When it was new, it is said to have been the biggest compressor house in the world. At that time, it contained nine horizontal mixed gas compressors for the compression of nitrogen and hydrogen for the Synthesis Plant, and it was an important building in the Haber-Bosch production line. Another four compressors were added between 1948 and 1961.

The building clearly reflects early 20th-century modern architecture. It is a rendered concrete structure with steel frames, and has tall, wide windows with steel glazing bars mounted flush with the exterior wall. It has an almost flat hip roof. The building has smooth surfaces without décor and lacks historicising elements. The production hall was open, light and airy. The building has a typical utilitarian design. It has a floorspace of 8 200 m^2. The building houses the deuterium (heavy hydrogen) gas facility, which, in the 1990s, was moved from Såheim where it had been part of the heavy water production plant after 1971. It is no longer in operation.

The building is furthest west on the factory site and the first to catch the eye of visitors coming down the Vestfjorddalen valley from the west.

Changes: It was originally 27 metres wide and 117 metres long, but in 1946, it was extended eastwards to 162 metres. The exterior of the building remains virtually unchanged and much of the interior building structure has also been preserved. It has new doors and gates.

Function today: Yara Praxair currently produces gas in the eastern and middle parts of the building, and overhauls gas cylinders in the western part of the building. The gas is filled into gas cylinders on the ground floor.

8.9 Synthesis Plant (Building no 229)

Synthesis Plant in the 1930's and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen

Built: 1928–1929

Architects: Morgenstierne and Eide.

Function: Synthesis Plant serving the 'New Production Facilities'. Also contains control functions and instrumentation for the furnace groups. The plant was closed down in 1989.

Description: Adjacent to the low one-storey building was a line of ammonia synthesis furnaces held in place by a steel structure. The synthesis plant was at the very centre of the ammonia method in that it was here that H2 and N2 were catalytically combined to form gaseous ammonia. The plant consisted of a large, long steel structure which held in place the 13 metre high outdoor synthesis furnaces, each weighing 80 tonnes, and an adjacent control house. In the beginning, the plant consisted of seven circulators and seven furnace groups, each consisting of a synthesis furnace, pre-cooler, regenerator, supercooler and separator. The plant also included ten oil filters and two tanks for intermediate storage of liquid ammonia. After a few years, the plant was simplified in that all seven regenerators and supercoolers were removed from five of the groups. Furnace groups 8 and 9 were put into operation in 1948 and furnace group 10 in 1955. The number of circulators was increased accordingly.

The building is in the Functionalist style with rendered concrete and windows with steel glazing bars. The flat roof has a simple overhang.

Changes: Today, the building measures 25 x 17 metres, but it was originally about 100 metres long and consisted of a long service corridor and sections of adjacent rooms. The corridor and two of the sections have been preserved, along with subsequently added changing rooms installed between them. The rest of the building was demolished in the late 1980s. Only part of the control house remains. Some of the steel structure also remains in the form of standing poles. A production plant for catalyser material was built onto and over some of the roof of the present-day building in the 1980s. It will be demolished in 2013.

Function today: None.

8.10 Mechanical Workshop (Building no 230)

Mechanical Workshop in 1928 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Helge Songe.

Built: 1928

Architects: Thorvald Astrup.

Function: Built as a service workshop for the synthesis furnaces for gas production and for the maintenance of other production equipment. Because of the high temperature loads, for each of the nine furnaces used in production in the Synthesis Plant, there was one redundant furnace and one furnace being serviced. Development and better maintenance of the production plant, particularly the compressors, were the key to greater efficiency and operational safety.

Description: The Mechanical Workshop is in the same architectural style as the Nitrogen Plant and based on the same construction principles. The building measures 63 x 35 metres. On the western side, a big 100-tonne crane reaches out from the building through separate gates.

Changes: The building has some new doors and gates. New windows were installed on the western side in the 1970s. An extension has been added to the western gable.

Function today: None.

9. Production equipment

What remains of industrial plant and machinery from Hydro's days is limited, but some key items have been preserved as mementos. Old equipment parts are still being discovered or recognised, and are then preserved.

9.1 Ceramic pots

Ceramic pots. Pots similar to these were used in different stages of the production. To the right: From the Tower House in 1905. Left photo: Trond Taugbøl. Right photo: Norsk Hydro.

The absorption system for nitric acid was developed by AS Notodden Salpeterfabrikker. After having used small glass vials in the Test Factory, Hydro's engineers constructed absorption towers of granite that were placed in rows, together with a small number of towers of wood and iron.

Built: Probably 1906.

Function: Large ceramic pots were used for intermediate storage of the acid during the concentration process.

Description: Two such stoneware pots have been preserved in Notodden. They were used in the Test Factory which was part of production line B in the plant. The pots are the only production equipment to have been preserved from the Test Factory. The smallest pot is 1.7 metres high and 1 metre wide, while the biggest one is approximately 2 metres high. Both pots are located outside in the open air by the entrance to Furnace House A, close to the Birkeland/Eyde Furnace *(object 9.2).*

Function today: Museum objects.

9.2 Electric Arc Furnace, Notodden

Built: Probably 1905.

Function: Electric arc furnace for extracting nitrogen from air.

Description: This belongs to the first generation of furnaces used industrially and it is assumed to have been manufactured between 1905 and 1907 as one of the very first 'complete electric arc furnaces'. These were made in the testing plant at Vassmoen in Arendal, which was closed down in 1907.

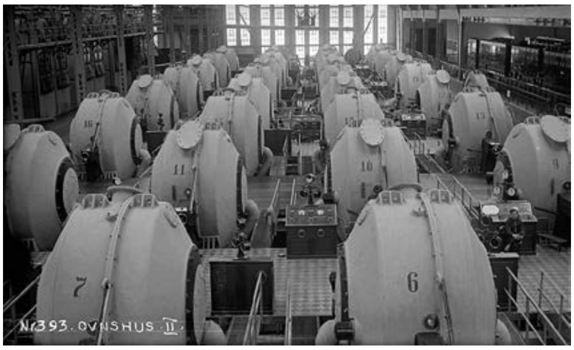
As an object, the electric arc furnace is 4.5 metres long, 3.5 metres deep and 2.5 metres high, and weighs approximately 17 tonnes. The actual furnace consists of four cast iron


The preserved Electric Arc Furnace in Notodden. Left photo: Per Berntsen. Right photo: Trond Taugbøl.

shells, where the magnetic windings and electrodes are installed on the two outermost shells, while the two inner shells are lined with refractory chamotte bricks. The shells are supported by steel beams, to facilitate repair work and modification of the furnaces. A trussed framework at each of the four corners supports the steel beams that carry the shells. The furnace was stored indoors until the mid-1990s when it was moved to its present position in the open air in front of the entrance to Furnace House A *(object 7.1).*

Function today: Museum object. The two parts of the furnace have been taken apart and partially disassembled, so that all parts can be easily viewed from both sides.

9.3 Electric Arc Furnace, Rjukan



The electric arc furnaces in Furnace House II in Såheim Power Plant to the left. The one that is preserved in Rjukan to the right. Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1912.

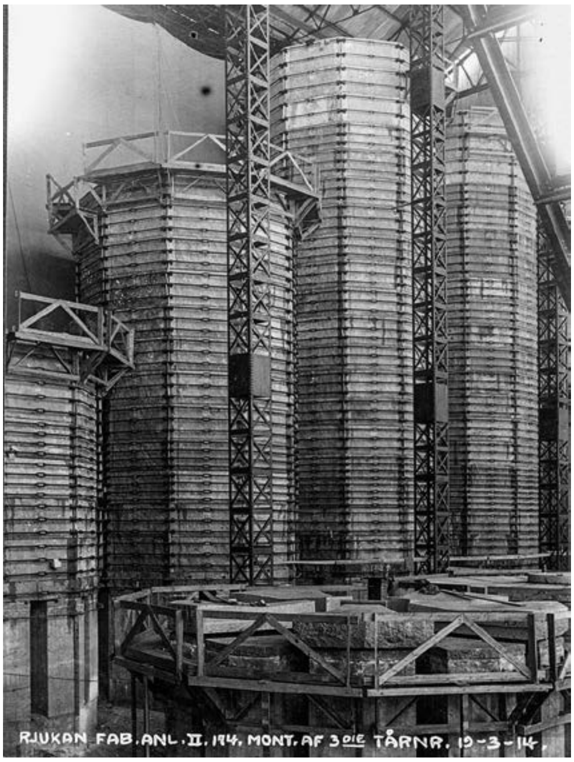
Function: Electric arc furnace for extracting nitrogen from air. The furnace was in use until 1941.

Description: The cast-iron electric arc furnace consists of two identical halves that have been bolted together. Either side has a big bolted-on cover of the same material. The magnetic windings are underneath these covers. The furnace is one of 40 furnaces that were installed in the Rjukan II plant beside Såheim power station, and it represents the last generation of this type of furnace. It is approximately 4 metres in diameter and 2 metres deep. The main structure is of cast iron with covers and cable ducts of steel. It is estimated to weigh a total of about 15 tonnes.

Changes: Unchanged.

Function today: Museum object mounted as a sculpture in the park in front of the Rjukan House *(object 13.10)*.

9.4 Acid Tower



Acid towers under construction in Tower House II in 1914 to the left, and the one Acid Tower that is preserved today to the right. Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1910–1911.

Function: Absorption of nitrogen to form nitric acid. Water was percolated through the towers to absorb nitrous gas from the electric arc furnaces. The acid towers were also used for absorption after the transition to Haber-Bosch synthesis.

Description: The approximately 23 metre high tower is constructed from 2.24-metre-long and 1-metre-wide granite blocks joined using crocidolite asbestos. They have a triangular cross section with an external diameter of 7 metres. The tower is encompassed by 58 steel ties with one turnbuckle on each of the tower's flat surfaces. The tower is filled with quartzite aggregate from Hydro's quartz quarry at Tinnoset. The granite tower rests on ten pie-shaped foundations with embedded iron sections. **The acid tower is the only one that remains from the original production plant in Rjukan**. It was one of 32 granite towers in Tower House I, of which the rest have been demolished, and it is currently standing in the open air in its original position. Together with the preserved Tower House A in Notodden, it represents a key element in the production line that was based on the Birkeland/Eyde process. In the early 1980s, the tower house and all absorption towers, with the exception of one, were demolished and replaced by a new nitric acid factory that was built close by.

Function today: Today, the remaining acid tower is a cultural heritage object.

9.5 AEG Pump

The AEG Pump in the Pump House. Photo: Per Berntsen.

Built: 1911.

Function: The pumps supplied water to the various phases of production.

Description: Pump no 3 – preserved pump with AEG engine. The engine was transferred from pump no 2, when the engine for pump no 3 burnt out. The two other pumps in the Pump House *(object 8.4)* were used well into 2011. A tool board containing tools for the oldest pumps has also been preserved.

Function today: The pump is still used as a back-up pump.

9.6 Tanks in the Hydrogen Plant

The tanks in the Hydrogen Plant. Photo: Eystein M. Andersen

Built: 1928 (?)

Function: It is not clear what function the tanks had in the production process. However, there was a need for tanks, including for storage of the caustic potash solution with which the electrolysers were filled to ensure electric conductivity. They may also have served as tanks for heavy water.

Description: All the production equipment in the Hydrogen Plant *(object 7.10)* in Notodden is gone today, but three tanks are preserved in a room on the first floor on the southern side. There is one riveted standing tank, while the two others are smaller and supported by a steel beam structure.

9.7 Synthesis Furnace, Rjukan

A synthesis furnace arriving to Rjukan in 1928 to the left, and the one preserved synthesis furnace today on the same wagon to the right. Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1929.

Function: Ammonia synthesis in the Haber-Bosch process. The Synthesis Plant in Rjukan was closed in 1989.

Description: The furnaces, which were built in Germany by 'Werkstatten der betriebesontolle Oppau IG Farbenindustrie Aktiegesellschaft', were transported using specially constructed Norwegian-built railway wagons in 1928/29 *(object 11.12).* One furnace weighted a total of 80 tonnes and was 13.5 metres long. It was originally built for an operating pressure of 200 atm. The engineers eventually discovered that Rjukan offered particularly favourable operating conditions and therefore increased the pressure to 250 atm. This is evidence of the engineers' technical insight and the quality of the plant.

Only one of the original nine synthesis furnaces in Rjukan remains. A few smaller-scale furnaces still exist in the world, including in the Carl Bosch Museum in Heidelberg in Germany, but most of the large furnaces are now gone. As far as is known, those in Leunawerke in Germany were the last to be operated, and Leunawerke was dissolved and the plant demolished in the course of the 1990s, following the fall of the Berlin Wall.

Transport system. Detailed description of buildings, constructions and units.

The whole transport system between Rjukan and Notodden remains intact as constructed by Norsk Hydro. The only exception is the Vemork railway track, where the rails have been removed.

10. The Tinnoset Line

10.1 Railway track with signalling and overhead line equipment

The Tinnoset Line at Lisleherad station to the left and Gaupesprang bridge to the right.
Left photo: Eystein M. Andersen. Right photo: Trond Taugbøl.

Built: 1909.

Description: The Tinnoset Line between the new railway station in Notodden and Tinnoset covers a distance of 30 km. It climbs a total of approximately 175 metres and is at its steepest, with a gradient of 2.8%, along the Svelgfoss gorge towards Lisleherad. The minimum curve radius is generally 180 metres, with a few exceptions where it is as low as 150 metres. The line has two steel truss bridges crossing the Tinnelva river. The Gaupesprang Bridge is the original bridge and similar to the bridges on the Rjukan Line. The track crosses a total of 14 bridges, with an aggregate length of 175.5 metres, and passes through five tunnels.

Overview of tunnels and bridges:

Name/place	Category	Length	Year built	Type
Notodden North	Tunnel	235 m	1909	
Kikedalen	Tunnel	240 m	1909	
Grønvollfoss South	Tunnel	47 m	1933	
Grønvollfoss North	Tunnel	194 m	1933	
Kleivdal	Tunnel	23 m	1909	
Storemo	Bridge	68 m	1968	Steel deck bridge
Gaupesprang	Bridge	54 m	1909	Truss bridge, riveted steel

Changes: The line was rerouted at Grønvollfoss in 1933, so that the Tinnelva river could be dammed up for the construction of the Grønvollfoss power plant. The track was laid higher up in the landscape and through two new tunnels. In 1968, a minor part of the track was straightened at Storemo, which included the addition of two new bridges across the Tinnelva. The side tracks that were constructed for the Grønvollfoss and Årlifoss power stations have been pulled up.

Function today: The railway line is owned by the state and has 'traffic suspended' status. It has not been formally closed down. Intermediate stations and building stock have been released and sold to private owners.

The overhead line equipment between Notodden Railway Station and Tinnoset Railway Station is from the latter half of the 1950s. It largely consists of wooden creosote-impregnated masts, 629 in number. There are 23 concrete masts along the track, used in pairs in all places where there are boost transformers. The station at Tinnoset has steel masts from 1911, and Notodden from 1917. On the two steel bridges, cantilevers have been installed of the type used in portal structures and which are also found in some of the tunnels and cuttings through which the line passes. All cantilever fixings in tunnels and cuttings are, in general, not galvanised. There are two portal structures along the track. These are installed at Grønvollfoss railway station. Many of the masts along the track are stayed using anchoring wires, curve ropes and detensioning stays.

The overhead line equipment on the Tinnoset Line from 1911 originally consisted of steel masts with 80 mm^2 Cu contact wire and 50 mm^2 Cu messenger wire. In several places between Notodden and Tinnoset, traces of the original masts can be observed where the foundation tops and lower part of the original masts protrude from the ground. A new overhead line went live in 1963.

The line is divided into a total of ten boost transformer sections. One booster transformer (no 7) has been removed. All booster transformers, with the exception of no 9 at Grønvollfoss, are fixed to concrete masts. Fourteen of the wooden masts were cut down when the overhead line's copper wire was stolen in 2012.

Notodden old railway station building when it was in use between 1909 and 1918.
Photos: Norwegian Industrial Workers Museum.

Built: 1908–1909.

Architects: Thorvald Astrup.

Function: Built for Norsk Transportaktieselskab as a terminal station for the Tinnoset Line and a switching station for the industrial side track to Rjukan Quay, from which transport continued by water down the canalised watercourse to Skien. The station was in operation until 1919 when the Bratsberg Line (from Skien) and the new railway station in Notodden were opened. The building was then incorporated into the Hydro Industrial Park and used as office premises.

Description: The building has architectural features representing the historicising Art Nouveau style that characterised much of the architecture in Norway and Notodden around 1900. The station building has a pitched slate roof, two chimneys and front gables decorated with cast-iron rosettes. It is built of rendered brick on foundations of natural stone. The lower part of the wall is unrendered to form a ground sill. A curved cast-iron balcony and oval windows at the top of each gable have ornamentation in the Art Nouveau style. Between the windows on the northern façade, the wall boasts dragon-style carved wooden figures that were probably made by the woodcarver Jon Borgarson. Under the eaves on both sides is an entablature of natural stone with a rosette decor.

The location of Notodden's first railway station shows the direct link between Hydro's production premises and railway transport.

Changes: Originally, the roof of the building had a wooden extension supported by poles above the main entrance on the north-eastern side, towards the railway track. It was demolished when the station was taken out of service and what used to be a door was replaced by a window. The middle and side doors on the northern façade have also been replaced by windows. The old platform is gone and the terrain has been filled in to approximately one metre above the original level. Several basement windows have also been covered up. The stairs leading up to the door on the western façade has been removed. The interior of the building has been radically modernised and none of the original details have been preserved. Notodden's first railway station was originally in an

Notodden old railway station building at the jubilee in 2009. Photo: Trond Taugbøl.

open location with a platform on the northern side. On the eastern and southern sides of the building, railway tracks (side tracks for freight) were laid and a freight house (equivalent to the one at Tinnoset) erected. The freight house has been demolished, but a small section of the pertaining freight track has been preserved and is still in place. Between the wars, landscaping was carried out to create a park structure to the south of the station building. In 1933, the southern entrance could be approached via a footpath lined by a formal arrangement of bushes and trees on either side. The more organic design of today was introduced after World War II. Buildings have been erected close to the western side of the building and there is a parking area adjacent to the park. The station building was repaired and partially restored in 1995. The track connections were restored in 2004, and a new platform has been built as a terminal for local train traffic.

Function today: Offices. The building is included in Notodden Industrial Park as building no 52 in Hydro’s register.

10.3 The Railway Quay, also known as the 'Rjukan Quay'

The Rjukan Quay in 1916 and today. Left photo: Notodden Historielag. Right photo: Trond Taugbøl.

Built: 1909.

Function: Transfer of goods between the Rjukan Line and barges for transportation to Menstad via the Skien river.

Description: Remains of the track system from the old Notodden railway station to Rjukan Quay at Tinnesandbukta bay and back to the factories on the Hydro site. Concrete foundation of two cranes that were used for transferring goods from railway wagons to barges. The track from the station crosses a bridge over the Hvålabekken stream. The beck flows overground in an open and visible culvert revetted with stone. Where the stream passes through the Hydro Industrial Park to its outlet in Heddalsvatnet lake, it flows underground, the lake having been partially filled in to form the current terrain.

Function today: Small craft marina.

10.4 Notodden Railway Station with eight buildings

Notodden Railway Station around 1920 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1917.

Architects: G. Hoel and G. Fischer, NSB's Architectural Department.

Function: Station in Notodden linking the Rjukan Line and the Bratsberg Line. Service office with signal box. A separate building contains transformer station with charging station and lodging room.

Description: The station building is a typical urban railway station of the grand type (it has many features in common with Kongsberg, which was built at the same time). The façades are washed brick with decorations in the Baroque revival style. Details include reliefs in the form of cornice brackets, pilasters and arches, ashlar corners and fascia strips marking the transition to the floor above. Steep curved roofs with a ridge turret with spire for ventilation. The ***freight house*** and ***transformer station*** were drawn by the same architect in a style that supports the main station building.

The station area also has many buildings of more recent date, including an engine shed with two tracks and with a manually operated turntable in front, ***wagon weighing hut*** with intact machinery, carpenters workshop with smithy etc. The overhead line equipment with riveted lattice masts, lattice beams and portals from 1917, is among the oldest in Norway. It has several details that are rarely seen today, including suspended track information signs.

Changes: Some of the doors and windows of the station building are not original. The freight house was extended in 1930.

Function today: Offices, cafeteria.

10.5 Tinnoset Railway Station with three buildings

Tinnoset railway station building around 1920 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen

Built: 1909.

Architect: Thorvald Astrup (station building, outhouse and freight house).

Function: The service office with waiting room and goods store on the ground floor, and the stationmaster's apartment on the first floor of the station building. Tinnoset railway station was manned until 1988 and in operation until the line was closed down in 1991.

Description: The ***railway station building*** has architectural qualities representing the national romantic style and Astrup's regionally inspired architecture in keeping with the location. The station building was constructed of cog-jointed round timber and its first floor has cantilevered joists with a built-in gallery towards the north. The barge boards have carved decor at the ends and there are spires over the porch and at the ridge of the gable ends. Turned poles flank the main entrance and the northern gable wall, which also has decorated barge boards in the cantilevered gallery. The gallery has decorated wall planks.

The outhouse was architecturally designed to match the station building and functioned as a privy and wood shed. The building has stud walls with horizontal timber cladding. The pitched roof has flat red brick roofing tiles, gable spires with a pendant and barge boards with carved décor at the ends. The vertical cladding on either end also has a carved décor.

The freight house and ramp are situated immediately to the north of the railway station building. It has clad stud walls, a pitched roof with the original red clay roof tiles with wide eaves and gable spires. The layout has mainly been preserved, but part of the ground floor interior was refurbished with a waiting room and resting lounge in 1952. The freight houses at Notodden (old station), Tinnoset, Mæl and Rjukan stations were originally identical. Today, only Tinnoset has retained what is virtually its original appearance.

Changes: The pitched roof on the station building was originally turfed, while the porches had slate roofing. Since then, the turf has been replaced by slate. The doors and windows are original. The windows have multiple small window panes, moulded frames and shutters. The general arrangement and characteristics of the interior have largely been retained, even though some modifications were made in the early 1950s and also in the 1990s.

Function today: None.

Tinnoset Railway Station with three buildings, the outhouse in front. Photo: Per Berntsen

11. The Rjukan Line

11.1 Railway track with signalling system and overhead line equipment

The Rjukanbanen Line with Gaustatoppen in 1935 and today. Left photo: Anders B. Wilse. Right photo: Trond Taugbøl.

Built: 1909

Function: Transport of artificial fertilizer and other products from Hydro's factories in Rjukan to the world market, and transportation of raw materials etc. for use in the production in Rjukan. General transport of passengers and goods to and from Rjukan and Vestfjorddalen.

Description: The Rjukan Line runs a distance of 16 km from the ferry quay at Mæl to Rjukan railway station. It climbs a total of approximately 120 metres and the steepest gradient is 1.8%. The minimum curve radius is 180 metres, and the original rail weight was 25.0 kg/m, designed to support axle loads of 10 tonnes. The rails have subsequently been reinforced, first to 35 kg/m and then to 49 kg/m. Some sections, including Rjukan railway station, still have rails of 35 kg/m dating back to the 1920s. There was also an extensive track system inside Hydro's factory area, with a total length of almost 20 km.

The railway has nine bridges with an aggregate length of 117 metres. The longest are Miland Bridge and Mæland Bridge, both crossing the Måna river. They are truss bridges of the same type as Gaupesprang Bridge across the Tinnelva river. The only tunnel is the Såheim tunnel, which runs through the power station. There are six level crossings with interlocking systems, and 55 level crossings without such systems. The railway line has no block system. A 2 metre-high and approximately 350-metre-long windbreak wall was built at Miland after gusting winds had blown some wagons off the track in 1926. Rjukan station has a turntable.

Overview of tunnels and bridges:

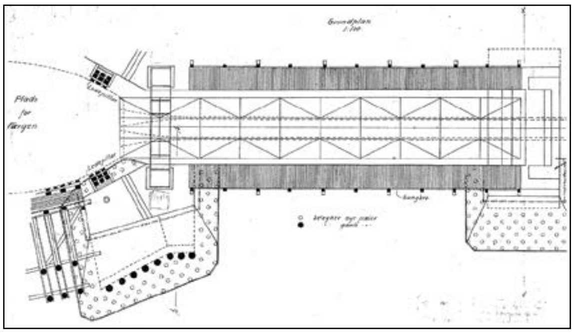
Name/place	Category	Length	Year built	Type
Miland	Bridge	41.4 m	1909	Riveted steel truss structure
Mæland	Bridge	41.4 m	1909	Riveted steel truss structure
Såheim	Tunnel	240 m	1912	With rest lodge

Changes: The Rjukan Line follows its original route, with the exception of some minor changes that were made in 1912 when Såheim Power Plant was built. From 1966, the axle load was increased to 18 tonnes and later to 22.5 tonnes. The rails for the Vemork railway track have been removed.

Function today: Museum railway, for which the Norwegian Industrial Workers Museum at Vemork is responsible.

The ***overhead line equipment*** includes what are largely original masts and portals from 1911, though some replacements were made in the 1960s. The system was erected with steel masts of types B and H along the open track, with portals at the stations. The system was modernised for the first time in the 1930s. Today's overhead line equipment was installed at the time of the changeover from 10 kV to 15 kV with 16 ⅔ Hz alternating current that was completed in 1966. There are two booster transformers along the track. The whole line is divided into sections with manually operated disconnect switches. All masts are earthed directly to the rails. Two converters were installed in the western extension to Furnace House I. A third converter was put into place in 1913. One of the converters at Svælgfos was moved to Såheim in 1958 and took over the supply of power for the Rjukan Line.

11.2 Tinnoset Ferry Quay with six buildings



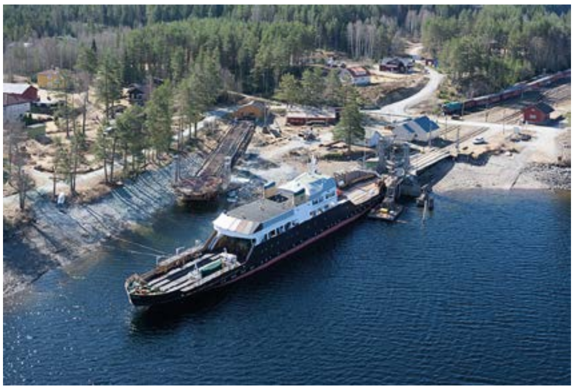
Drawing from 1908 of Tinnoset Ferry Quay to the left and the Quay in the 1950's to the right.
Both: Norwegian Industrial Workers Museum.

Built: 1909

Function: Link between railway and railway ferries.

Description: The Ferry Quay comprises a number of different elements. There is a ***ferry landing*** consisting of a riveted iron substructure that is lifted according to the water level, and a superstructure consisting of wooden planks with one set of tracks that divides into two at the ferry end. It rests on foundations of concrete and natural stone at the shore end. The ferry landing has a gangway along each side, with old iron rails and more recent lamp posts. The handrailing for the eastern gangway has a box attached, which held the earthing rod for the overhead contact wire. During the early years, the western gangway was equipped with narrow gauge trolley rails. At the end of the gangways is a ***truss portal*** of riveted iron fitted with lanterns, wires, pulleys, insulators, weights etc. The portal is 7.5 metres wide and 9.2 metres high and supported by concrete foundations. Adjacent to the portal on the eastern side is a pertaining ***winch house*** with hoisting machinery.

The approximately 10-metre-long fender wall on the western side consists of wooden poles clad with vertical boards on the ferry side. Closest to the portal, it is made of concrete with wood cladding. The poles are supported by diagonal poles that rest against an underwater concrete wall. The top of the fender wall has old decking and wood railings. At the ferry end is a lantern from 1980, in the form of a steel pole with a green light at the top. Closest to the portal is a new water meter shed on concrete foundations, and a concrete bollard. The approximately 40-metre-long fender wall on the eastern side consists of a robust concrete wall with platforms at the outer end and steel poles with wooden cushions on the ferry side. The top of the fender wall has iron railings, a lantern from the 1980s in the form of an iron pole with a red light at the top, mooring ring and bollard. Furthest out on the top of the fender wall is a platform for filling fuel oil from the fuel oil pipe that runs along the fender wall. Extending from the fender wall are wooden poles with supports that rest against a concrete underwater wall.



Tinnoset Ferry Quay today. Left photo: Per Berntsen. Right photo: Trond Taugbøl.

In addition to the slipway with winch house *(object 11.3)* the ferry quay has six other buildings. There is a tank facility for filling fuel oil, a small boiler house for heating the oil, a combined storage and workshop building, a combined storage and blacksmith's building, a rail warehouse and ***workmen's hut*** for those who worked on the ferry quay. These buildings were all erected in the 1950s, with the exception of parts of the storage and blacksmith's building, and the workmen's hut that was drawn by Thorvald Astrup and built in 1909. The general arrangement of the workmen's hut with its hipped roof was changed when it was refurbished in 1948.

The *tank facility at Tinnoset* was constructed in 1957 as a fuel oil facility for 'M/F Storegut'. It consists of a covered part with an opening for the railway track that carried the tank wagons, and a main part with *inter alia* two fuel oil tanks, two pump stations, gauge columns, ladders, control panel and lights, and a supported overground pipeline from the building to the platform for transferring fuel oil to the boats and ferries. The pumps were supplied by Brook Motors Ltd in England in 1936. The tank facility has concrete foundations and a framework of steel with profiled aluminium sheeting. The roofing was replaced by steel sheeting in around 2005. The part holding the rails rests on concrete pad foundations and a roof was built over it in 1977. There is an oil catchpit below the rails. A fuel oil pipe runs from the northern façade and down to the platform. The pipe rests on iron supports with concrete foundations.

The *boiler house* contained a steam boiler for heating the oil. The building is probably from the 1950s and is currently used for storage. It has a mono-pitched roof with felt roofing, fibre cement cladding with wooden corner boards, and concrete foundations with a ramp leading up to the door on the western side.

The *storage and workshop building* is probably from the 1950s. It measures 13x6 metres and is erected on a concrete slab, with fibre cement wall cladding and wooden corner boards, and a pitched, felted roof. The building consists of two main wings: a western wing with storage space and a small office, and an eastern wing with storage space and a workshop in addition to a room for fire-fighting equipment.

The *storage and blacksmith's building* is in three parts, with the blacksmith's workshop furthest east, storage space and an office in the middle, and the paint stores furthest west. The history of this building is complex and unclear. The western part appears to be the oldest. The building measures 23.7x4.15 metres and, at the north-facing front of the building, there is a roofed concrete slab. The building has stud walls with horizontal timber cladding. It has a mono-pitched corrugated iron roof with a metal-sheet chimney above the smithy.

The *rail warehouse* is from the 1950s. It is a 12x3,8 metre superstructure without a floor, resting on ten timber columns (five on each side). It has stud walls and a rafter roof structure with diagonal supports at each gable. The exterior walls have raw wooden cladding with vertical corner boards. Half the gable end towards the north is open. The building has a corrugated iron mono-pitched roof.'

Changes: The ferry quay has been upgraded, reinforced and modified several times. The winch house was extended eastwards in 1963–1964 and refurbished with new concrete foundations at the same time as new brakes were installed for the hoisting machinery. At the same time, it was also extended southwards to include a waiting room for shift crew. The hoisting machinery was originally protected by a half-roof, but was fully enclosed in around 1920. New hoisting machinery from A.C. Smith & Co AS in Oslo was installed in 1959 and reinforced in 1980. The fender walls extending from the foundations for the portal were originally of timber, but have been rebuilt using concrete.

Function today: Part of the Rjukan Line museum railway, for which the Norwegian Industrial Workers Museum at Vemork is responsible.

11.3 Tinnoset Slipway with winch house

Tinnoset Slipway. Left photo: Per Berntsen. Right photo: Trond Taugbøl.

Built: 1909

Function: Vessel overhauls and repairs.

Description: The slipway lies just east of the ferry quay. The first slipway was 110 metres long with a gradient of 1:10. The slipway is made of hand-riveted iron, and includes, *inter alia*, a slipway wagon, stay bars, a rolling frame, rails, wooden keel blocks (pads) and four inspection towers. Three of the inspection towers are made of hand-riveted iron, with ladders and platforms on three levels. One inspection tower is made of timber and has only one level with ladder and platform. The slipway has a 161-metre-long rolling track that runs into the sea at a gradient of 1:12. It rests on wooden sleepers and concrete pillars, and has new concrete foundations at the end nearest the winch house. The rolling track holds an approximately 113-metre-long rolling frame with an approximately 76-metre-long slipway wagon on top. These are pulled along the rolling track by a winch-operated wire rope. There is also an auxiliary winch operated by compressed air. The design and position of the slipway is from around 1915, but many parts and elements have been replaced and upgraded since then.

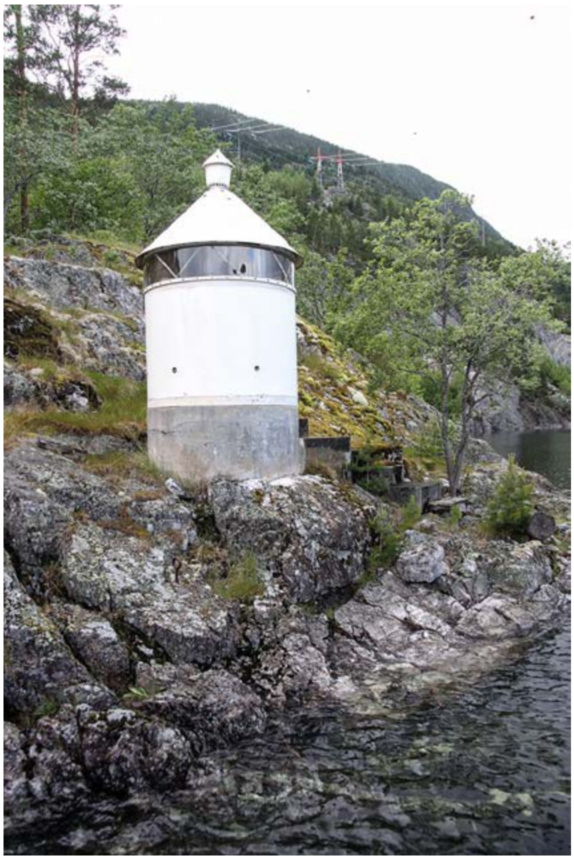
A new winch house was built 19 metres further in from the shore in 1914. The current winch house has concrete foundations and walls of rendered brick. It has a pitched roof structure of iron. Next to an iron gate with a concrete ramp, a hand-riveted circular air tank (for compressed air) is fastened to the wall with a rod, from which a pipe runs into the building. It is marked as having been supplied by Hartmann in Kristiania (Oslo). The winch house consists of three main rooms with the compressors furthest south, a workshop in the middle room and a winch room furthest north. The winch room contains electrically powered drums with winch cables and cog wheels, all marked as having been supplied by Brown Boveri, Norsk Elektricitets Aktieselskab, Christiania (Oslo). The winch room has an open ceiling up to the corrugated iron roofing.

Changes: The slipway was refurbished in 1931, with new foundations, new rails, extension of the slipway wagon by 15 metres to a total length of 60 metres, a new block wagon running on a separate track and alterations to the hauling winch. When 'M/F Storegut' was built in 1956, the slipway wagon and the underlying rolling frame were extended by 10 metres and the keel blocks were modified; and in 1955, the slipway was extended by 10 metres, the crane track by 15 metres and the slipway wagon by 14 metres. Changes were made to the sighting tower in 1961. While vessels were docked here during the period 1969–1971, reinforcement and repair work were carried out.

The current winch house was built of brick in 1937 when the old one from 1914 was struck by lightning and lost to fire. A plate on the building marks it as the Rjukan Line's building no 5. It has a wooden extension from around 1960.

Function today: Part of the Rjukan Line museum railway, for which the Norwegian Industrial Workers Museum at Vemork is responsible.

11.4 Lighthouses along Tinnsjøen lake



The two types of lighthouses. The oldest one from 1908 on the left with transport chute in front, and the newer one from 1962 on the right. Both photos: Eystein M. Andersen.

Built: 1908/1939/1962

Function: Navigation marks for the ferries.

Description: Ten of the original eleven lighthouses along Tinnsjøen lake are still in place. Standard lighthouse types were drawn for Hydro in 1908 and 1962. The earliest type is octagonal with approximately 50 cm wide panels and a base of 1.34 m^2. The height is 178 cm to the windows and 240 cm to the eaves. The interior height is 3 metres. It consists of a framework clad with boards that are painted white, and the windows slant out toward the roof. The windows are approximately 40 cm high, 45 cm wide at the base and 65 cm wide at the top. The roof is covered in galvanised metal sheets painted red and has a vent pipe. The lighthouse has a single board-clad door leaf. The type installed after 1962 is made of plastic, cast in one piece and erected on concrete foundations on a rock base.

It has a 1.8 metre wide circular base, a height of 1.9 metres under the eaves and a vertical curved row of eight window panes divided by muntins. All the lighthouse lamps run on acetylene. The gas cylinders were brought by boat. Several of the lighthouses are at some distance from the lake and have transport chutes for the gas cylinders. The supported iron chutes were probably built in the 1960s.

Tinnoset lighthouse at the approach to Tinnoset was erected in 1939 and is an octagonal cast iron structure with a diameter of 1.7 metres and a height of 1.8 metres to the underside of the windows. The windows slant out towards the roof. An iron ladder provides access to the lighthouse. The roof is covered in galvanised metal sheets painted red and has a vent pipe on top. The lighthouse has its own hoisting device made of round iron bars for hoisting gas cylinders. The iron rack for the gas apparatus, two brackets for holding gas cylinders and a venting hood have been preserved inside the lighthouse. The gas apparatus (lamp) has been preserved, but was temporarily removed to be repaired in 2011.

Brennemo beacon is a 3 metre high signal beacon erected in 1962. It had white, green and red sectors. It is a steel structure made of four diagonal angle bars, with the beacon mounted on a checker plate at the top. A hoisting device for gas cylinders is attached to the top. A wooden box with a gauge and two pipes for acetylene cylinders are attached to the back. The whole structure is placed around some concrete foundations. Around 1970, the beacon was moved further inland after a landslide.

Raua lighthouse is of the new type that was introduced in 1962. It was erected in 1962 and flashed every five seconds, with white and red sectors and one green sector. A metal rack and a shelf for the gas apparatus, the gas apparatus (lamp), a gauge and two pipes for the acetylene gas cylinders, red and green glass panes and a venting hood have been preserved inside. An iron ladder provides access to the lighthouse from the lake.

Fanteneset lighthouse belongs to Hydro's earliest standard type from 1908. It was erected in 1908 and flashed every five seconds, with two red sectors. A shelf for the gas apparatus, two pipes for acetylene cylinders and a venting hood have been preserved inside. The gas apparatus (lamp) and other equipment are gone. In addition to the lighthouse, an approximately 15-metre-long chute to the lake has also been preserved, which was used for transporting gas cylinders.

Dalen lighthouse is of the new type that was introduced in 1962. It was erected in 1962 and is similar to Raua. A metal rack and a shelf for the gas apparatus, a gauge and two pipes for the acetylene gas cylinders, red glass panes and a venting hood have been preserved inside. The gas apparatus (lamp) and other equipment are gone.

Stangodden lighthouse belongs to Hydro's earliest standard type from 1908. It was erected in 1908 and flashed every five seconds. A shelf for the gas apparatus, two pipes for acetylene cylinders and a venting hood have been preserved inside. The gas apparatus (lamp) and other equipment are gone. In addition to the lighthouse, an approximately 11-metre-long chute to the lake has also been preserved, which was used for transporting gas cylinders.

Langøya lighthouse belongs to Hydro's earliest standard type from 1908. It was erected in 1908 and flashed every five seconds. The gas apparatus (lamp), a shelf for the gas apparatus, two pipes for acetylene cylinders, a venting hood and retainers for coloured glass panes have been preserved inside. In addition to the lighthouse, an approximately

10-metre-long chute to the lake has also been preserved, which was used for transporting gas cylinders.

Ormsodden lighthouse belongs to the earliest standard type from 1908. It was erected in 1908 and flashed every five seconds, with red sectors along the shoreline. The gas apparatus (lamp), a shelf for the gas apparatus, a gauge and two pipes for acetylene cylinders, a venting hood and retainers for coloured glass panes have been preserved inside. In addition to the lighthouse, an approximately 14-metre-long chute to the lake has also been preserved, which was used for transporting gas cylinders.

Urdalsodden lighthouse belongs to the earliest standard type from 1908. It was erected in 1911 and flashed every six seconds, with red sectors along the shoreline. The gas apparatus (lamp), a shelf for the gas apparatus, a gauge and two pipes for acetylene cylinders, a venting hood and retainers for coloured glass panes have been preserved inside. In addition to the lighthouse, an approximately 11-metre-long chute to the lake has also been preserved, which was used for transporting gas cylinders.

Håkanes lighthouse at the approach to Vestfjorden is of the earliest standard type from 1908. It was erected in 1908 and flashed every five seconds, with red and white sectors. It is erected on concrete foundations on a rock base. The gas apparatus (lamp), a shelf for the gas apparatus, a gauge and two pipes for acetylene cylinders, a venting hood and coloured glass panes and their retainers have been preserved inside.

Changes: Gas apparatuses marked 'System ASA Dalen' were procured from Sweden in 1936 for Tinnoset and the four northernmost lighthouses (Langøya, Ormsodden, Urdalsodden and Håkanes).

Function today: Part of the Rjukan Line museum railway, for which the Norwegian Industrial Workers Museum at Vemork is responsible.

11.5 Mæl Ferry Quay

Mæl Ferry Quay. Left photo: Eystein M. Andersen. Right photo: Trond Taugbøl.

Built: 1909.

Function: Link between railway and railway ferries.

Description: The Ferry Quay comprises a number of different elements. The ferry landing is of the same type and construction as Tinnoset, supported by concrete foundations on the shore side. The gangway rests on wooden poles, but is otherwise identical to the

Mæl Ferry Quay around 1920. Photo: Anders B. Wilse.

one at Tinnoset. A box for the earthing rod for the overhead contact wire is fastened to the railings along the northern gangway. The truss portal of riveted iron with lanterns, insulators etc. are identical to the one at Tinnoset. The portal has fog lights installed, and these were modified to provide stronger light in 1971. The winch house and hoisting machinery are on the northern side of the portal.

On top of the northern fender wall are old iron railings, a flag pole, bollard and lantern (green). The lantern is trapezium-shaped, approximately two meters high and made of riveted iron. It is painted green and has a flashing light on top. The approximately 40-metre-long supporting structure on the southern side is reinforced with built-in wooden poles. On this side, the railings are of more recent date. On top of the fender wall is a lantern (red) corresponding to the one on the northern wall and two bollards.

Changes: Upgraded, reinforced and modified several times, the first time as early as 1913. In the fender wall extending from the portal foundations, timber was probably replaced by concrete after 1950. The winch house was upgraded and given a new appearance in 1963, at the same time as the winch house at Tinnoset.

Function today: Part of the Rjukan Line museum railway, for which the Norwegian Industrial Workers Museum at Vemork is responsible.

11.6 *Mæl Railway Station with four buildings*

Mæl railway station building in 1925 and today. Left photo: Anders B. Wilse. Right photo: Trond Taugbøl.

Built: 1909/1917

Architect: Thorvald Astrup.

Function: Service office with waiting room, stationmaster's house and freight house.

Description: Mæl railway station has several buildings. The ***stationmaster's house*** was drawn as a station building for the opening in 1909. It was refurbished as a stationmaster's house in 1917 when the station received a new station building, also drawn by Astrup. The building has two storeys, and a hipped roof with two dormers and one extension, all with slate roofing.

Mæl railway station seen from Tinnsjøen lake. Photo: Eystein M. Andersen

The ***station building*** was drawn in 1916 and was completed the following year. It replaced the old station building from 1909. The building was placed on the opposite side of the railway track, and the logistics around the station were thus changed. Details of both the exterior and the interior decor are preserved, including Art Nouveau ornamentation on barge boards and columns. The service office on the ground floor has a service hatch with desk and ticket-stamping machine, ticket cabinet and wall clock, in addition to a writing desk from the 1960s with the signal board for Mæl station. The building was restored in 1993.

The ***freight house*** was originally of the same type as the ones in Rjukan, Tinnoset and Notodden, drawn by Thorvald Astrup i 1908. The middle part of the building with gates on both sides is probably original.

Changes: The stationmaster's house has been modified and altered several times. The interior was completely renovated in the 1960s. The original general arrangement plan has not been preserved. The building remains in its original position and has largely retained its shape, and some architectural details have been preserved.

In 1959, the middle part of what was originally an open gallery outside the waiting room and service office was enclosed to form a hallway.

The freight house was originally next to the stationmaster's house, but was moved to its current position in 1943 when it was also altered and extended to appear as it does today.

Function today: Part of the Rjukan Line museum railway, for which the Norwegian Industrial Workers Museum at Vemork is responsible.

11.7 Mælsvingen 10–15 with five houses

Mælsvingen mid 20th century and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Trond Taugbøl.

Built: 1914 (approximately)

Architect: Ove Bang

Function: Houses for employees connected to Hydro's transport activities.

Description: Adjacent to Mæl Ferry Quay and Mæl Railway Station, a number of family housing units were built for those who operated the ferry system. Mæl was a strategic hub in Hydro's transport system, which was operated by the subsidiary Norsk Transportaktieselskab. The company operated two railway sections with an aggregate track length of more than 50 km and one ferry section with several vessels. The system comprised both goods and passenger transport. A considerable workforce was therefore needed.

A group of five multi-family wooden houses of two different types clearly illustrate that this was part of the town housing that Norsk Hydro built for its employees. Each house has two storeys and contains four flats. The architect Bang has given them a shape that is reminiscent of traditional large farms, while panels and carved details bear witness to contemporary ideals at the time when they were built. At Mæl there are also a number of smaller houses of Hydro's catalogue types. They have been modified to different degrees, but still give a feel of their origins as Hydro houses.

Changes: The exterior remains largely unchanged.

Function today: Housing.

11.8 Ingolfsland railway station building

Ingolfsland railway station in 1919 and today. Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1919

Architect: Thorvald Astrup.

Function: Service office with waiting room, goods storage room and station mater's apartment.

Description: Of rendered brick, this is the only brick station building along the Rjukan Line. Astrup was responsible for all the building's details, including the exterior lamps. From the balcony on the eastern gable a 13-metre-long extension with a pitched roof leads to a square privy house with a pyramidal roof.

Changes: The roofing has been replaced and the two chimneys have been removed. The intermediate structure, which was originally just a roof over some benches and open at the sides was walled in in the 1960s.

Function today: Meeting premises.

11.9 Rjukan railway station building, freight house and engine shed

Rjukan railway station in 1910 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen

Built: 1909/approx. 1920 /1926–1927

Architect: Thorvald Astrup

Function: Service office with waiting room, stationmaster's house and freight house. Engine shed and wagon repair shop.

Description: In addition to the station house, Rjukan railway station has several other buildings. The first freight house in Rjukan, drawn by Thorvald Astrup and erected in 1909, quickly became too small, and a new and considerably larger freight house was built up against the western gable of the old one in around 1920. A small engine shed was built as early as 1910, but was replaced by the engine shed at Såheim in 1916 *(object 11.10).* The engine shed at Rjukan Railway Station was built in 1926–1927, when the Rjukan Line's main workshop was moved from Notodden to Rjukan and the engine shed at Såheim was converted to become part of the hydrogen plant at the time of the transition to the Haber-Bosch method.

The ***railway station building*** (1909) has two storeys and was originally equivalent to the one at Mæl. The clad façades were framed in the Classicist style and had horizontal ribbon friezes.

The ***freight house*** (1920) has stud walls and rests on concrete pillars and a joint natural-stone foundation wall. It has a hoist gable on the northern and southern sides. There is a wide concrete ramp on the western side, a small concrete ramp on the eastern side, a timber ramp on the northern side and a corresponding enclosed timber ramp on the southern side.

The ***engine shed*** (1926–1927) lies a little further to the west. It includes a wagon repair shop. The building measures 25x87 metres and consists of two adjoined main parts: with the engine shed to the west and what used to be an iron warehouse extending from it to the east. The building has a low pitched roof and rests on concrete foundations. The engine shed part consists of an older southern part with a northern extension from 1963. The oldest part is of concrete and has seven tall windows with iron glazing bars, and two external steel gates. The interior space is the full height of the building and is divided into two by a similar set of gates. It has two tracks, four pits and venting hoods.

Changes: The station building has been altered and modified several times, but has retained its main design. The separate privy house, corresponding to the one at Tinnoset, has been demolished, and new facilities have been installed in a building with a hipped roof extending from the station building's eastern wall. The building was damaged during a bomb attack in 1943, after which some alterations were made. An extension for the signal box was built as part of alterations made in 1963. The desk with the signal board for the whole station has been preserved. The general arrangement on the ground floor is from the 1960s and includes a waiting room, lunch room and cafeteria. The general arrangement of the stationmaster's apartment on the first floor has been changed.

The freight house has been altered and an extension added. The oldest part was demolished in 1930 and replaced by a new extension. Between 1960 and 1963, the freight house was extended towards the west, and the loading ramp on the western side and the two hoist gables were built. In the 1990s, the ramp along the southern façade was enclosed to form a corridor. The extensions to the west and east have concrete foundations. The track closest to the freight house has been removed.

Rjukan engine shed in the 1950's and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen

The engine shed was extended to the north in 1963, using pre-fabricated concrete elements. The extension has two iron gates, two railway tracks and four pits. Iron gates lead from the southern track to the iron warehouse, thus providing a third main space for the locomotives. The latter room has one track, a travelling crane and a narrow gauge service track. The ceiling of this room is formed by the iron warehouse's iron beams.

Function today: Museum site. There is a radio studio on the first floor of the station building. Rolling stock is kept in the engine shed.

11.10 Såheim engine shed

Rjukan engine shed in the 1950's and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen

Built: 1916–1918.

Architect: Thorvald Astrup.

Function: Engine shed and wagon repair shop. From 1928, part of the Hydrogen Plant *(object 8.6).*

Description: As it stands today, this is a building of concrete and brick measuring 56x14 metres, with both a flat and a mansard roof. The western end is adjoined to the adjacent building. The walls facing south and west have tall arched windows with iron glazing bars, separated by pilasters. Inside, the large area holding the repair workshop and engine shed with through light (north–south), is largely intact with its visible structures. Architecturally, the long building is akin to the historicist style locomotive and tram sheds from the first decades of the 20^{th} century. The long building housing the workshop and engine shed, which were separated by a row of columns, was terminated by taller sections with pitched roofs at either end to the east and west. Originally the building had two arched gates on the western façade, one for the engine shed with the flat roof to the south and one for the workshop with its taller mansard roof to the north. The railway-architectural features have largely been preserved in the engine shed, particularly along the sides and inside the main shed.

Changes: Around 1930, the engine shed and repair shop functions were wound up, and the building was converted to a facility for the use of Hydro's ammonia method (water distillation plant) *(see object 8.6).* The building was altered at both ends, so that the roofs became flat and some of the arched windows were removed from the eastern part which was converted to offices etc. with new windows and doors in several places, and the western end was adjoined to the new hydrogen plant. The exterior walls have recently been insulated and clad with rendered wall panels fastened with bolts.

Function today: Small industry, mechanical workshop.

Vemork railway track in 1911 to the left and the 1950's to the right.
Left photo: Anders B. Wilse. Right photo: Norwegian Industrial Workers Museum.

Built: 1908

Function: Internal transport of goods to Vemork Power Plant. As early as 1908, the track was used for transporting turbine pipe, plant, equipment and materials for building Vemork Power Plant *(objects 3.1–3.3).* It was later used during the construction of the hydrogen plant in 1928 and the new power plant in 1970.

Description: The Vemork railway track was a 5.2 km-long siding that ran from the railway station area in Rjukan to Vemork Power Plant 560 masl. It was the steepest track in Norway with a gradient of 55,6 ‰ and a minimum curve radius of 56 metres. The line was blasted out from the north-facing valley-side and is highly prone to landslides. One kilometre south of Vemork, a 72-metre-long superstructure has been built to protect against landslides. The track forks at Vemork Power Plant, with one track leading to the back of the old power station between the main station building and the penstock, and one track running into the new power station and ending underground in the turbine hall. The crane from 1910 that was used for lifting turbine pipe off the wagons is still in place between the main power station building and the penstock. Going down from inside the power station, approximately 250 metres of track have been preserved. Sporadic remnants of railway-technical installations can be observed along the line.

Vemork railway track today.
Photo: Eystein M. Andersen.

Changes: Much of the track, along with other railway installations, was demolished when it was closed down in 1991. Some elements have been preserved, however. The line was cleared and upgraded with gravel to support heavy vehicles in 2011/2012.

Function today: The section is used as the only access route for heavy goods transport to Vemork Power Plant, for example during Hydro Energi's ongoing upgrade of the power plants along the Måna river. Other access is via a suspension bridge which is unable to support heavy loads.

11.12 Rolling stock with 16 units

Electric locomotive no 9 in the 1950's and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Trond Taugbøl.

Built: 1908–1954

Function: Traction power and transport units for moving goods to and from Hydro's calcium nitrate plants and passengers to and from the urban community in the Vestfjorddalen valley.

Description: A considerable part of the Rjukan Line's rolling stock has been preserved and is owned by Norwegian Industrial Workers Museum. The nomination proposal includes sixteen selected units of this stock. This is rolling stock stationed on the Rjukan Line, protected by law together with and as part of that line, which includes Tinnoset. The rolling stock is protected as permanent fixtures, as the railway section is physically separated from the rest of Norway's railway network by the Tinnsjøen lake. The protection order includes the following units of rolling stock:

Two electric locomotives, RjB Nos 9 and 10, built by Secheron in Geneva in Switzerland (electrical supplier) and Jung in Germany (mechanical supplier). These are 13.15-metre-long four-axled bogie locomotives weighing 60 tonnes with an axle load of 4x15 tonnes, an engine power of 1 080 hp/794 kW, starting tractive effort of 176.6 kN and a maximum speed of 55 km/h. They were prepared for the conversion from 11 to 15 kV that took place in 1966.

Two passenger coaches constructed by Skabo Jernbanevognfabrikk A/S for the opening of the line are included. Type B No 1 from 1908, a two-axled 10-metre-long second class railway coach (Type B) with toilets in the middle, weighing 7.6 tonnes. It was converted to an open saloon coach in the 1930s, was used internally from 1953 and later became a maintenance wagon for the overhead line system. Passenger coach ***C No 5*** was constructed in 1910 as a two-axled third-class coach (Type C). The coach body was completely destroyed by fire in 1917, and was replaced by two second-hand trailer vehicle bodies from the Holmenkollen Line in Oslo, which were placed one after the other and widened. In the 1950s the coach was put to use as a mobile worker's hut for the Rjukan Line's track department.

Eleven goods wagons are included. Together with the ammonia wagons, the Types L4 and Lo3 wagons made up the majority of the wagons that travelled to and from Herøya. L4 214 was built in Germany and is one of 646 such wagons that were sold to Norway during World War I because of the wagon shortage. The Rjukan Line took delivery of 50 such wagons in 1919. The wagon was being used to transport limestone and calcium nitrate. It is a high-sided open box wagon (Type L) with an iron frame and horizontal timber cladding. The wagon is the only one of its kind to have been preserved in Norway. ***Lo3 144*** was built by Skabo Jernbanevognfabrikk A/S in 1914 and was one of a series of 24 such wagons. It was used *inter alia* to transport limestone and calcium nitrate. It is a high-sided bogie box wagon (Type Lo) with a load capacity of 32.5 tonnes. ***Tsfo 76*** was built by Skabo Jernbanevognfabrikk A/S in Oslo in 1928. It was procured to transport synthesis furnaces and transformers. It is a purpose-built piggyback wagon with eight axles for transporting large and heavy goods (Type Tsfo = platform wagon, purpose-built wagon, brake house, bogie wagon). It weighs 29.5 tonnes, is 18.3 metres long and can carry loads of up to 80 tonnes. In its time, it was Europe's biggest goods wagon. ***Tso 75*** was built by Skabo Jernbanevognfabrikk A/S in 1909 and procured to transport large and heavy goods. It is a four-axled purpose-built piggyback wagon with stanchions for securing the load (Type Tso). ***G3 174*** was built by Skabo Jernbanevognfabrikk A/S in 1914. It was procured to transport miscellaneous goods. It is a two-axled enclosed goods wagon of NSB's standard type (Type G3) for 12 tonne axle loads, with vertical timber cladding and a sliding door on each side. The wagon has a 3.66-metre-long wheel-base and a usable space of 34 m^3. It is one of three wagons of this type that have been preserved from the Rjukan Line.

Tank wagon for ammonia.
Photo: Eystein M. Andersen

Tank wagon Q3 55 is an old, two-axled goods wagon of the M type, constructed for the Rjukan Line by A/S Strømmen Værksted in 1908. It was rebuilt in 1916 when the superstructure was removed and a riveted iron tank for sodium hydroxide solution (NaOH) was installed on top of the frame (Type Q2). The tank was later replaced by a bigger one, and the 112 hl lank that we see today was installed in 1940. At the same time, the frame was extended by 70 cm and supporting brackets were mounted at each end. The wagon has been used internally for spraying herbicides and transporting transformer oil. The ***Q4 307*** and ***Q4 310*** tank wagons were procured from Skabo Jernbanevognfabrikk A/S in 1948 to carry ammonia between Rjukan and Herøya. This type of wagon was a fixed part of the integral trains for bulk goods. It weighs 16.8 tonnes and the tank has a usable space of 18 m^3. The tank is of iron and can be removed to be transported by barge from Notodden to Herøya. ***Tank wagon Zckk 722 5121-5*** was bought second-hand from the Swedish company Korsnäs to carry concentrated nitric acid (HNO3) between Rjukan and Herøya. The tank was installed as new in 1966 and is of aluminium, which is resistant to concentrated nitric acid. The wagon went in as Type Q5 on the Rjukan Line, and got its present type designation and number in 1983. ***Refrigerated wagon Hso4 500 119*** was one of two purpose-built wagons that Norsk Hydro procured from Eidsfos Værk in Vestfold in 1954 to carry dry ice (carbon dioxide/CO_2). ***Hopper wagon Ø3 882*** is a two-axled hopper wagon for the transport and distribution of gravel for track maintenance. It was built on the undercarriage from Ls48 supplied by Skabo Jernbanevognfabrikk A/S in 1908 which had been used for bunkering coal on board the railway ferries. Ashore, the wagon was loaded with coal and driven on board the ferries where it was discharged into special hatches on deck. It was converted to a gravel wagon in 1964. Parts of the superstructure have riveted joints.

Flanger car RS 832 is of the old type that was hauled along the track. The undercarriage originates from a bolster wagon supplied by Skabo Jernbanevognfabrikk A/S in 1913. It was not registered on the Rjukan Line's rolling stock list and probably belonged to the calcium nitrate plant in Rjukan. It was converted to a flanger car for use on the Vemork track in 1935.

Changes: Some conversion and upgrading.

Function today: Museum pieces, part of the transport system for which the Norwegian Industrial Workers Museum at Vemork is responsible.

11.13 'D/F Ammonia'

D/F Ammonia after 1930 and today.
Left photo: Norwegian Industrial Workers Museum.
Right photo: Anders J. Steensen.

Built: 1929

Architect: Carl Conradi (interior)

Function: Railway ferry for transportation of railway wagons and coaches carrying goods and passengers.

Description: 'D/F Ammonia' is a double-screw railway ferry of riveted steel built by A/S Moss Verft og Dokk and assembled on a temporary bedding at Tinnoset. She is 230.6 ft long, 35.2 ft wide and has a draught of 12.8 ft. She has a gross tonnage of 929.34 and a net tonnage of 339.14. With 120 metres of track on board, she has room for 16 or 17 railway wagons. She can carry deck loads of up to 630 tonnes. At the same time, she could also carry 150 passengers, but the lounges have seating for 250 passengers. Two 450 hp triple-expansion steam engines are used for propulsion, and she had a cruising speed of 12 knots.

'D/F Ammonia' was ordered as a consequence of the increased need for transport following the expansion of the calcium nitrate plant in Rjukan in 1928/1929. The ferry became the transport company's main ferry with first and second class lounges below deck: first class to starboard and second class to port, in addition to two ladies' lounges. The wheelhouse deck had two directors' lounges, a smoking lounge and a dining room, in addition

The lounge for Hydro's directors and important guests. Photo: Norwegian Industrial Workers Museum.

to another first-class lounge immediately behind the wheelhouse. 'D/F Ammonia' was considered a masterpiece in terms of interior decoration, with hand-cut glass panes in the doors and its bridge deck lounges that were lined with fine wood panelling. The furniture consisted of heavy black leather chairs and sofas. The architect Conradi died in 1930, and the Tinnsjø ferry was one of the last vessels he saw launched.

'D/F Ammonia' was retired in 1957 when the new ferry 'M/F Storegut' took over, but it was operated as a back-up ferry until 1991. Very little has been changed on board since the ferry was built. The hull has not sustained much damage from the fresh water. Most of the equipment and moveable items are intact, including furniture, crockery, tools, documents and manuals.

As a surviving steam-powered ferry, 'D/F Ammonia' is a rarity, also in global terms. Only three other such vessels exist: one in Germany (Stralsund) and two used for river crossings in Paraguay.

Changes: The lounges below deck have been combined into one. The single ladies' lounge has been converted to a galley with a kiosk for serving food to customers.

Function today: Museum vessel.

11.14 'M/F Storegut'

M/F Storegut in the 1960's and today. Left photo: Norwegian Industrial Workers Museum. Right photo: Trond Taugbøl.

Built: 1956

Function: Railway ferry for transportation of railway wagons and coaches carrying goods and passengers.

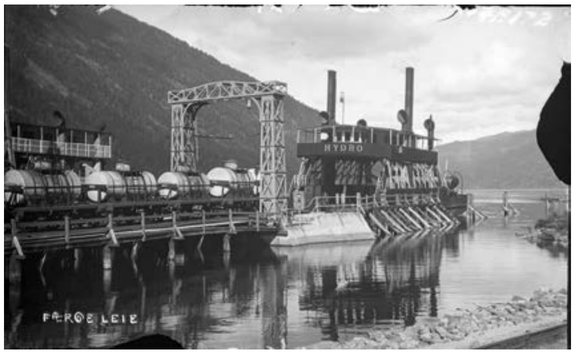
Description: 'M/F Storegut' was the biggest inland vessel in the Nordic countries. She is a triple-screw railway ferry built in steel as build no 150 by Glommens Mekaniske Verksted AS on the ferry slipway at Tinnoset. The wheelhouse is of aluminium. The ferry is 82.11 metres long, 11.31 metres wide and has a draught of 3.75 metres. She has a gross register tonnage of 1 119 grt. With 156 metres of track she had room for approximately 19 railway wagons. The maximum deck load was 800 tonnes. In addition, she could also carry 400 passengers. Three six-cylinder four-stroke diesel engines from Motoren Werke Mannheim are used for propulsion, each with an output of 750 hp. She sails with a speed of 13–14 knots with two engines running, and she can reach 18.5 knots when all three engines are in operation. The ferry was the first vessel in Norway to be equipped with bow thrusters.

'M/F Storegut' became the transport company's main ferry. She has lounges under the railway deck as well as on a separate lounge deck above the railway deck. The dining room and smoking lounge at the aft end of the upper lounge deck were previously reserved for Hydro's management and the company's visitors. The lounges below deck have stencil-painted Huntonit wall panels, while the other lounges feature veneer. The seating on board is made of nickel-plated steel pipe upholstered with artificial leather, with the exception of Hydro's lounges where the furniture is upholstered with fabric. The protection order includes large fixtures and fittings such as lifeboats, the reserve anchor, furniture, special tools and kitchen machinery.

Changes: Only minor changes have been made since the vessel was completed in 1956.

Function today: Museum vessel.

11.15 'D/F Hydro' – shipwreck

D/F Hydro before it was sunk in 1944. Photos: Norwegian Industrial Workers Museum.

Built: 1914.

Function: Railway ferry for transportation of railway wagons and coaches carrying goods and passengers.

Description: 'D/F Hydro' was a double-screw steam-powered railway ferry of steel, contracted by Norsk Hydro and built by A/S Akers Mekaniske Verksted in Kristiania (now Oslo). She had a gross register tonnage of 493.6 grt. The deck has 88 metres of track, providing room for 12 railway wagons. The maximum deck load was 300 tonnes. She could carry 120 passengers. Two 250 hp triple-expansion steam engines were used for propulsion. She had a cruising speed of 8 knots, but could manage 9.5 knots when pressed.

The ferry was sunk on 20 February 1944 during a sabotage operation against the German occupying force's transportation of heavy water from the factories in Rjukan to Germany with a view to developing nuclear weapons. Her position at 430 metres' depth in Tinnsjøen lake outside Perskås is known, and she is standing upright with her keel buried in mud about half-way up to the waterline. The bow is partly submerged in mud, but looks as if it is otherwise relatively complete. She has railway wagons on deck. Three barrels of heavy water were found approximately 60 metres from the side of the wreck. Two of these have been recovered. One is kept in the Norwegian Industrial Workers Museum at Vemork, while the other is said to have ended up in the USA. Nothing else has been removed from the wreck.

A memorial has been erected by the trunk road that runs along Tinnsjøen's western shore, directly ashore from where the ship was sunk.

Lying in fresh water, the wreck is remarkably well preserved. Photo: Thor Olav Sperre.

Urban communities, company town. Detailed description of buildings

The nominated urban areas include built-up areas that were developed at the same time as and in conjunction with the hydroelectric power plants and the plants for industrial production, and which, in Rjukan, form a complete company town and, in Notodden, constitute important parts of the town.

12. Notodden Hydro Town

In Notodden, the nomination proposal includes Norsk Hydro's housing developments of Grønnebyen and Villamoen with the Admini and Casino buildings, in addition to the Hydro Industrial Park. Grønnebyen was the first urban community developed purely for the workers. The other parts of the town lie in the World Heritage Site's buffer zone.

12.1 Grønnebyen (the 'Green Town')

To the left Grønnebyen seen from the Minaret in 1928. To the right Grønnebyen before 1920.
Photos: Norwegian Industrial Workers Museum.

Built: 1906–1911.

Architect: There is some uncertainty as to who was the architect for this house type that was designed for Hydro's planning office.

Function: Twenty-five two-family houses for the workers and three one-family houses furthest east for the factory area's caretakers.

Description: Wooden type houses (type J) for two families. They were built in a pine forest above the factory, and were originally green. The same house type was also used in Rjukan, in Flekkebyen (the 'Patch Town') and Rødbyen (the 'Red Town') *(objects 13.4 and 13.12)*, where the colours of the houses likewise gave rise to the names under which the areas were known. The buildings are relatively simple with few details, but with sound proportions. The plan drawings show a living room, kitchen and hall on the ground floor and bedrooms on the first floor. The houses are mostly grouped in rows and there are a few variations between them: The division between the housing units may be along the width or the length of the building, and the entrances may be on the same or different sides. The structure of the area, with a linear row of houses along three straight roadways, was set out in the town plan from 1904. The roadways with gravel surfacing are avenues lined with linden trees, which are cared for and pruned together. Some original elements such as lamp posts and litter bins can still be seen in the area.

Grønnebyen today. Photo. Trond Taugbøl.

Changes: When the houses were restored with insulation and new cladding in 1952, colour variations were introduced that were designed to allude to the rainbow. The work was initiated by Hydro with the assistance of architects. Outhouses were originally built for the housing units. These were replaced by garages with outdoor sheds during restoration work in the 1950s. The garages are in the same place as the original outhouses and have the same base area, and because they are of an identical type, the uniform character of the area is preserved.

Function today: Housing (detached houses).

12.2 Villamoen housing area

Villamoen at an early stage to the left and today on the right.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen

Built: 1908 – approximately 1918.

Architects: Helge E. Blix, Henning Kloumann and Carl Borch.

Function: Housing for administrative staff.

Description: The built-up area at Villamoen consists of varied housing in a planned structure with 17 houses located behind Hydro's own Admini building *(object 12.3).* The houses were built over a ten-year period along the Hydros gate, Villaveien, Lindalléen and Skogveien roads. Villamoen is situated on a terraced plateau above Grønnebyen, and was, on that basis, reserved for administrative staff and engineers who were considered to be of higher rank than the factory workers. The houses were therefore individually designed and several architects were involved. The houses were originally painted white, and they feature several of the contemporary styles: Art Nouveau, Baroque revival and Classicism. Some are tall with steep roofs, while others are more squat. Hydro built a total of 18 houses here, containing 23 housing units with a living space of between 200 and 250 m^2. The Cable House *(object 6.1)*, which was part of the transmission system for power from Svelgfoss to the Hydro Industrial Park, stands at the eastern flank of the housing area. Hydro bought Helsebo, Notodden's former hospital, and moved the building to Skogveien. Along Hydros gate in the western part of Villamoen, there are several religious assembly halls. They were built by the respective congregations. Parts of the built-up area are well preserved, and the double row of eight houses in the middle of the area is particularly illustrative of the planning initiative. The roadways consist of avenues lined by trees on both sides.

Changes: Some new houses have been built in the area, including some in the 1960s. Many of the original outhouses have been replaced by garages.

Function today: Housing.

12.3 The Admini (administration) building in Notodden

To the left a photo in color of Admini in Notodden in 1910 taken by Auguste Léon . To the right the building today. Photo: Per Berntsen.

Built: 1906.

Architect: Henning Kloumann.

Function: Hospitality premises, offices and residence for Sam Eyde during his stays in Notodden, lodgings for prominent guests.

Description: The imposing building stood on a head of land at the southern end of Villamoen, one level above Grønnebyen and overlooking the factory area at the lowest level down by Heddalsvatnet lake. The relationship between these elements reflects the old trisection from the first international phase of industrialisation: the factory – the workers' houses – the 'manor', and the buildings and their position in the landscape form a clearly decipherable structure that is a testimony to the phase during which Hydro first established itself in Notodden. The classical building has a grand, finite and symmetric structure, with a mansard roof and a temple-style gable over a tall central avant-corps that takes in the view towards the south. The windows and interior and exterior decorative details are in the Art Nouveau style. Excellent craftsmanship is found in the interior in the form of carved wooden columns and banisters, a soapstone fireplace and furniture with associations to the international Arts and Crafts Movement. The motifs are of national origin. The building is surrounded by a garden. Norsk Hydro used the Classicist vocabulary in its brand-building. With its reference to the elitist architecture of the residences of senior government officials as well as exclusive Italian manor houses, the Admini is a manifestation of Sam Eyde's wish to demonstrate that he was a man of both cultural and financial means.

Changes: Largely unchanged.

Function today: Hospitality and meeting premises for Norsk Hydro.

12.4 The Casino with four buildings

The Casino in Notodden. Photo: Trond Taugbøl.

Built: 1909.

Architect: Thorvald Astrup.

Function: Lodgings and posting station for visiting engineers and Notodden Salpeterverker A/S's staff on business trips.

Description: The complex was built as a guesthouse for the company's visitors who did not rank high enough to stay at Admini. The Casino became a gathering place for guests and visitors to the new factory facilities, and was also a posting station to and from which guests were brought by horse and carriole. The ground floor of the ***main building*** had three large lounges and two smaller rooms (a study with telephone and a room for the 'carriole boys'). The first floor had eight guest rooms, including two doubles, and rooms for the housekeeper and maid. The house also had a wine cellar. The wooden building has a hipped roof with dormers. The façade at the front of the house has Art Nouveau features. The western end has a large enclosed veranda and the supporting posts have acanthus leaf carvings. The Casino in Notodden has clear features in common with Admini in Rjukan, which was also drawn by Astrup. The Casino was formally owned by A/S Rjukanfos until the place was taken over by Hydro in 1918.

The complex includes an ***outhouse*** and two villas. The outhouse had stables, a wagon shed and a room where the carriole drivers could stay overnight. The ***northern villa*** had an engineers' mess over two storeys under a half-hipped roof, five bedrooms and a maid's room, in addition to lounges, a dining room and large kitchen with pantry. The ***southern villa*** was an imposing building, built for the German chief engineer (at the time of Hydro's and BASF's first joint industrial venture), who later demanded to have the same accommodation in Rjukan. The German engineer was probably Dr Scharff, posted as operations manager by BASF.

Changes: Interior refurbishment for change of use. The windows in the southern villa have been replaced with another type. The northern villa has new cladding, new roofing and new windows and doors.

Function today: The main building is today used for housing. The outhouse has garages and apartments. The villas are home to a kindergarten.

13. Rjukan Hydro Town

In Rjukan the nominated area includes Våer and Vemork in the west, the town centre from Krosso to Fjellveien and several sub-areas up to and including Tveito furthest east. The town continues into the Bjørkhaug – Dale area, which is of more recent date and excluded from the nomination proposal's time line.

13.1 Krosso housing area

Krosso housing area in 1920 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1919–1920.

Architect: Unknown.

Function: Workers' housing.

Description: Variants of building types 14 and 18 from Hydro's building catalogue were built along Fossoveien road at Krosso. The eight brick houses are positioned along a linear roadway with clear-cut building volumes. For visitors arriving by the main road from the west, this group of buildings is their first view of Rjukan Hydro Town, and the urban character of the large brick houses stands in marked contrast to the unbuilt natural landscape in the west.

Changes: Windows and chimneys have been replaced.

Function today: Housing.

The Krosso Aerial Cableway in the 1930's and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Hans-Dieter Fleger.

Built: 1927.

Architect: Adolf Bleichert AG.

Function: Gondola lift built as a welfare measure to bring the workers up into the sun during the winter season and improve access to the mountains in general.

Description: The Krosso Aerial Cableway was built by Norsk Hydro on the initiative of Sam Eyde, after a lengthy planning stage with much time spent on the drawing board. It was Northern Europe's first aerial cableway for passenger transport when it opened in January 1928. It is a suspended cableway, where the cables pass over a mast that divides the span into two spans of 744 and 70 metres, respectively. The upper station is Gvepseborg at 890 masl. With a vertical distance from the valley station of 495 metres, and a horizontal distance of 814 metres, the resultant gradient is 0.6:1. The cableway was built by the German company Adolf Bleichert AG. The cableway's machinery and other technical installations have been replaced. The winch stations at the top and bottom of the cableway are concrete structures with an almost Functionalist design. The cableway was operated by Norsk Hydro until October 1987, when Tinn Municipality took over. The red and blue gondolas ('Tyttebæret' – the Lingonberry, and 'Blåbæret' – the Blueberry) have been in operation since the cableway opened, except during the war and for a period between 1989 and 1991. A house known as the ***Gollner House***, named after the Austrian designer Stephan Gollner who lived there, is still in place by the upper cableway station.

Changes: The lower station has an annex of supporting value, with waiting room and toilets.

Function today: Gondola cableway. The Gollner House is visited by kindergartens and school classes on day trips.

13.3 Fjøset farm building with housing

Fjøset farm building with housing around 1930 and today. Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1915 /1916 – 1917

Architect: Bjarne Blom /Helge Blix.

Function: Animal husbandry to supply the population with milk and other food products. Housing for those who worked there.

Description: The Fjøset farm building and the three housing complexes were built when Hydro had to alleviate the milk shortage in Vestfjorddalen valley. When new, Fjøset was the biggest and most modern farm building in Norway. It had room for 160 cows and stabled 25 horses, and the basement had a pigsty with room for 70 pigs. Hydro had a similar project at Våer, with 15 cows. To begin with, animal husbandry was the responsibility of the Rjukan store, but the operation was eventually transferred to Rjukan Byanlæg. Feed for the animals was obtained from most of the green fields in Vestfjorddalen, in addition to what could be gathered on the pastures in the mountains. The Skardfoss marshes (around Skardfoss Dam) were cultivated and used as pasture, as were six hectares of land belonging to Øverland Farm (where Tinn Museum is located today). Hydro also bought a summer pasture farm known as 'Selskapssetra' (the Company summer pasture farm) up in the mountains by Klokshovd south of Vestfjorddalen. Milk and cheese were sent by a system of aerial cables down the mountainside and across the valley to Fjøset. The operation was closed down in 1934. A ramp used for carrying hay to the farm building leads straight from Stallbakken (the main road) and into the building.

The farm housing was built in 1916-1917 with 20 housing units for those who worked in Fjøset, and was used as bedsits with a canteen during a period of housing shortage at the time of the Rjukan II development at Såheim.

Changes: The interior of the farm building has been refurbished. The windows in the surrounding houses have been replaced.

Function today: Fjøset currently consists of premises for lease. The surrounding housing is used as housing.

Flekkebyen in colour in 1910. Photo: Auguste Léon.

Built: Approximately 1907–1919.

Architects: There is some uncertainty as to who was the architect behind the house type that we find in Flekkebyen. The architects Thorvald Astrup, Johannes E. Nielsen, Magnus Poulsson and, subsequently, Ove Bang were responsible for most of the villas in Villaveien.

Function: Houses for Hydro's high-ranking administrative staff and directors up in the valley side, and workers' housing down on the river plain. Villaveien No 5 was Rjukan's first infirmary.

Description: The area Flekkebyen – Villaveien with 71 buildings is like a Rjukan in miniature, and clearly illustrates the social and functional relationships of the early Rjukan community. The topography is used to mark the position of Hydro's various categories of employees on the social ladder. Directors, higher-ranking administrative staff and chief engineers were given houses with a garden up in the valley side, where they were favoured by the sun that came over the horizon for a much longer period of the year than down on the valley floor where the ordinary workers' housing was built.

Flekkebyen was the first workers' housing that was built in Rjukan (1907–1913), based on house type J, which was a variant of the type used in Grønnebyen in Notodden. Unlike in Notodden, varying colours were used from the very beginning during the construction period, giving rise to the name 'Flekkebyen' (Patchy Town). Twenty-four identical vertically divided two-family houses were built in a simple Art Nouveau style. More variants of the same type were added later. There was a great housing shortage during the development period, and, to save time, the houses were built without a cellar, though cellars were dug out at a later stage. The housing stock along Bråvollveien consists of various type houses from Hydro's catalogue.

Villaveien-Flekkebyen housing area around 1915 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

The housing stock along ***Villaveien*** is largely from before 1920, but includes more recent houses of supporting value. One Functionalist-style house from 1927 was drawn by the architect Ove Bang. Typical of the houses in Villaveien is their economical and finite shape, the steep roofs and their placement on levelled flat plots in steep terrain. The houses on the upper side of the road tend to have front gardens with supporting walls and stairs leading down to Villaveien. The houses are individually designed, which was the only socially acceptable thing to do for the town's upper class. Even though the houses have unique designs or were few in number, they are denoted by type number in Hydro Byanlæg's catalogue.

Astrup's and Nielsen's villas tend to be in a heavy, grand style – a cross between Classicism and Art Nouveau with some Baroque features. Magnus Poulsson, on the other hand, was inspired by the national Norwegian building tradition, and this was even more true of Ove Bang's romantic villas, which have features in common with *inter alia* the houses of high-ranking government officials in Western Norway.

Changes: Although most of the houses in Flekkebyen have been refurbished or altered, the uniform character of the area can still be clearly deciphered.

Function today: Housing.

13.5 The old town centre

The old town centre around 1915 and today. Left photo: Directorate for Cultural Heritage. Right photo: Per Berntsen.

Built: 1907–1923.

Architect: Thorvald Astrup, Levin et al.

Function: Rjukan's first commercial centre with chemist, bakery, butcher and general store for food, clothes and shoes. The latter was in its time Norway's biggest retail store, with up to 86 employees.

Description: The built-up area at Bråvoll consisted of six houses. After temporarily using a residential house, the ***Store*** moved into its own building in 1910, where there was also a cafeteria, restaurant and a few hotel rooms as well as an apartment for the manager. The Store had branches at Våer and Vemorktoppen, and at Møsvatn while the dam was being built. Hydro sold the Store in the mid-1920s. The ***post office and chemist's building***, drawn by the architect Levin, was completed in 1912. The ***butcher's shop*** on the other side of the street opened in 1923.

To the east of the post office and chemist's building lies Hydro's ***first 'Kasino'*** building, the 'office workers' mess', drawn by Thorvald Astrup in 1908, consisting of a mess, canteen and lodgings for people who worked on short-term assignments for Hydro and who did not rank high enough to stay in the Admini building. Just across from Sam Eydes street, in Villaveien 5, is the building that from 1912 served as the Hydro Town's ***first hospital***, with 11 beds. It was extended to make room for 25 beds in 1914, and was used until Rjukan Hospital was opened in 1920.

Changes: Alterations and changed function, largely minor exterior alterations.

Function today: Housing.

13.6 The Admini (administration) building in Rjukan

The Admini building in Rjukan when it was new and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: 1909.

Architect: Thorvald Astrup.

Function: Hydro's hospitality premises. Sam Eyde's residence during stays in Rjukan. Home and workplace for directors and high-ranking administrative staff on business trips, and for prominent guests.

Description: The administration building was built at the eastern access to the area, at the same time as the first housing areas. The building was drawn in a classicising Art Nouveau style and is one of Norway's finest wooden buildings from that period. It has exquisite details and is well-proportioned with a symmetrically finished main volume. It has a hipped roof, columns and arched bays. An outstanding feature of the interior is the sitting room with the fireplace, which is in the style of Norwegian national romanticism. Outside the Admini, a red servants' house and some *bur* and *loft* (storehouses) are the only remnants of the farm that once lay there. A big public park belongs to the building, landscaped in the style of English romanticism with winding paths, a small brook and a pond. It was opened in 1928 and had its own music pavilion among other things. The park was a municipal initiative, but it was Hydro who saw to its implementation.

Changes: Largely unchanged. An annex has been added to provide further lodgings (the Casino).

Function today: Hydro's hospitality premises, now closed.

13.7 Gatehouse and fire station (Building nos 296 and 121)

Gatehouse and fire station in 1911 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1911/1917.

Architect: Unknown.

Function: Gatehouse with access control until the 1980s. Fire station with a garage for emergency vehicles until the fire service moved to new premises around 2000.

Description: The gatehouse was built as part of the Rjukan I factory facilities. The fire station was built in two stages as an annex to the guardhouse, with the oldest part being from 1917. The building is situated at the end of the Factory Bridge and was an important building because everybody had to register and pass this point to access the factory area. This was the dividing line and the meeting point between the town and the factories. The fire chief lived just across the Factory Bridge and could be called out at short notice. Those who lived in Flekkebyen had their rent reduced because they were obliged to act as backup fire-fighters.

Changes: The general arrangement of the fire station was altered in 1963 and the gates were replaced by new ones in 1966.

Function today: Used by the ambulance service.

13.8 Construction office in Hydro Industrial Park (Building no 297)

The Construction office to the left, around 1915, and today. Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1912–1913.

Architect: Thorvald Astrup.

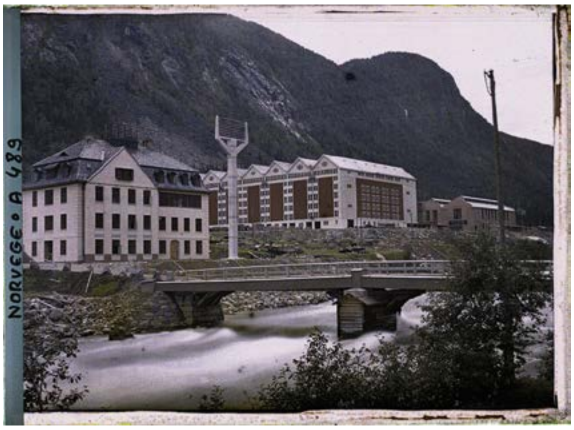
Function: Offices for engineers, drawing office for Rjukan Byanlæg.

Description: The building known as the 'Krüger Palace' had stud walls and was built in the Classicist style. In the early phase, it contained offices for engineers, and it is named after the engineer Krüger who constructed the power pylons that were used in Vestfjord-dalen and that were a distinctive feature of the landscape. Rjukan Byanlæg, Hydro's department for town planning and architecture, used these premises in the early phase. Since then, the building has had a number of functions, both as apartments and office premises.

Changes: A low extension towards the east, otherwise virtually unchanged. The interior was converted to apartments in 1930, and to offices in 1965.

Function today: Administration premises for industrial enterprises that have their production premises in the 'Central Workshop ('Sentralverkstedet' – building no 291) *(see the Industry section under supporting values).*

13.9 Office building in Hydro Industrial Park



Office building in 1910 and today. Left photo: Auguste Léon. Right photo: Eystein M. Andersen.

Built: 1911/1929.

Architect: B. Keyser Frølich (1911)/Christian Morgenstierne (1929).

Function: Administration premises for Rjukan Salpeterfabrikker A/S, Rjukan Byanlæg and the Rjukan Line.

Description: The office building was built in several stages, with the first building phase in 1911 and the second building phase in 1929. The main volume of the building as it appears today was erected during the second phase. On the building's four storeys there were premises for all kinds of staff – from the managing director, accountants, and payroll staff to the messenger boys, in addition to housing Rjukan Byanlæg's offices and drawing office. It has a dominant position down by the river as the factory site's face on the town side.

Changes: A lower western extension was built around 1970, which has been used as a payroll office among other things.

Function today: Offices for the industrial park's management and for private commercial services, accounting office.

13.10 The Rjukan House

The Rjukan House around 1950 and today. Right photo: Per Berntsen.

Built: 1930.

Architect: Jacob Hanssen and Georg Iversen.

Function: Assembly house with stage and cinema, offices, editorial offices etc. for the activities of the labour movement.

Description: The Rjukan House (the People's House) was built by the labour movement for cultural, political and union activities when it had grown in strength over a number of years. It was centrally located and much was invested in the façade and interior to ensure a strong symbolic manifestation. The costs were considerable, and as the national union organisation did not have enough liquid funds at the time, private loans had to be raised, to which Norsk Hydro contributed. The two architects from Oslo drew the building during a period of opposition between the Nordic-style Neoclassicism of the 1920s and Functionalism. The building is clearly inspired by the interface between Functionalism and Art Deco, but has some Classicist features such as the symmetry of the main structure and the column contours along the front. The horizontal rows of windows, the flat roof and other details represent the language of Functionalism. The interior of the building is Neo-classicist in character. This can be seen in the stern design of the proscenium arch, and in the detailed design of the upper circle and doors to the banqueting hall. Hanssen was one of the first cinema architects in Norway, and Oslo's Colosseum cinema from 1928 is among those that bear his signature. By contemporaries, the People's House was perceived as one of the most magnificent assembly houses in Scandinavia – one had to go all the way to Helsinki to find anything grander.

During the depression in the 1930s, with industrial disputes and lockout in 1931, the labour movement had to give up its house. It was taken over by Hydro in 1935 and its name was changed to the 'Rjukan House'. Hydro's ownership lasted until 1949, when the labour movement was able to negotiate its repurchase. The labour movement's ownership lasted until 1989, when the house was sold to Tinn Municipality. A new cinema was opened in the building in 1991. In 2012, the building was repaired and the windows and colouring restored. The letters FH (acronym for 'Folkets Hus' - the People's House) on the façade, which were chipped off during the Hydro period, have now been reinstated. Today, the building is a worthy testimony of the workers' contribution to building the urban community.

Changes: Largely unchanged, though the roof structure was altered during the 1960s.

Function today: Cinema, municipal culture department, municipal school of music and performing arts, meeting rooms, art gallery and cafeteria.

13.11 Såheim private school with teacher's residence

Såheim private school. Photo: Helge Songe

Built: 1911–1912.

Architect: Levin.

Function: Hydro's lower secondary school of general education, with a separate teacher's residence.

Description: In 1908, Hydro's administrative staff established a private school in the Flekkebyen area. At the time, the name of the Hydro Town, and hence also of the school, was still Saaheim. The school provided five years of primary education qualifying for admission to four years of lower secondary eduction, and it had between 50 and 80 pupils. The working class children attended separate municipal schools. The private school was a manifestation of the class differences, which increasingly came into conflict with democratic ideals. In 1911, as a result of the growth of the town, Hydro started work on a building in Birkelunden road, big enough to hold both the primary school and a lower secondary school. In preparation, Hydro had studied German school buildings. The company obtained sketches for a new school building in Spayer am Rhein from Bayerischer Architekten- und Ingenieur-Verein, a cost estimate for a glass roof over the art room from Stuttgart and a quote for the school's furnishing and fittings from another German company. The large wooden ***school building*** was completed in March 1912, and was opened in August 1912 with 60 pupils and 4 schoolmistresses. The primary school also moved into the new building, which changed its name from 'Forskolen Saaheim' to Rjukan private school. In 1916, the local government decided to establish a municipal lower secondary school. The plan was to incorporate Hydro's private school in the municipal school in 1917, but the private school continued for some years before it was taken over by the municipality. A municipal upper secondary school was established in 1922, and, in 1925, the building was extended to make room for both the lower and upper secondary school with a total of 183 pupils. The first class to complete its upper secondary education in Rjukan took their school-leaving exam in 1925. At that time, the school was the only private upper secondary school in Norway with the right to hold school-leaving exams. Since then, the building has, *inter alia*, been used as a students' hostel/hall of residence from 1946 until 2000.

Teacher's residence in 1911 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

The ***teacher's residence*** next to the school on the corner of Sam Eydes Street was built at the same time as the school. It illustrates the focus on proximity between home and workplace, and continued as a teacher's residence until the 1970s.

Changes: Some alterations have been made to the façades of the school building, but the form, design and ethos of the building are still easily decipherable.

Function today: Offices. Housing.

13.12 Rødbyen (the 'Red Town') and Tyskerbyen (the 'German town') housing areas

Rødbyen and Tyskerbyen around 1915 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Built: From 1910 and onwards

Architect:

Function: Housing for workers and for German engineers during Hydro's period of collaboration with BASF.

Description: ***Rødbyen*** consists of eight two-family houses of the type (type J) that was used in Flekkebyen and Grønnebyen (Notodden). Rødbyen was developed after Flekkebyen, from 1910 and onwards. The area is directly adjacent to ***Tyskerbyen***, which was built at the same time and which is also characterised by romantic planning schemes based on the English garden city concept, but where the German inspiration can be clearly seen in the architectural design of the individual buildings. When this housing area became known as the 'German Town', however, it was because of the many German engineers who lived there. Most of the buildings are two-family wooden buildings. Each family had its own entrance and its own garden patch, just as in the areas with J type housing, but there was more space both inside and outside the buildings in Tyskerbyen. The buildings were also to a much greater extent individually designed and various architects were used. Emphasis has been given to architectural finesses and details, with arched bays, annexes and various roof structures lending life to the townscape. One of the town's old transformers, currently owned by the municipal power company Tinn Energi, still remains in the area.

Changes: Mainly minor, exterior alterations.

Function today: Housing.

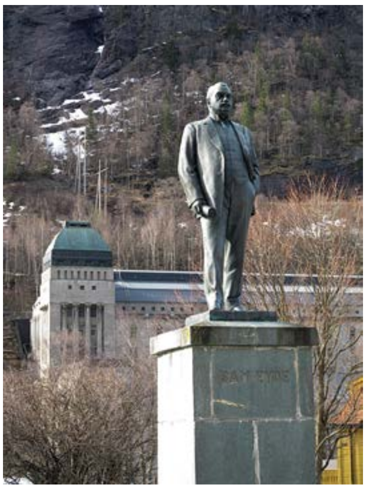
The Market Square in 1922 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1921/1924.

Architect: Thorvald Astrup.

Function: Buildings for public services and functions, such as postal and telegraph services, library etc. Marketplace.

Description: The ***Market Square*** marks the final building phase in the development of Rjukan town. It had a grand design with large brick buildings in the Classicist style designed to house a post office/chemist and library on the eastern and western sides of the square, respectively. The ***post office building*** was completed in 1921 and included premises for a telephone switchboard, telegraph office and chemist. It was an elegant building and was therefore known as the ‘Patent Leather Shoe’. The ***library*** was built as an appendage on the western side and was completed in 1924. The library goes under the name of the ‘Red Library’ due to its large collection of Marxist literature. These buildings were intended to flank an elegant city hall to the south. The city hall with its peristyle, foyer, municipal offices, banqueting hall and stage, local government assembly hall and mayor’s offices was never built, leaving the Market Square with an open view all the way to Såheim power station on the southern side of the Måna river. The town’s statue of Sam Eyde now occupies the site intended for the town hall.



Sam Eyde statue.
Photo: Trond Taugbøl.

The unveiling of ***Sam Eyde’s statue*** in the middle of the Market Square in 1920 was a much celebrated occasion, following prior festivities organised by committees that were appointed in every town where Eyde had set up business (Rjukan, Notodden, Kristiania (now Oslo) and Eydehavn). The task was assigned to the sculptor Gunnar Utsond. Funds were contributed by Tinn Municipality, AS Rjukanfos, groups and associations and though collecting money from employees of Hydro’s various departments. The statue arrived in Rjukan in 1918, but it had not been assigned a place yet, one of the reasons being that the zoning of the Market Square was taking time. Rjukan Byanlæg erected the statue on a plinth drawn by the architect Thorvald Astrup and cast in concrete and clad in dark soapstone taken from a quarry above the new hospital. The statue was moved from the centre of the Market Square to its current position in the 1960s.

Changes: Largely unchanged.

Function today: The post office building contains the municipal service centre, the tourist information office and other municipal services. The library building contains the library and functions as Tinn Municipality's town hall, with assembly halls for the local council and the municipal executive board, and offices for the mayor and deputy mayor. In the daytime, the Market Square is used for parking. There are plans to upgrade the square to become a meeting place, a place of activity and a marketplace following an architects' competition in 2013. A sun mirror is being installed on the mountainside which will reflect sunlight down to the square in Rjukan all year round.

13.14 The New Town (house type O)

The New Town before 1940 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Trond Taugbøl.

Original drawing of house type O for four families.
Norwegian Industrial Workers Museum.

Built: 1910–1912.

Architect: Unknown.

Function: Workers' housing.

Description: The houses in the New Town were O type houses, and with subsequent supporting additions the building stock of this area currently consists of 32 wooden houses, each containing four apartments, or a total of 128 housing units. Numerous houses of this type were built, forming certain continuous environments in which the monotonous similarity of the buildings is a clear manifestation of Hydro's control of the urban development into a company town. The large wooden houses were built in a kind of historicising Art Nouveau style with some variation in the décor and the gables.

Changes: The exterior remains largely unchanged.

Function today: Housing.

13.15 The Baptist Church

The Baptist Church. Photo: Per Berntsen.

Built: 1922–1932.

Architect: Lorenz H Ree.

Function: Church and assembly hall for the Baptist congregation.

Description: Rjukan's Baptist congregation was formed in 1917 and it took many years before they were able to build their own assembly hall. Norsk Hydro made a central plot available. An architect from Oslo was chosen for the assignment and drew a typical Neo-classicist building with a tight square design and a circular tower placed at the corner of the building to the right of the arched entrance. The main building volume has a gently curved pyramidal roof, and a copper-clad dome. The building work was partially carried out on a voluntary basis and it took ten years to complete. The small hall was completed in 1923 and the big hall in 1932. Both the exterior and the interior of the building remain largely unchanged. The current organ was manufactured by the German Walter factory, the best organ builders in the 1920s and 30s. Originally installed in Austbygda Church, it was moved to the Baptist Church in Rjukan in 1972.

Changes: Largely unchanged.

Function today: Church and assembly hall for the Baptist congregation.

13.16 Rjukan Church

Rjukan Church before 1940 and today. Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1915.

Architect: The brothers Carl and Jørgen Berner.

Function: Church.

Description: Rjukan Church was built by the Church of Norway's parish council on a free plot provided by Hydro, which also donated considerable funds. The church is a cruciform stone building with a solid-looking tower with a steep pitched roof in front of the transept. The building has certain Baroque revival features, and the materials used and the form and design of the building are reminiscent of the signal buildings that were built for more worldly, industrial purposes during the same period, including Hydro's power plants. The building is big, with seating for 350 people, and it has a prominent position on a piece of high ground next to Sam Eydes Street. The organ with its 23 pipes was the most modern in Norway. The altarpiece was consecrated in 1917.

Changes: Entry to the church was originally via stone steps leading up to the southern façade from Sam Eydes street and Mæland Bridge *(object 13.23).* The big tower on the southern side was flanked by two smaller towers. The church caught fire during the shooting of a film in 1965 about the sabotage operations around Rjukan during World War II ('Heroes of Telemark', featuring Kirk Douglas among others), and the interior was lost. The church was rebuilt with a new entrance from the west and the two small towers and the stone steps were removed to allow the road to be widened. The restoration work was completed in 1968 with the installation of a new stained-glass painting.

Function today: Church.

13.17 Rjukan Hospital with Chief Physician's residence

Rjukan Hospital mid 20th century and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1917–1920/1928.

Architect: Bjarne Blom /Ove Bang.

Function: hospital/physician's residence. The hospital was operated by Norsk Hydro until 1971, when it was taken over by the authorities.

Description: Rjukan's first infirmary was located in Villaveien 5, in an ordinary house of the type we find in Flekkebyen, but, in 1913, Sam Eyde and Hydro's directors decided to build a new ***hospital***. The architect Bjarne Blom from Rjukan Byanlæg made the first draft, but the matter was postponed in favour of other priorities with the advent of the World War I. The construction work did not start until 1917. By then the project had been considerably downscaled and Blom had revised his drawings. The hospital opened in October 1920. The hospital was constructed in the Classicist style, with an accentuated midsection and dormers on the hipped roof. It was a long brick building set in the steep valley side. The long façade is a distinctive feature in the urban space, visible from afar.

The ***Chief Physician's residence*** was built somewhat later, in 1928. It was drawn by Ove Bang and displays some Functionalist features. The drawing is marked 'New pastor's residence' and was intended as a replacement for a house that was destroyed in a landslide during a flood in June 1927.

Changes: There have been some changes to the hospital's façade. A number of extensions have been built. These have been added in the longitudinal direction, but are generally further back than the oldest part so that they are less prominent from a distance.

Function today: Local hospital with both a medical and a surgical department.

13.18 Tveito School with five teachers' houses

Tveito School in the 1950's and today. Left photo: Norwegian Industrial Workers Museum. Right: Per Berntsen.

Built: 1919–1920.

Architect: Haldor Børve in Porsgrunn. Johan E Nilsen

Function: Primary school.

Description: ***Tveito School*** is a large brick complex. The first part of the school was constructed on the basis of the Classicist design of the time. The drawings also show the extensions that were added later. The school was built in collaboration between Hydro and Tinn Municipality, with Hydro providing the plot at cost. The western part is the oldest part, while the other wings have been added later.

Teachers' houses. Photo: Per Berntsen.

The colony of ***five teachers' houses*** in Tveitolia was constructed in conjunction with the school. These are simple, wooden buildings with a hint of 18th century-inspired historicising décor. There are similarities between the shape of the houses, but some variation in the detailed design. The building application for these houses was submitted in 1920, based on drawings signed by Johan E Nilsen. A series of steps leading down the slope between the school and the houses allowed for fast and direct access.

The primary school at Bøen was another school built by Tinn Municipality and Norsk Hydro together. During the war, Tveito School became the German headquarters in Rjukan.

Changes: A shelter has been added on the eastern side towards Sam Eydes street, while a gym and an apartment have been added on the eastern side. The apartment has been converted into school premises.

Function today: Primary school. Housing. Some of the houses stand empty.

13.19 Tveito Park and Tveito Avenue

Tveito Park in the 1950's and today. Photo: Norwegian Industrial Workers Museum. Right photo: Wikimedia.

Built: 1928.

Architect:

Function: Public park with music pavilion.

Description: Tveito Park is situated at the eastern end of the Ingolfsland – Tveito housing area. It is a large public park encircling Tveitotjernet, a small lake supplied with fresh water from the mountainside. To the north, Tveito Avenue flanks the park and divides it from Tveito School. The brick housing along the avenue was built between 1917 and 1918. In addition to the small lake, Tveito Park has a playground, a pavilion and a sand volleyball court. The music pavilion is similar to the one in the park surrounding the Admini building *(object 13.6).* The park and the avenue are clear manifestations of the town planning initiatives for the area and an example of Hydro's efforts to provide for amusement and leisure activities.

Changes: Some work has been done to the lake and a sand volleyball court has been established.

Function today: Leisure area for the residents of this part of the town. Playground. Arena for concerts and events.

13.20 Mannheimen single men's home and Paradiset housing complex

Mannheimen single men's home before 1940 to the left, and Mannheimen and Paradiset housing complex today to the right. Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1913–1916/1918.

Architect: Harald Aars/Johan E Nilsen

Function: Housing for single lower-level administrative staff and workers/family housing.

Description:
Mannheimen in the Ingolfsland–Tveito housing area is a robust brick building with four storeys in historicising Art Nouveau style drawn by Harald Aars. Together with the Paradiset housing complex, Mannheimen formed a belt of brick houses across the valley. The building consisted of small flats for rent, and 39 double and 13 single rooms provided accommodation for 91 lodgers. Hydro sold the building to Tinn Municipality in 1924. Tinn Municipality established a nursing and retirement home on the three upper floors, while the local college of home economics moved in on the ground floor and stayed there until after the Second World War. Mannheimen was Rjukan's retirement home until 1984, when Tinn Municipality built a house for the elderly at Bjørkhaug.

Paradiset housing complex round 1920 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

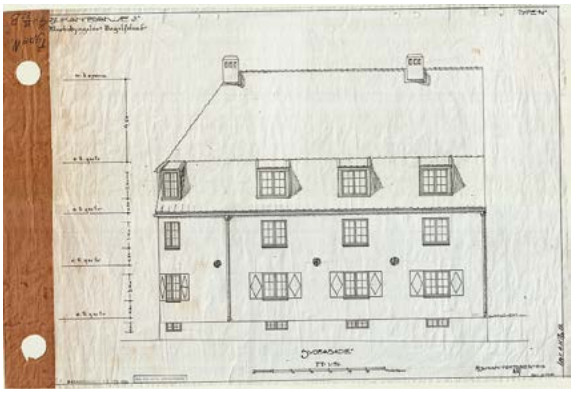
Paradiset is a large brick housing complex consisting of six buildings along Tinngata and another one nearby. The buildings were based on drawings of housing types 18, 19, 26 and 27, signed by Johan E Nilsen. The drawings were produced as a result of Hydro's guidelines for the construction of a series of new brick houses in the town in 1916. During the four years that followed, a number of brick buildings were erected, and Paradiset was completed in 1918. The complex consists of four buildings in a U-shaped formation, and two buildings in an L-shaped formation. The buildings are well preserved and have a simple Classicist design with tall hipped roofs with dormers. The entrance sections are constructed of wood.

Mannheimen and Paradiset together are a good example of the brick buildings that were constructed as part of Hydro's housing developments.

Changes: An extension was added to Mannheimen in the 1960s to make room for more residents in the retirement home. Some changes have been made to the entrance section.

Function today: Mannheimen is a home for asylum seekers. Paradiset consists of housing units.

13.21 Sing Sing housing quadrant



Original drawing of Sing Sing housing quadrant from 1916 to the left, and a photo from 1917.
Both: Norwegian Industrial Workers Museum.

Built: 1918.

Architect: Bjarne Blom

Function: Housing complex for workers and their families.

Description: The housing quadrant had 83 two-room apartments and filled whole blocks. The name Sing Sing was by way of reference to an American prison, as the occlusive design and gates that were closed at night were reminiscent of an unconquerable fortress. In the European context, and particularly in the Norwegian context, Sing Sing is an early example of this type of workers' housing. It had its 'golden age' in Europe from just after the World War I until around 1930. In Oslo, it was much used during the latter half of the 1920s and beginning of the 1930s. Sing Sing is testimony to the planners in Rjukan Byanlæg's familiarity with the international trends in urban planning.

Hollow concrete blocks were used for the buildings, which is yet another example of the early use of pre-fabricated building elements of modern materials. The drawings of the architect Bjarne Blom were used as the basis for the two housing quadrants. The buildings have been renovated and have a relatively sober though varied exterior design that contrasts with the standardised flats inside.

Sing Sing today. Left photo: Jan Solgård. Right photo: Per Berntsen.

Changes: Upper Sing Sing was demolished in the mid-1970s and there are no buildings on the site today. Lower Sing Sing, which is bigger, is intact with few changes. It was restored in the 1980s, and the windows were replaced.

Function today: Housing.

13.22 Triangelen housing complex in Ligata

Triangelen housing complex in the 1920's and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

Built: 1919.

Architect: Ove Bang.

Function: Housing for administrative staff.

Description: What is known as Triangelen consists of a group of five horizontally divided wooden two-family houses, designated as house type 119 D on the drawings. A total of seven houses were built of this type, two along Sam Eydes street a little further east and the remaining five as part of this triangle.

Changes: Largely unchanged.

Function today: Housing.

13.23 Fabrikkbrua Bridge, Birkeland Bridge and Mæland Bridge

Fabrikkbrua bridge around 1930 and today. Left photo: Norwegian Industrial Workers Museum. Right photo: Bjørn Iversen.

Built: 1952 /1918 /1915.

Architect: Unknown/Gregus G Vogter/Berner & Berner.

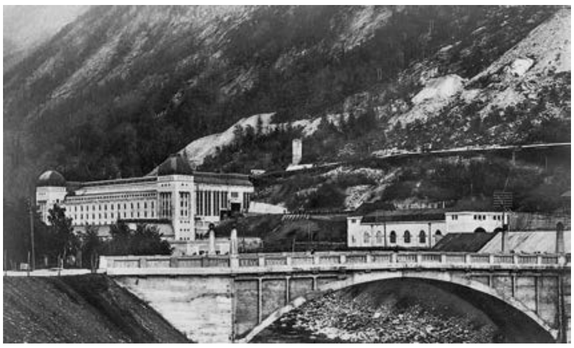
Function: All three bridges cross the Måna river between the housing on the north bank and the factory area on the south side.

Description:

Fabrikkbrua (the 'Factory Bridge') was originally built of timber in 1907. The current bridge was built in 1952 as a two-span beam bridge. The main loadbearing structure consists of steel beams, with concrete abutments and pillars. The total span is 29.2 metres. Fabrikkbrua Bridge extended from the factory gate and was the link between the factory on the south side and the town on the north side of the river. It was a busy hub at the start and end of the workday.

Every year at noon on 12 March, Fabrikkbrua Bridge is favoured by the sun when it appears above the horizon after months of absence behind the mountain massif in the south. It is a Rjukan tradition to mark the occasion by arranging a Sun Festival and carnival.

Birkeland Bridge was drawn by the engineer Gregus Gregussen Vogter and completed in 1918. It is an single-arch concrete bridge with a span of 30 metres. The bridge has concrete railings. During a restoration project in 2011 the original bridge lighting was



Birkelands bridge before 1920 and today.
Left photo: Norwegian Industrial Workers Museum. Right photo: Per Berntsen.

reconstructed: four metal light boxes on top of separate, cone-shaped, concrete columns. Birkeland Bridge was built to provide better communication between the town and Rjukan Railway Station.

Mæland Bridge was drawn by Berner and Berner at the same time as the church *(object 13.16).* It is shown in the architects' plan drawing for a project that included the church, some stairs and the bridge. The bridge below the church was completed in 1915, at the same time as the church. It is a three-span beam bridge with a main loadbearing system of steel beams. The bridge deck is an in-situ cast concrete slab with reinforced concrete joists at the sides. Concrete abutments and pillars and drystone walls. The bridge has a total span of 41 metres. The railings are of steel. The lighting on the bridge is not original. The bridge was built for better communication with Såheim Power Plant.

Changes: Largely unchanged.

Function today: Public bridges.

Supporting values

The proposed World Heritage Site also contains cultural heritage sites not listed as being of outstanding universal value (OUV) in the nomination proposal. Cultural heritage sites that are not linked to the story of the hydroelectricity-based processing industry in the upper part of East-Telemark will not be given further consideration here. The remaining cultural heritage sites fall into two categories:

1. Cultural heritage sites that belong to the nomination proposal's four thematic components, but which lack sufficient integrity and/or authenticity to be of outstanding universal value.
2. Cultural heritage sites that are related to the development of the industrial communities of Rjukan and Notodden in a coordinate manner.

Both categories of cultural heritage sites can be found either inside the proposed borders of the World Heritage Site or in the surrounding buffer zone. An overview of these values is provided below.

Thematic component	Number	In the nominated area	In the buffer zone
Hydroelectric power	7	3	4
Industry	7	7	-
Transport	4	3	1
Company town	2	-	2
Related values	6	1	5

Heritage from hydroelectric power production

Energy production has enjoyed stable profits since the beginning of the industrial adventure, and Hydro is a big player in the field of hydropower. The power plants have retained their original function. Based on Rjukan – Notodden's long history of hydroelectric power production, the first plants are important supporting values in that they have not been modernised for continued operation. This applies in particular to Hydro's first power stations in the Tinnelva river: Svælgfos I and II, and Lienfos. The power stations in Svelgfoss were pioneering large-scale hydroelectric plants. The site was also the first that Hydro developed itself, and the place where Hydro built its first urban housing. Because of its central role in the establishment of a calcium nitrate industry in Telemark and the broad content of the ***Svelgfoss cultural environment*** it is an important supporting value, and the only thing that stands in the way including it in the nomination is its poor integrity and authenticity. The cultural environment is described under the hydroelectric power component even though it includes some urban community attributes. ***Kloumannsjøen lake***, ***the timber flume*** and ***Lienfoss cultural environment*** are each of independent value, though they are also linked to Hydro's utilisation of the energy in Tinnelva's waterfalls. The activities of Tinfos AS by the Tinnfossen waterfall, which from around 1900 were based on hydroelectric power, form the ***Tinnfoss cultural environment***.

A supporting value in the Vestfjorddalen valley is the shell of a temporary power station in the Vemork gorge, built for the development of Såheim. Møsvatnet lake, the regulating reservoir on the Hardangervidda plateau, is an important supporting value representing the exploitation of the natural resources constituted by high-lying water systems.

Industrial heritage

Since the processing industry is technology-based, it is inherent in its nature that the production methods and equipment have a limited functional life. Industries addressing the world market will also be subject to economic fluctuations, trade patterns, competition etc. The factories in Notodden and Rjukan were the first generation of their type and have been closed down. Artificial fertilizer is now being produced elsewhere, but not by Hydro. In Rjukan, we find some traces of demolished objects, such as ***gasometer foundations*** and ***remains of dissolution plants***, which are important as supporting values, because their imprint is a testimony to the old production processes. A ***heavy water column,*** of the type used after the war, complements the picture of Hydro's production following the transition to the Haber-Bosch method. Some secondary buildings with service functions of a general nature also stand out as supporting values.

The significant objects that have been selected in the industrial areas consist of buildings and structures with functions that were directly linked to the industrial processes for the production of what used to be Hydro's main product, namely artificial fertilizer. In cases where such objects have been reduced to minor remains, they have been deemed to constitute supporting values. The same applies to ***buildings for by-products and support functions,*** which in all cases have been part of the factory areas when these were at the fullest extent of their construction, and which may in some cases also have architectural qualities.

Heritage from the transport system

The transport system was closed down at the same time as the factories. Neither the route corridor nor the infrastructure have been put to use for other purposes, and they have museum value. Some of the objects in the transport system were built and/or operated by companies other than Hydro. They constitute supporting values where they were used by Hydro for a shorter or longer period. Some ***buildings***, such as intermediate stations, have had a subordinate function directly linked to the transport needs of the factories or the urban communities, while they have also in some cases been subject to change, and are thus deemed to constitute supporting values. ***Notodden Steamship Quay,*** on the other hand, is intact but was constructed by someone other than Hydro long before the establishment of industry.

Heritage from urban communities

The towns of Notodden and Rjukan live on after having undergone some restructuring processes. In Rjukan, many of the original social, commercial and service functions that were originally provided by Hydro, have been maintained, but under new ownership. ***Notodden's town centre*** was built by private companies. Hydro was behind the development of several parts of the town, of which ***Tinnebyen*** is at some distance to the others that form complete urban environments. Apart from the ***'Femrader'n'*** (the row of five), most of the houses have been extensively altered. Tinfos AS built housing linked to its factories and power plants at Tinnfossen, all being part of the Tinnfoss cultural environment.

Heritage from related activity

The history of the processing industry in Rjukan and Notodden has many facets. Related supporting values that are linked to the central story are essential in order to understand the totality, the depth and the breadth of the historical phenomena that forms the basis for the nomination proposal. This applies to inter alia cultural heritage sites and cultural environments that bear testimony to ***settlements*** in the area before any industry was established, to ***tourism*** which first drew attention to this landscape of waterfalls, and to ***acts of war*** that took place as a result of the industry's strategic importance to the warring powers. ***Houses from Vestfjorddalen valley in Tinn Museum*** illustrate the sharp contrast between the old rural society and the modern society that was introduced with the Second Industrial Revolution, in terms of housing, living conditions and production. The Rjukan waterfall was an attraction whereby tourism in Vestfjorddalen became a pioneering activity in the same way as industry became a pioneering activity later on. Relics of tourist cabins, hotels, cart roads etc. are part of the ***Krokan cultural environment***. The two world wars during the first half of the 20th century had their impact on Rjukan and Notodden. During World War I, Hydro shifted its production to profitable exports for the war industry. The products were of strategic importance to the warring parties Germany and France, and both nations had shares in the company. Most of the products were sold to the Allied powers. Hydro established its own ***anti-aircraft defence*** in Vestfjorddalen as the first in Norway. This was repeated during World War II, and when the German occupants arrived, they expanded and reinforced the system to protect against Allied bombing raids. What was being protected was not just the production of explosives for the arms industry, but also the ***heavy water*** that was an element in the production of nuclear weapons.

Supporting values. Description of sites and environments

Supporting values – overview

Municipality	Supporting value	Attribute
Notodden	Svelgfoss cultural environment, ruins and buildings	Hydro electric power
Notodden	Kloumannsjøen lake	Hydro electric power
Notodden	*Lienfoss cultural environment, ruins, bridge and buildings*	Hydro electric power
Notodden	*The Svelgfoss – Tinnfoss timber flume*	Hydro electric power
Notodden	*Tinnfoss cultural environment*	Hydro electric power/ industry
Tinn	*Ruins of temporary power station, Vemork gorge*	Hydro electric power
Vinje	Møsvatn lake	Hydro electric power
Tinn	*Remnants of dissolution plant, Hydro Industrial Park in Rjukan*	Industry
Tinn	*Gasometer foundations, nitrogen, Hydro Industrial Park in Rjukan*	Industry
Tinn	*Gasometer foundations, ammonia, Hydro Industrial Park in Rjukan*	Industry
Tinn	*Telephone workshop (building no 270), Hydro Industrial Park in Rjukan*	Industry

Municipality	Supporting value	Attribute
Tinn	*Central workshop (building no 291), Hydro Industrial Park in Rjukan*	Industry
Tinn	*The 'Kasino' building, Hydro Industrial Park in Rjukan*	Industry
Tinn	*Heavy water column, Hydro Industrial Park in Rjukan*	Industry
Notodden	Notodden Quay	Transport
Notodden	*Lisleherad railway station building, the Tinnoset Line*	Transport
Notodden	*Gransherad stationmaster's house, the Tinnoset Line*	Transport
Tinn	*Mælbyen, built environment, the Rjukan Line*	Transport
Notodden	The town centre, the 'Art Nouveau' town	Urban communities
Notodden	Tinnebyen housing area, Notodden Hydro town	Urban communities
Tinn	Houses from the Vestfjorddalen valley, Tinn Museum	Related value/settle-ment
Tinn	Krokan cultural environment	Related value/tourism
Tinn	*Tinnsjø Kro (guesthouse) in Mælbyen*	Related value/tourism
Tinn	Anti-aircraft defence positions, World War I	Related value/war-time history
Tinn	Anti-aircraft defence positions, 1939 – 1940	Related value/war-time history
Tinn	German anti-aircraft defence, 1943 – 1945	Related value/war-time history

The objects in cursive lie within the borders of the nominated World Heritage Site. The rest lie in the buffer zone.

Hydroelectric power – supporting values. Description of buildings, plants and environments

Svelgfoss cultural environment: ruins of power plants, houses etc.

Svelgfoss was where Hydro built its first hydroelectric power station and the first housing. The cultural environment around Svelgfoss was made up of many elements related to power production and a community that, at its largest, amounted to 140 inhabitants. Today only ruins remain, in the form of the floors that supported the turbine generators in the ***Svælgfos I and II power plants,*** both replaced by a larger power plant further downriver. The houses have been sold, many have been altered, some have been demolished and others are derelict. While the whole area used to be in the style of a park, much of the landscape is now covered by shrub vegetation that partly conceals the cultural heritage. A lightning arrester house is the only building with sufficient authenticity and integrity to constitute a significant object. That is why the area as such has been assigned the status of supporting value rather than outstanding value in the nomination proposal. The area is nonetheless historically very significant, in that the pioneering aspects linked to Hydro's establishment in Telemark are prominent. The experience gained at Svelgfoss was transferred to the more extensive developments that followed.

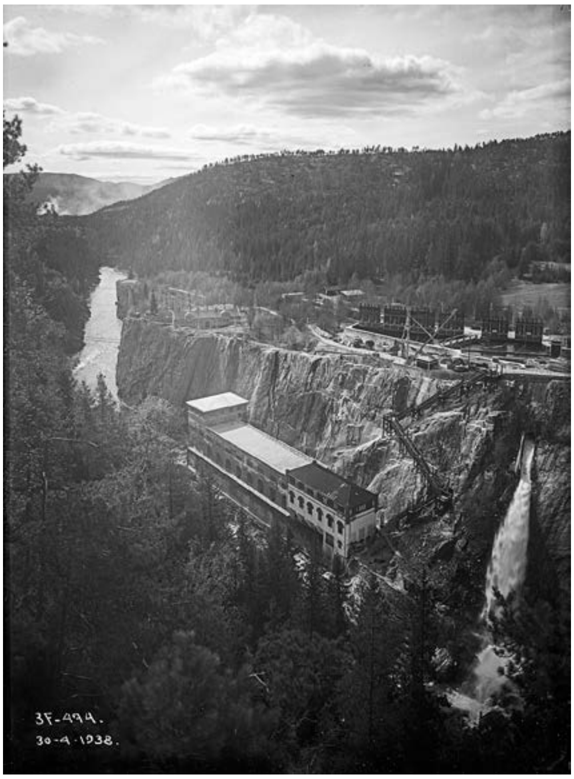
Svelgfoss needed a relatively large workforce, because of persistent running-in problems at the first power plant, which had to be supplemented by a back-up power plant to provide the factories with a stable power supply. During the development period, 400 workers were accommodated in workers' huts on the flat piece of land at Svelgfoss. Between 1906 and 1913, Hydro built 16 houses with 33 flats in this area, in addition to a local school and laundry. A group of ***five identical multi-family houses*** for the workers was built where the workers' huts had stood before – large, simple, barracks-like houses of four housing units and a shared water closet in the basement. Four of these houses remain, but they stand empty. A number of two-family houses and detached houses were also built for the engineers. An elegant ***house for the chief engineer*** was built apart from the others, based on a stern design and richer in detail than the other houses. It was named the Fougner villa after the name of the manager, and it marked the end of Hydro's housing projects at Svelgfoss when it was built in 1913. Some of the housing stock was demolished in the early 1950s. Today, 12 houses at Svelgfoss can be identified with certainty as Hydro houses from that period. Seven of these have relatively well preserved façades (two single-family houses, one two-family house and four four-family houses). Of the original buildings, one

To the left: part of five identical multi-family houses. To the right: House for the chief engineer. Photos: Trond Taugbøl.

burnt down and three have been demolished, including one that was demolished to make room for a public bathhouse. The bathhouse with its brick walls between the ground and first floor, has been sold and converted into a residential building. ***Hydro's office building*** from 1905 is also in this area, but has been converted to housing. The ***local school***, built by Hydro around 1910 still remains. At one time (1932) it was Norway's only private school with the right to hold school-leaving exams. Today, the building houses a kindergarten. Three single-family houses outside Hydro's property were probably built as 'Own Homes'. A workshop built around 1950 is now used as a house.

In architectural terms, Svælgfos I and II were very much alike. Svælgfos I was a fortress-like building in a Romanesque revival style with arched windows. The form and design of Svælgfos II was stern and surprisingly modern and free of historical references. It was a distinctive industrial building in relation to its time.

Svælgfos I power plant was built between 1906 and 1907 based on drawings by the architect Henning Kloumann, just below the cliff, close to the distribution reservoir. The penstock ran almost vertically down to the level of the generator hall floor, and continued horizontally to the plant, where it fed four horizontal double Francis drum turbines



Svælgfos I in 1938 and today. Left photo: Norwegian Industrial Workers Museum. Right photo: Trond Taugbøl.

supplied by I. M. Voith in Heidenheim in Germany. Each turbine had a maximum output of 11 200 hp with a water consumption of 23.6 m^3 per second, and a maximum efficiency of 86 %. The excitation dynamos were operated by two 520 hp spiral turbines. The main turbines operated three-phase 10 500 kVA, 10 kV generators supplied by ASEA in Västerås in Sweden. With an output of 28 MW, this was the biggest plant in Europe in 1907. It is worth noting that the power from Svelgfoss was transferred in an unmodified state to Notodden – a voltage of 10 kV was sent straight through the power lines to the furnaces and machines in the factories. In 1953, a lift was installed to provide better access to Svælgfos I, which until then had only been accessible via 222 steps in the steep rock face.

Svælgfos II power plant was built between 1909 and 1912, based on drawings by the architect Thorvald Astrup. The plant had two main turbines of the same type as Svælgfos I, and two 300 hp spiral turbines, all supplied by Kværner Bruk in Kristiania (now Oslo). The 11 000 kVA, 10 kV three-phase generators were supplied by ASEA in Sweden.

Water was fed to the two Svælgfos power plants through an open canal and a 500-metre-long ***tunnel*** from Kloumannsjøen lake to an open distribution reservoir with six pipe inlets. Four 2.8-metre-wide penstock pipes were embedded in concrete inside a blasted rock shaft leading to Svælgfos I. Two 450-metre-long overground pipelines fed water to Svælgfos II. They were 4.0 metres wide at the top and 3.2 metres wide at the bottom and supported by a series of large concrete foundations at intervals of 6 metres. Svælgfos I utilised a head of 47.8 metres, while at Svælgfos II, further downstream, the head was 49.05 metres.

The position of the power plant in the river gorge was not an optimum one. In the 1950s, Hydro therefore built a new power plant that replaced Svælgfos I and Svælgfos II. A new canal was built from Kloumannsjøen lake, bypassing the developed area on the

Svælgfos II in 1916. Photo: Anders B. Wilse.

western side, to the tunnel intake for the new underground Svelgfoss plant. The Kloumannsjøen Dam has been renovated so that the flood water runs into Svelgfossen during periods of flooding.

The former power plants at Svelgfoss were subsequently demolished down to the generator floor. The outline of the ***generator floor for Svælgfos I,*** which measured 49x11.1 metres, can be easily seen next to the river below the steep rock. The remains of the building are currently completely inaccessible, but bear testimony to the character of the plant as a first-generation large-scale production plant for electric power. The intake channel and joint distribution system for the power plants have been filled, but they have left some traces in the landscape. The ***concrete foundations*** for the approximately 275-metre-long penstock of double-riveted iron pipe down to Svælgfos II stand out in the landscape. All 57 foundations have been preserved. They are approximately 10 metres wide by 1 metre deep with heights above the terrain of up to 1.5 metres and with holes for the water pipes. In the two places where the penstock changed direction, large concrete structures can be seen. They are approximately 10x12 metres with a height of 6 to 7 metres and have two circular through holes that held the two pipes in a tight grip. Only fragments remain of Svælgfos II. A concrete floor behind an approximately 3-metre-high and 10-metre-long wall of cut stone along the river are still in place. Parallel to the penstock is a ***wooden timber flume.*** Between the timber flume and the cliff above the gorge was a flood-protection embankment in the lower part of the area, followed by the penstock, a road and a power line further up. What is left of the flood protection is a 2–5 metre-high and approximately 150-metre-long wall of blasted rock along the timber flume, and an approximately 1.5-metre-high and 50-metre-long cut stone wall along the penstock belt. The concrete foundations for a mast can be seen in the filled area behind the wall along the timber flume.

In addition to the lightning arrester house *(object 2.1)*, the area has two small buildings of natural stone with steep pitched roofs. One of these is a ***transformer tower*** which has now been phased out. The building was erected in the 1930s to supply power to Lisleherad Church and the farms around Kloumannsjøen lake. The houses at Svelgfoss had their own power supply when they were built around 1910, and all the installations that were built for that purpose are gone. The church and the farmers in the vicinity paid for the power cables while Hydro installed the transformer to provide Lisleherad with electricity. The other building is close to the lightning arrester house and may have been a ***winch house***. Its function was to lower materials and machinery parts down into the river gorge during the construction of Svælgfos I. The building contained an engine room from which the cranes on the cliff edge were operated. A number of ***steel masts*** and pylon foundations can be found in the area, as can foundations for the cranes that had to be built to transport the machinery down to the power station at the bottom of the gorge.

Hydro built an approximately 1.5 metre wide ***road*** from the power station/housing areas at Lienfoss to Svelgfoss. The road followed the western shore of the Lienfoss dam, and continued towards the north along the ridge above the gorge. Where the ridge came to an end and the mountain west of the river stood in the way, the road was cut into the mountainside. Just south of the timber flume outlet below Svælgfos II, the road made a turn and ran in a straight line to the ***office building*** for the Svelgfoss plants. The road was known as the 'Lovers' Path' ('Kjærlighetstien'). Two parts of the road are intact, though derelict and overgrown. The section of the road that is cut into the mountainside lies just south of Svælgfos II.

Kloumannsjøen lake

The construction work for the power plants at Svelgfoss included the building of a 25 metre-high dam at the top of the natural gorge in the Tinnelva river. The work was supervised by the engineer Sigurd Kloumann. The river was dammed up approximately 17 metres to contour height 115.55 to form a 5 km long lake known as Kloumannsjøen. A timber flume had to be built to take account of registered rights to float timber past the waterfall.

Lienfoss cultural environment

Lienfos power plant was drawn by Henning Kloumann and built between 1909 and 1911. It was a river power plant, based on a 200-metre-long dam that ran straight across the river and was 21 metres high at its highest point. The plant lay just below the dam and had four main turbines of 5 100 hp. Three of these were supplied by I. M. Voith in Heidenheim, and the fourth was from Kværner Bruk in Kristiania (Oslo). The generators to which they were directly connected were supplied by AEG, each with an output of 6 600 kVA and 10 kV. The dam had four regulating outlets, each with an automatic gate, so that the amount of water that passed through the plant was kept constant, regardless of the turbines' water consumption. Two power lines with the same dimensions as those from Svelgfoss ran from the power station to the calcium nitrate factories in Notodden.

Lienfoss power plant with access bridge in 1911, and the site as seen today.
Photo left: Anders B. Wilse. Photo right: Trond Taugbøl.

The power plant was located below Svælgfos II, at Lienfossen in Tinnelva. It was demolished in 1958, when Hydro put the new Svelgfoss power plant into operation. The latter replaced both Svælgfos I and II and Lienfos, and utilises the whole vertical distance of 70 metres from Kloumannsjøen to below the Lienfoss waterfall.

The power station building has been demolished to the level of the generator hall floor.

The ***ruins*** comprise the south-eastern corner of the building and the full length of the eastern wall (approximately 15 metres) up to a height of approximately one metre. Approximately ***20 metres of the dam*** are left running from the eastern abutment to the spillway. The preserved section includes the opening for the ***timber flume***. Downstream of the dam on both sides of the river, some 2–7 metre-high ***concrete walls*** are still intact. The concrete wall that flanks the river to the east is integrated in the remains of the dam and is intact along its entire length of approximately 100 metres. Approximately 40 metres of the western wall have been preserved, from the western abutment of the Lienfoss bridge to above the power plant, including concrete paving between the concrete wall and the power station. Further on, the route corridor for the Tinnoset Line siding for transporting building materials and machinery parts to the power plant site has been preserved. The side track ends in a plateau from which the route of a cable car drops steeply down to the ***Lienfoss bridge*** across the Tinnelva river. The Lienfoss bridge has a long main span made of riveted steel, which is preserved and in good order. The short span from the abutment on the western bank, across the tailrace and on to the power plant has been demolished.

Operations manager's residence today. Photo: Inge Farstad.

The timber flume crossing over Tinnelva river. Photo: Telemark County Council.

The ***plant operations manager's residence*** lies east of the river. It was drawn by Thorvald Astrup and built in 1911. More extensive alterations have been carried out on two neighbouring houses that were also built by Hydro. The cultural environment at Lienfoss includes the housing Hydro built on the western side of the river during the period 1912–1920, consisting of eight houses, and a somewhat more recent workshop building.

The Svelgfoss – Tinnfoss timber flume

The timber flume from Kloumannsjøen lake at Svelgfoss to below the Tinnfossen waterfall is a continuous 4 193-metre-long timber flume, said to be the longest in Norway. As far as is known, it is also the longest in the Nordic countries. Originally, the flume consisted of several flumes which were joined into one in 1959 to appear as it does today. The original flumes were built in connection when the power plants were constructed, so that the timber could be floated past them. A flume was built at Svelgfoss between 1905 and 1907, and at Lienfoss between 1909 and 1911; it was extended to bypass the Sagafossen and Tinnfossen waterfalls in 1924 and rebuilt at New Tinfos I in 1955. The flume passes through ***two tunnels*** in addition to crossing ***two bridges*** and various other timber and steel structures, some of them quite large. The flume is mostly made of wood, in some places reinforced with iron sheets, while the upper part leading down to the tunnel past Svelgfoss is made of concrete.

The upper part of the timber flume is made of concrete where it passes through a 493-metre-long tunnel section. A ***floaters' hut*** stands next to the intake from Kloumannsjøen lake. It is built of timber and is assumed to have been moved from Flåten farm which is situated by the same lake.

The timber flume from Kloumannsjøen to Tinnfoss is unique of its kind in Norway, and perhaps also internationally. It illustrates the interplay between local forest resources, floating and the power resource. The timber flume is an integral part of the overall cultural environment along the course of the river. It is part of the protected Tinnfoss cultural environment, and the upper part is also an element in the Svelgfoss cultural environment. The timber flume is an important object of museum value.

The timber flume passing by Sagafoss in the Tinnelva river. Left photo: Telemark Museum.Right photo: Trond Taugbøl.

Tinnfoss cultural environment

The cultural environment at Tinnfossen is associated with the industrial operations of Tinfos AS and the housing that was built by that company. The background to Tinfos AS is described in 2.b, under the section *Historical preconditions for the industrial success story; the national context*. The cultural environment consists of many elements, some of which have been described separately. Tinfos AS's two power stations have been described as separate objects (*object 1.1* Tinfos I with Myrens Dam and *object 1.2* Tinfos II and the Holta Canal) because the company sold electric power to Hydro, as has the above-mentioned timber flume from Svelgfoss to Tinnfoss. The Tinfossen waterfall was what gave rise to Notodden as an industrial community, and the old route for crossing the watercourse lay above the waterfall.

Traces of early attempts to tame the waterfall can be observed in the area, starting with a water tunnel that supplied water to the farmers' flour mill. A pulp mill and a paper mill followed in 1873. Several of Tinfos A/S's factory buildings have been preserved: the ***Old Paper Mill*** from 1888, the ***Pulp Mill Hall*** from 1898, and the ***Old Drying House*** and the ***Old Administration Building***, both from around 1900. The industrial buildings for pulp and paper production were of brick and timber. The first workers' housing built by the company was erected before 1900, west of the Tinnelva river in the area surrounding the factory. The carbide plant recruited workers from outside the area, including Sweden, and a big timber house, the 'Carbide Lodge', was built to provide lodgings. When Hydro set up business in Notodden, the focus on retaining important labour through offering good housing became stronger. Hence Tinfos AS resumed the work of building houses for the workers, but unlike previously, they were now built on the eastern side of the watercourse, where the houses along the Kanalveien road and in 'Kanalbyen' (the Canal Town, popularly called ***Hyttebyen*** – the 'Cabin Town') at the top were built between 1905 and 1920. The two-family houses called ***'Finnstuene'*** in Kanalveien are from 1908. Along the Holta Canal the houses were in the form of villas for high-ranking staff. More was invested in these buildings and their ornamentation, and there are elements of Swiss chalet style architecture as well as Historicism and Classicism in their form and design. The workers' houses in the Hyttebyen ('Cabin town') consist of a collection of about 30 small red timber houses with two rooms and a kitchen. One of the houses was a school for the workers' children.

Hyttebyen ("cabin town").
Photo: Telemark County Council.

The area also has privately built houses. Both the latter and the company-built houses reflect different development stages and styles of house-building. Tinfos AS mostly used architects who gave the houses strong common features, while the privately built houses were built by local master builders and are more individual in character. In 1908, Tinfos AS completed a new ***office building***, inspired by Hydro's Admini building. It is of rendered brick with a hipped roof, playfully ornamented with so-called national motifs in the natural-stone framed entrance and in the carved details in the interior. The architect was Finn Knudsen, the oldest brother of the architect Sverre Knudsen. The Tinfos II power plant and other buildings for Tinfos AS were drawn by these brothers together.

Together, the housing areas, the paper mill, the timber flume and power station built by Tinfos AS constitute the core of the protected cultural environment area by the waterfall, which also includes the New Tinfos I power plant from 1955 and housing from the same period, the new concrete slab Sagafoss Dam above it and a control centre.

Temporary power station Vemork gorge in 1913 and today. Left photo: Norwegian Industrial Workers Museum. Right photo: Trond Taugbøl.

Ruins of temporary power station, Vemork gorge

A temporary power station was built in 1911 in the gorge below Vemork in order to provide electricity for the Såheim construction works. It used the water from Vemork that was routed to the Måna river until the tunnel to Såheim was completed. The plant had two generator sets and an output of 600 hp. The shell of the building that held the plant, built of brick and natural stone, can be observed from the suspension bridge across the Måna river that forms part of the access route to the Vemork Power Plant. The full height of the walls remains, but the roof is gone. Traces of the water inlet pipes can also be seen.

Møsvatn lake

Møsvatn lake was dammed several times before it reached its present level and shape. Several smaller and bigger lakes have been dammed to form one. The biggest were Storfjorden with Hamrefjorden, Kråmvatnet and Martinsfjorden. The dam building started in 1906 with the local forest owners' association's (Øst-Telemarkens Brukseierforening) regulation of the whole watercourse from Møsvatn to Heddalsvatnet for timber floating. Hydro joined the owners' association and was behind the extension of the dam which created what became the biggest regulating reservoir in Norway, and which is estimated to rank as number four today with an energy potential corresponding to approximately 2 300 GWh. The catchment area is 1 500 km2 and the dam has room for 1 064 million cubic metres of water. The water level is regulated between 918.5 and 900 masl, and the area of the lake can vary considerably, from 78 km^2 to 80.9 km^2. The ***Torvehovd dam***, also known as the Nesbukt dam, had to be constructed as a moraine dam in order to prevent the water from overflowing down to Rauland in the west. The dam is lined with stone on the water side, following an official order to reinforce the dam in the 1990s.

Regulation of Møsvatn lake meant that the scattered farms that formed the Møsstrond rural community had to relocate their farm houses. In compensation for this inconvenience, they were granted the total sum of NOK 55 000. No further compensation was granted when Sam Eyde and Hydro extended the regulating reservoir, without applying for concession. This was done as early as in 1907-1908, in anticipation of the Concession Laws. Prior to the regulation, Sam Eyde is said to have bought some of the farms along the shore, according to the locals through telling untruths about his intentions. The farms were resold immediately, subject to a clause whereby the buyers perpetually waived all rights to compensation. ***Ruins of farmhouses*** that had to be moved because of what became known as the Deluge, can still be found in submerged areas. It was only when further regulation took place after 1942 that concessions were required whereby the regulators had to comply with certain conditions.

Møsvatn Lake in month of May. Photo: Per Berntsen.

The Møsstrond rural community is the highest-lying in Norway. Traffic is done on Møsvatnet lake all year round, during wintertime across the ice, however the ice is not safe

Settlement at Møsvatn to the left, and harbour at Hovden to the right. Photos: Trond Taugbøl.

in the periods of freezing and melting. There is a long history of settlement in the area. Archaeological research projects have discovered many traces of old activity on the submerged shores and islands of Møsvatn lake. Here we find one of the richest areas in the country as regards iron extraction during the Iron Age and Middle Ages. On the tongue of land between the two southern arms of Møsvatn lake alone, more than 100 iron extraction sites have been found, most of them in the original shore zone. Scientists have estimated that there are probably more than 1 000 iron extraction sites in the area around the lake, on the islands and in nearby areas. Archaeological research since the 1960s shows that iron extraction must have been an important part of the basis for settlement along Møsvatn from around 500 A.D. until the time of the Black Death, particularly towards the end of the Viking Age. The volumes produced were great enough to supply iron to a much wider area than the nearby villages. The production was probably used in gift exchanges or trading over long distances.

A number of settlements from the Stone Age have been found along the Møsvatn shores. They can mainly be linked to reindeer hunting, but other mountain resources were clearly also utilised during that period. Ruins of several big houses have been found in the area, some of which have been excavated. On the Mogetangen promontory furthest north in the lake, a house constructed of poles and with curved side walls was excavated in 1959. The house of 11x6 metres has had several fire places, and houses of this type are believed to have been common in Northern Europe during the Iron Age. Many loose objects were also found during the excavation of the site, such as arrowheads and many tools made of iron, bronze and bone. The finds marked the start of 20 years of archaeological investigations at Møsstrond. At Hovden and Neset, ruins of a very different type of house have been found, with sleepers resting on stone foundations. The house at Hovden has had several rooms. It was probably a notched log house, which is smaller than a longhouse but which could be built as part of a row. The excavated ruins in Hovden date back to the 13th century. Various tools were also found there, but one remarkable difference from the Mogetangen site was the absence of weapons. Similar ruins have been discovered and excavated at Neset, while other sites have been registered but not excavated. At the foot of the Viningskyrkja mountain at the northern end of the lake, the ruins of a church and a marketplace have been registered.

Remains of the dissolution plant in Tower House I. Photo: Eystein M. Andersen.

Remains of a dissolution plant from Tower House I, Hydro Industrial Park in Rjukan

The dissolution plant was a crushing plant and filter system at the back of the former Tower House I, where limestone was tipped from wagons on the Vemork railway track and nitric acid was added in open dissolution vats. It was built in 1910 and was in operation from 1911 to 1957. The workers called the plant 'Little Hell' because of the working conditions, in which harmful exposure to nitric acid vapour and limestone dust which destroyed the lungs. The arches of the concrete silo wall can be traced along the back wall, which was also a supporting wall for the railway track to Vemork. Where the vats were before, is an open tarmacked space today. The wall transitions into a ring wall, which formed a safety trough for two storage tanks for nitric acid in the event of a leakage. By the ring wall stands a garage of more recent date.

Gasometer foundations, nitrogen – Rjukan

A gasometer for nitrogen was built in 1928 for the New Production Facilities. An imprint in the form of a circular tarmacked flat surface can be seen on the ground east of the other buildings that formed part of the New Production Facilities for ammonia synthesis (Haber-Bosch method).

Gasometer for nitrogen under construction in 1928 to the left and the remains today. Left photo: Norwegian Industrial Workers Museum. Right photo: Eystein M. Andersen.

Remains of the gasometer for ammonia. Photo: Eystein M. Andersen.

Gasometer foundations, ammonia – Rjukan

A gasometer for ammonia was built in 1928 for the New Production Facilities. An imprint in the form of a circular tarmacked flat surface can be seen on the ground between the location of the Synthesis Plant (in the New Production Facilities for ammonia synthesis, Haber-Bosch method) and the Vemork track.

Telephone workshop/offices (Building no 270)

The building was erected in 1912 to house an electrical workshop, stores and an office for the storekeeper. The architect is unknown. The building has had a number of functions and has been home to, inter alia, an instrument maker's workshop, messenger boys, a telephone workshop, the town planning department's workshop etc. From 1979, it was used by the safety department. It is a concrete building with two storeys and a total floor space of 700 m2. On the western side of the building stood the sack warehouse and packing house which were demolished in the late 1980s. The building has recently been renovated and the interior has been altered. Today it houses an SMB centre.

Telephone Workshop. Photo: Eystein M. Andersen.

Central workshop (Building no 291)

The first part of the building was erected in 1910 as a mechanical workshop and smithy. This was the central workshop for Hydro's industrial activities in Rjukan, where blacksmiths, mechanics, electricians and other professional tradesmen ensured that the machinery could be operated continuously. From 1927, the western part of the building was also used for workshop functions. The building was extended in several stages between 1917 and 1951. The oldest part, of brick, is flanked by the newer parts on either side. The building represents a support function for Hydro's activities and constitutes a structuring element in the area. Today the building is used by an industrial company (Scana Skarpenord).

Central Workshop. Photo: Eystein M. Andersen.

The 'Kasino' building/ Canteen (Building no 271)

The building was erected in 1912 as a canteen and has also contained bedsits for Hydro's fire service and for employees, including single women, as well as a messenger boys' centre. It was drawn by the architect Keyser Frølich. 'Kasino' was the name used for a place that served open sandwiches and hot meals to employees, and where overtime meals were prepared. During World War II, the building was used as a mess for German officers (Offizier-Kasino), offering both board and lodging. The walls above the ground floor are of cast concrete, while the

The Kasino building. Photo: Eystein M. Andersen.

second floor has stud walls. The exterior of the house remains unchanged, but the interior has been modernised. It now includes a modern kitchen, canteen and offices.

Heavy water column – Rjukan

In 1971 when the hydrogen plant at Vemork closed down, the heavy water production plant that had been built there in 1956 was moved to Såheim to meet the growth in demand. Heavy water production is a process in ten steps, starting with hydrogen electrolysis and ending with heavy water cells. These steps are organised in a vertical column in a tower-like concrete extension to the compressor house *(object 8.6)*. Hydro was the world's biggest producer of heavy water, and even though Hydro met with competition from the Canadians, the heavy water column in Rjukan is unique in a global context, as this type of column is no longer used in the production of heavy water. The cell column is of the second-generation type, i.e. from after the Second World War, but it is a rare example of its kind in a global context. Of the first type from before 1940, only remnants remain in the form of a single cell, on display at the Resistance Museum ('Hjemmefrontmuseet) at Akershus Fortress in Oslo.

The heavy water colum on its present location. Photo: Bjørn Iversen.

The heavy water column in Rjukan is of special interest for historical reasons due to its association with geopolitical events during World War II, and to the subsequent development of nuclear weapons by various nations. Historical events are described under heavy water sabotage operations (p. 219), and in a separate sub-section on heavy water (p. 272-273) under the section on Hydro's changeover to the ammonia process and hydrogen electrolysis.

Heavy water was a by-product of water electrolysis. There were many hydrogen electrolysers in the Rjukan factories. The status of the few remains that exist has not been clarified. A Pechkranz electrolyser of the first, centrally cooled type exists in its various unassembled parts, and as far as is known, has not been preserved anywhere else in the world. There are plans to assemble this electrolyser. A lathe of German make that was set up in Rjukan in 1928 for maintenance of the synthesis furnaces is also preserved. With a length of 25 metres and the capacity to handle metal components of up to 90 tonnes, it was the biggest of its time in Northern Europe.

Transport system. Supporting values, description of buildings and environments

Notodden Steamship Quay

The steamship quay was built in 1876 to receive ships in passenger service. It was also known as the 'Canal Quay'. Steamship traffic on the lakes of Telemark started with the canalisation of the watercourse between Norsjø and Heddalsvatnet lakes in 1852, and reached ocean level at Skien in 1861. The voyage from Fjærekilen at the southern end of Norsjø lake, and later from Skien, terminated at Tangen in Heddal. Notodden was served by a landing site at Tinnesand. The latter fell into disuse when the 'Canal Quay' was built, and from 1894, Notodden took over as the terminal for scheduled traffic. The paper mill Tinfos Papirfabrik built a horse-drawn railway from Upper Tinnfoss to the steamship quay.

Notodden Steamship Quay. Photo: Trond Taugbøl.

The steamship quay is intact in the form of a stone-paved quay front and an open wooden roof structure along virtually the whole length of the quay. The details of the wooden structure are typical of the time it was built. Between the quay and Hydro's former factory area is Tinfos AS's slipway from around 1920, with a large workshop building erected in the 1950s.

Lisleherad Railway Station – building and outhouse

The station building was erected in 1930 based on NSB's type drawings from 1923. The 'Veggli' type, drawn by B. F. Baastad and G. Hoel, was much used by NSB for small, intermediate stations on the Sørlandet, Numedalen, Nordland and Bratsberg lines. The wooden two-storey building had a service office, waiting room and an apartment for the stationmaster, in addition to a freight room at the northern gable end on the first floor.

The station, located 5.3 km north of Notodden, was originally opened in 1909, at which time it consisted of a converted workers' hut, just like the one at Gransherad railway station. That building was demolished in the 1920s, after the Tinnoset Line was taken over by Tinnoset-Porsgrunnbanen A/S. The station was in operation until 1960, was a manned stop until 1970, after which it continued as an unmanned stop until the line was closed down in 1991. The station building was sold to private owners in 1984. A veranda on poles was added to the southern gable wall at a later stage.

Lisleherad station building. Photo: Eystein M. Andersen.

The Outhouse has stud walls with horizontal wooden cladding. The oldest part of the outhouse is probably the original part containing the privy, drawn by Thorvald Astrup and built in 1909. The interior of this part is partly preserved with cubicles and original doors. When the new station building was erected, the outhouse was moved, given concrete foundations and extended towards the south.

Gransherad stationmaster's house

The building was drawn by Thorvald Astrup for Norsk Transportaktieselskab, as a converted workers' barrack built in 1908 for the construction of the railway line. A separate stationmaster's house was built because the station building, another converted workers' hut, had only one storey and no apartment. The stationmaster's house is the only remaining workers' hut from the construction period. The station building was sold and moved to Hørte in Gransherad in 1986, where it is used as a residence.

Gransherad station around 1920 and today.
Left photo: Norwegian State Railways Museum. Right photo: Per Berntsen

Mælbyen built environment

The housing area was developed between 1910 and 1920 for employees associated with Hydro's transport activities. In addition to the group of multi-family houses in Mælsvingen 10–15 *(object 11.7)*, the area has a number of smaller houses. Several of them are probably house types from Hydro's catalogue, but most of them have been altered to a varying degree. In the buffer zone stands an assembly hall and more houses, some of a more recent date. A former school has been demolished.

Urban communities. Supporting values, description of buildings and environments

Notodden's commercial centre, the Art Nouveau Town

Notodden town centre with shops, public and social institutions and housing areas started out as a regular brick town in the early 1900s. A classical grid-style street network was planned, designed and drawn once Sam Eyde had realised the potential of the place, and the town centre at the lower end of Storgata with the Grønnebyen housing area was subsequently developed in accordance with the overall plan.

The old centre was at the upper end of Storgata as it appears today and the existing buildings represent the meeting point between the rural landscape and an emerging town structure. The buildings that remain along the upper part of Storgata are where the urban growth started and they define the street corridor leading down to Notodden's current town centre. Before 1904, a partially developed lower centre with residences for independent entrepreneurs, and a few shops had emerged as a consequence of increased traffic along the canal and the establishment of Tinfos. Storgata nos 28 and 32 represent the oldest buildings from before 1905 along with the Teledølen building in the Square, which was also home to Notodden's first post office.

During the period after 1905, around 40 tenements/buildings were built that formed the basis for naming Notodden centre the Art Nouveau town. The buildings were designed to fit into the quadrants of the grid that had been established in the town plan from 1904. From 1908, the Norwegian Building Act became applicable to the urban centre, with ensuing fire regulations and mandatory use of bricks/concrete. From 1912 Notodden was zone planned in accordance with the Norwegian Building Act of 1869, and in 1913 town status was awarded.

The centre was mainly developed by private farmers and landowners who had their roots in the area, and the buildings were often named after the landowner/client (Hefregården, Cowardgården, Haugerudgården, Bøengården, Medalengården, Mørkgården etc.). Most of the brick town was drawn by architects such as Otto Hansson, Helge Blix, Haldor Børve, Heinrich Joachim Sebastian Karsten and Herman Major Backer, most of whom had been educated in Germany. With the exception of Blix, none of these architects worked for Hydro. The buildings drawn by Hansson in 1905, and subsequently by Karsten, Børve and Blix and finally Backer in 1912 had certain Art Nouveau features, and in 1910/1911, Neo-classicism was represented by Otto Hansson in particular. The use of architects and master builders meant that the buildings from this period were of high quality, just as those built by Hydro and Tinfos during the same period. During the period when Hydro's plants were being constructed, the town had as many as eleven hotels at one time, most of them in the aforementioned brick buildings. The town got its first hospital in 1919, drawn by a Hydro engineer and built by the municipality. The church from 1938 was a gift from Tinfos A/S.

Of the 40 buildings that were built in the town centre during the core period prior to the industrial development, 29 remain today. A bathhouse, school and cinema are among the buildings that are no longer there. Several functions have moved into new buildings erected for the purpose, including the municipal administration and cultural centre.

Tinnebyen in Notodden

With Hydro's 'Own Homes' project from 1910, the Femrader'n ('the row of five') housing development and the development of Tinnebyen during the years before 1920, the land belonging to the farms Hvåla, Kattekleiv and Tinne East was incorporated into the town of Notodden. Own Homes were built on the Hvåla field in 1910–1912, up above the moraine terrace where Villamoen was built. A total of 44 horizontally divided two-family houses are said to have been built, with two rooms and a kitchen on each floor. After they were built, the houses were sold to Hydro's workers and staff, on terms that gave the company pre-emptive rights to buy or rent out the houses.

The Femrader'n ("the row of five"). Photo: Trond Taugbøl.

In 1917, Norsk Hydro bought 10 hectares of land from Hvåla farm in order to build the housing area that was named Tinnebyen and which was largely completed by 1920. In Vålagata in this area, five identical four-family houses were built of hollow concrete bricks, which were popularly called 'Femrader'n' ('the row of five').

They are very similar to the houses in Rjukan, including the rows of houses at Krosso. In Notodden they are set along a curved street. The houses had hipped roofs. Each flat had two rooms and a kitchen and there was a water closet in the basement for every two flats.

Most of the Own Homes houses have been converted and there is hardly any uniformity left. Of the row of five in 'Femrader'n', one house has been demolished.

At the same time, housing was also being privately built in the area, starting with the houses between Hvåladalen and Tinneveien around 1910 and continuing along Roald Amundsens street towards Kattekleiv.

Like the houses built by the industrial companies, the houses that were built privately during Notodden's period of growth between 1905 and 1914 were generally of high quality in terms of both design and workmanship, and the architectural qualities of several of the well-preserved houses along Roald Amundsens street are good examples of this.

There are no visible traces left of the former power line corridor that passed through Våladalen on its way from Svelgfoss to Hydro's factory plants. Parts of the Sætrebekken beck, which formerly ended up in the area of the railway, have been routed through a culvert, but it is still visible as part of the surrounding landscape.

Pre-industrial settlement, supporting values

House from the Vestfjorddalen valley, Tinn Museum

Many of the farms in Vestfjorddalen have been settled since long ago. When Norsk Hydro established their industry in the valley, a series of archaeological artefacts from, inter alia, the Viking Age were found. The history of settlement belongs to the responsibility of Tinn Museum. The open-air museum was built around the Øverland farm just east of Rjukan. Together with the farm buildings, other buildings that have been moved there form a collection of timber houses from the old rural communities of Vestfjorddalen and Tinn. Here we find houses for people and their animals, and for storage and production, including farmhouses that date back to the 1600s, stabbur and loft (outside storehouses), stables, a cowshed/barn and a smithy. A school building from Nedre Dal, erected at Tverrgrot near Rjukan in 1882, has been rebuilt at the museum. A guesthouse built in the 1830s to provide accommodation for tourists visiting the Rjukanfossen waterfall has been moved to Tinn Museum. It was the farmer and mountain guide Ole Torjersen Dale who built Vestfjorddalen's first house for receiving tourists on his farm.

Farmhouse from Øverland farm at Tinn Museum. Photo: Norwegian Industrial Workers Museum.

Tourism to the wonderland of waterfalls; supporting values

Krokan cultural environment, Vestfjorddalen

During the 19th century, the number of tourists attracted to the spectacular mountains and waterfalls of Vestfjorddalen grew to a considerable number. Buildings and facilities were set up to cater for tourism. The Krokan tourist cabin at Rjukanfossen, built in 1871, was the first in Norway. In 1897, a fashionable hotel was built by the waterfall, and the waterfall was illuminated with electric light just like the Niagara Falls. The local trekking association and the hotel became pawns in a game for the rights to the power from the waterfall. This is described in more detail under 2.b in the sections on Travel and tourism (page 236-239) and Waterfall acquisitions (page 240-244). The Gaustahytta tourist cabin at 1 840 masl, built by the Skien – Telemark trekking association on Gaustatoppen in 1893, has been in continuous operation since. The buffer zone borders on the Gaustatoppen peak, reaching its highest point to the north of Gaustahytta at 1 883 masl.

Krokan tourist cabin was a refurbished former cotter's farm owned by Fosso farm. The Norwegian Trekking Association (DNT) bought the farm in 1869 and moved the building a few hundred meters further up the valley. A lodge was added in 1875, and in 1877, an adjoining building was erected so that the cabin assumed its present form. The building was used as an annex to Rjukan Hotel which was subsequently established at Fosso. From 1935, Krokan was used as a holiday home for employees of Norsk Hydro. In 2003, one hundred years after Hydro's acquisition of Krokan, the cabin was sold back to DNT for the price of NOK 1. The building was granted cultural heritage protection in the same year.

Rjukan tourist hotel and cabin around 1900 to the left, and Krokan tourist cabin today to the right.
Left photo: Directorate for Cultural Heritage. Right: Trond Taugbøl.

Rjukan Hotel was located at Fosso farm above the Rjukanfossen waterfall, in the place that today bears the name of Krokan. In 1945, the hotel building from 1897 was moved to Mæl, where it currently serves as a guesthouse under the name of Tinnsjø Kro. Footpaths and levelled tennis courts near the edge of the cliff are part of the cultural heritage from the hotel days. The hotel received electricity from its own power plant, which was the first power plant in Tinn.

Kvernhusfossen power station stood next to the Måna river some way upriver from Rjukanfossen, where the remains can still be observed. The power station was initially built by Rjukan tourist hotel in 1897 to provide the hotel with electric lighting and illuminate the waterfall. The developers of the Rjukanfossen waterfalls bought the hotel and waterfall rights in 1903, and expanded the power station to provide electric power for the construction of Vemork, for lighting, pumps, ventilation during tunnelling etc. The power plant was initially built with an output of 300 hp and was equipped with a 30 kW direct

Kvernhusfossen to the left and Maristigen to the right. Left photo: Bjørn Iversen. Right photo: Trond Taugbøl.

current dynamo with factory serial number 24 from Siemens Halske. With the addition of a second generator set, the output was expanded to 600 hp, which was sufficient for the construction works at Vemork. Remnants of the power station in the form of concrete and brick foundations can still be observed.

Maristigen was the old bridleway and hiking trail uphill from Krokan across the slippery bare rocks to Fosso. The steep rock section plunges into the Rjukanfossens gorge. The vehicular road through Maristigen was completed in 1895. The road followed the approximate route of the bridleway and was cut into the rock. A superstructure of steel has been built to protect it against rockslides. Guard stones connected by iron railings line the side facing the gorge. The road from 1895 is intact and a section of the road can be followed where National Road 37 runs through a tunnel behind it. A plaque commemorating Thomas Johannessen Heftye, the founder of the Norwegian Trekking Association has been posted where the modern road crosses the Maristigen road.

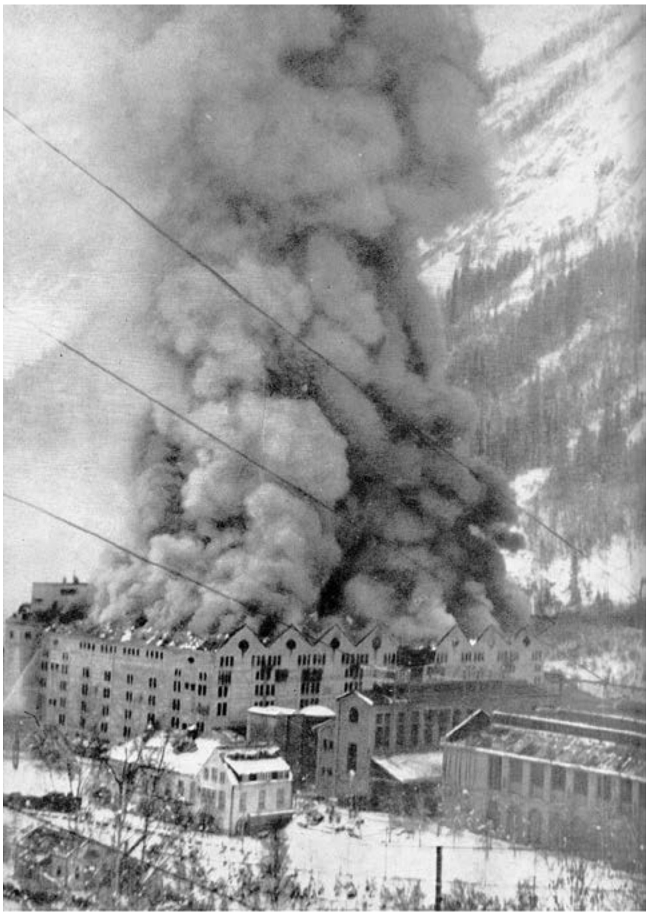
Tourists have given many a dramatic account of the trip along Maristigen. One by Jules Verne, who walked there in 1863, is particularly dramatic. Maristien got its name from the legend about Mari, of which several versions are told. The story of how Mari, the cotter's daughter, and Olav, the farmer's boy, shared their secret love by arranging nightly rendezvous by a pine tree above the gorge has been dramatised and the stage version is performed every July. Water is let into the Rjukanfossen waterfall when Mari, pining for Olav who slipped and lost his foothold one stormy night and disappeared into the depth of the gorge, finally throws herself after him.

Tinnsjø Kro at Mæl. Photo: Trond Taugbøl.

Tinnsjø Kro (guesthouse) in Mælbyen

The former hotel building at Rjukanfossen has been moved to Mæl, inside the area of the World Heritage Site. The building was drawn by the architect Finn Knudsen and completed in 1897. The timber building was moved to its present position in 1945. The building now serves as a guesthouse under the name of Tinnsjø Kro.

Heritage from World Wars I and II – supporting values



Hydros factories in Rjukan were targeted by allied air-force in november 1943. Tower House I was bombed. Photo: Norsk Hydro.

Norsk Hydro's products were of strategic importance to the warring powers. Operations of a military nature, both in the form of the construction of defence positions and in the form of attacks took place in Vestfjorddalen. These operations left a number of physical traces that can be observed in Rjukan and in Tinn. The factories in Rjukan were extended to meet the needs of the German occupying power. In addition, plans were made and work started on what was at the time the biggest ever industrial project in Norway, a production plant for light metals at Hydro Herøya near Porsgrunn. The aluminium was intended for aircraft production for the Luftwaffe, while the magnesium was also used in fire bombs. A large-scale development of the Mår watercourse in Tinn was started, and there were plans for a power station at Dale in Vestfjorddalen. The development was abandoned after an American aircraft bombed the factory premises under construction at Herøya. The development of the Mår watercourse was completed by the state in 1948.

Anti-aircraft defence positions, World War I

During the First World War, Norsk Hydro did not primarily produce artificial fertilizer, but ammonium nitrate, a very lucrative product for the company's shareholders. There was a great demand for this product from the arms industry, which used it in explosives. Hydro was the biggest supplier of nitrates to the French defence forces. They bought 53% of Hydro's production, while the Germans were only able to buy 13%. The company had both German and French shareholders. Norway's neutrality meant that the company's management had to be careful not to tip the balance in anyone's favour. The director general, Sam Eyde, and his management feared that the Germans would send saboteurs to Rjukan, who would use dynamite to gain access to the factory areas or arrive by air in what were known as Zeppelins. In 1915, 181 human lives had been lost to German bombs dropped from Zeppelins in England. On 3 May 1916, a German Zeppelin went down with a crew of 16 off the coast of Stavanger, after dropping bombs over Scotland. Rjukan was within the reach of German Zeppelins and Eyde wrote in his autobiography that 'The company procured 10 anti-Zeppelin guns, 8 guns, 15 machine guns, 9 acetylene floodlights and 8 electric floodlights. In 1916, Norsk Hydro established anti-aircraft defence positions around Rjukan in collaboration with the Norwegian armed forces. Field guns of the type 75 mm Puteaux M1897 for platform installation were purchased from France. Field gun positions were established in the mountainside on three sides at the upper Vestfjorddalen valley, at Krokan in the west, near Selstali in the south and in Bøensåsen directly north of Rjukan not far from Gvepseborg. A well-preserved field gun position can be seen beside the Krokan tourist cabin, where the natural stone foundations and slider remain. Remnants of the foundations can also be seen at the southern field gun position, along with the foundation walls of the hut where the gunners lived. Similar foundations are also visible at Gvepseborg. These field gun positions are early examples of organised military anti-aircraft defence efforts in Norway.

Anti aircraft defence positions, left at Bøensåsen from 1916 and right at Krokan from 1940. Photos: Bjørn Iversen.

Anti-aircraft defence positions, 1939–1940

In 1939, when the clouds of war were once again gathering over Europe, Hydro once again entered into an anti-aircraft defence collaboration with the Norwegian armed forces to protect Rjukan and Herøya. This time, Hydro bought ten Swedish guns of the Bofors 40 mm type. Six of these anti-aircraft guns were distributed between three artillery batteries in Vestfjorddalen. In addition, three cables were suspended across the valley to prevent the factories from being dive-bombed. These were hoisted into place in autumn 1939. Dive bombing had been used during the Spanish Civil War between 1936 and 1939, and in the German campaign against Poland in September 1939. At least one anchor point for the steel wire ropes that were used has been preserved today, near the Bakkenut artillery battery, just over 2.5 km from Gvepseborg. Of the three Norwegian artillery batteries from 1940, two have left clearly visible traces. At Bakkenut, the remains of the gun foundations are still visible in the landscape. At Krokan, the Norwegian forces took over the positions that had been used 23–24 years previously. The foundations are of concrete and the mounting plate for the gun is still clearly visible. At Mæland, where Rjukan Stadium is today, there are no traces of the anti-aircraft defence position.

When the war came to Norway on 9 April 1940, Rjukan Air Defence consisted of 250 persons, officers and crew. Many of those who participated were employees of Norsk Hydro and participated for the company's account. Second Lieutenant Tharaldsen, who was battery commander for Bakkenut, wrote in his report: 'A total of between 10 and 15 aircraft came under fire and between 300 and 400 shots were fired'. He was ordered to decommission the battery at 01:00 in the morning on 3 May 1940.

German anti-aircraft defence, 1943–1945

The German occupying forces built an anti-aircraft defence system with several positions around Rjukan and Våer. During the American air raid on Rjukan on 16 November 1943, the Germans replied with their 20 and 40 mm guns. The Germans were unable to inflict any documented damage on the 140 aircraft and realised that the anti-aircraft defence system around Rjukan had to be upgraded. This gave rise to plans for extensive defence installations in the vicinity of Piggnatten, just over 1.5 km northwest of Gvepseborg. In autumn 1944 the German Luftwaffe started up work on a heavy anti-aircraft artillery battery of 88 mm FlaK guns. The gun was popularly called 'Acht-Acht' and had incredible fire power. It was originally designed to neutralise aircraft flying at a height of up to 12 km. Photos taken by a German non-commissioned officer and a local eyewitness verify that at least one such 88 mm gun was ready for action, under the command of Flak-Abteilung 562. The area is popularly known as 'the Gun Position' ('Kanonstillingen'). The Krosso Aerial Cableway was used to carry large quantities of cement and necessary equipment up to the mountain plateau. There were probably plans for installing six such guns on plinths inside gun positions. A fire in the cableway's upper terminal on 1 November 1944 put a stop to the plans to expand the battery. The gun equipment was taken down from the mountain instead, and removed from Vestfjorddalen.

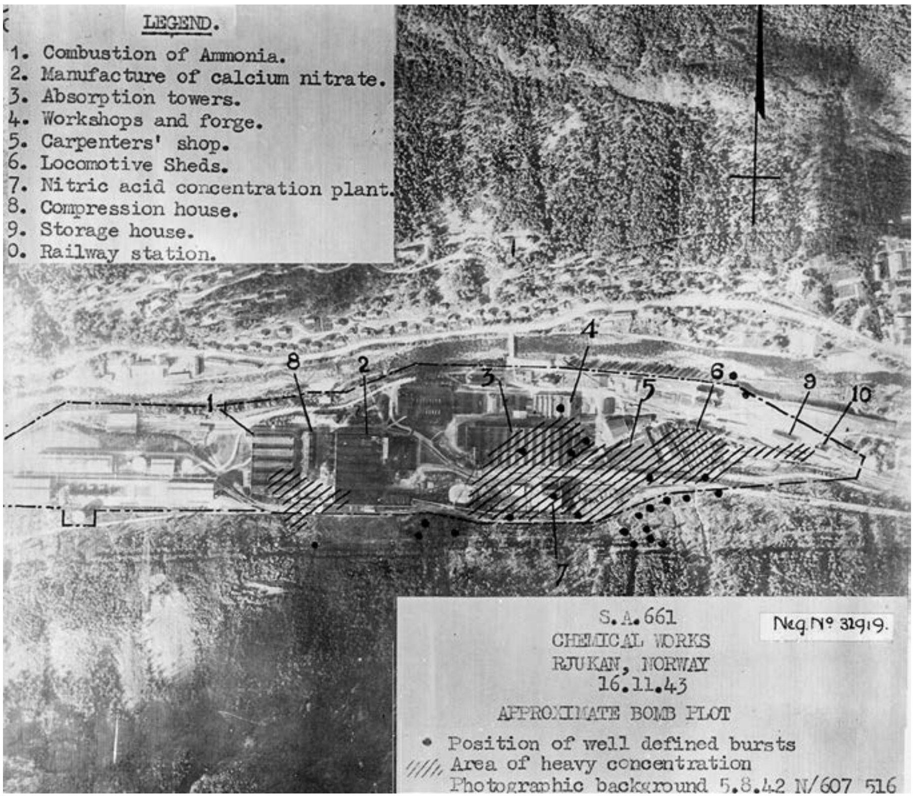
Artillery battery	**Map reference**	**World War I**	**World War II**
Name		**1916**	**1940 and 1944**
Krokan	59º 51' 56.57" N — 8º 28'23.55" E. Height above sea level: 747 m.	Natural stone foundations. Steel slider for the gun (Puteaux M1897, 75 mm).	Concrete foundations. Mounting plate for gun (Bofors 40 mm).
Selstali	59º 52' 06.53" N — 8º 35'02.21" E. Height above sea level: approx. 900 m.	Natural stone foundations. Foundation walls of watch cabin.	
Bøensåsen	59º 53' 13.14" N — 8º 34' 08.77" E. Height above sea level: approx. 900 m.	Natural stone foundations. Steel slider for the gun (Puteaux M1897, 75 mm).	
Bakkenut	59º 53' 06.08" N — 8º 30' 13.13" E. Height above sea level: approx. 956 m.		Concrete foundations. Anchor point for steel wire.
Gvepse-borg	59º 53' 35.83" N — 8º 31' 46.75" E. Height above sea level: approx. 1 100 m.		Foundations/concrete and natural stone walls, with anchor bolts.

The Hydrogen plant at Vemork during World War II with the penstock under camouflage. A famous sabotage action destroyed the heavy water production columns in 1943. The building was demolished by Hydro in 1977. Photo: Bjørn Iversen's archive.

Heavy water sabotage

Heavy water is a by-product of hydrogen electrolysis in the production of ammonia. Until 1989, a heavy water concentrate was produced in the electrolysis plants in Rjukan. During the 1940–1945 war, the German war power was involved in intensive research into how to develop nuclear weapons, and the German occupying power needed heavy water from Rjukan for its experiments.

During the war, there were several attempts on the part of the Allies to stop this production in Rjukan. Air raids were tried but failed. Precision bombing was difficult in the narrow Vestfjorddalen valley flanked by high mountains. Gliders were used for the first operation, which failed and claimed the lives of 41 Allied soldiers. A bold and spectacular sabotage operation was implemented to blow up the Hydrogen Plant at Vemork. It was named the 'Vemork Operation' or 'Operation Gunnerside' and was successfully completed on 27 February 1943. The explosion destroyed the heavy water cells, but nobody was caught and no lives were lost. The route that the nine saboteurs used to get to the plant unseen and to escape in the direction of the Hardangervidda plateau crosses the gorge below the power station and is known as the Saboteur Route. The Rjukan boy Claus Helberg participated in the operation. The operation delayed the German research into nuclear weapons but did not stop it. An unsuccessful American air raid on the Vemork plant, involving 143 aircraft, was attempted on 16 November 1943. It claimed the lives of 22 civilians when a bomb hit the housing area at Våer. Heavy water sabotage operations also included the sinking of the railway ferry 'D/F Hydro' *(object 11.15)* on Tinnsjøen lake on 20 February 1944, with a view to preventing shipments to Germany of lye containing heavy water, which was produced in Rjukan when the plant resumed its operations. A total of 18 people died as a result of this operation, consisting of German military personnel (4) and civilian passengers and crew (14)



On 16. November 1943, the American bombers had their target at Rjukan shown on this clandestine photograph, as "Approximate bomb plot".
Foto fra www.b24.net.

Posters for the film "The Heroes of Telemark" about the sabotage action.

Natural conditions – factors with a bearing on the nomination proposal

Geological conditions. Landforms and topography

The landforms, topography and climate of the applicable areas of Norway have had an important bearing on the events related to cultural history that caused Rjukan and Notodden to become unique places and to become nominated as a World Heritage Site. The nominated area is an inland district of Eastern Norway located at the edge of Southern Norway's mountain interior. The mountain range that forms the divide between East and West in Southern Norway contains the watershed and the sources of the watercourses running east and west and dropping steeply from the mountain plateau to form the waterfalls that were utilised in the industrialisation in Norway.

The industrial communities of Notodden and Rjukan are a manifestation of the meeting point between man and nature; in one sense they can be described as 'works created by human interaction with the environment'. Rjukan, in particular, represents an exploitation of the potential of the natural surroundings and the social, economic and cultural forces that were dominant at any time. The natural landscape of the Hardangervidda mountain plateau constitutes a vast natural hydropower reservoir. Economic forces are understood to mean the selective transformation of this natural water reservoir through methodical exploitation to produce electricity. Around 1900, this had become a technical possibility in the wake of developments since the 1860s. The watercourses were now regulated to allow for optimum utilisation of hydropower and maximise electricity production from the major watercourses on the eastern and western sides of the Hardangervidda plateau.

The Hardangervidda plateau and the watercourses

Hardangervidda is a bedrock peneplain with an area of 8 000 km^2, reckoned to be the biggest high mountain plateau in Europe. Virtually the whole plateau lies above the tree line, generally at a height of between 1 000 and 1 400 masl, and it is highest towards the west, where we also find the watershed between Eastern and Western Norway. Hardangervidda has many lakes. They are largest and greatest in number to the east of the watershed, where they overflow into the drainage basins of two of Eastern Norway's major river systems – the Skiens watercourse and Numedalslågen, which run into the sea at Porsgrunn and Larvik respectively. The Kvenna river is part of the Skien watercourse and runs into **Møsvatn**, the biggest lake on the whole peneplain. While the natural level of Møsvatn is 902 masl, the dam regulates its maximum level to contour line 919 masl.

Both in the east and west, Hardangervidda terminates in sharp steep edges towards the glacial valley formations below. The typography is characterised by great height differences. Several valleys have the shape of deep incisions in the mountain massif, particularly around the northern end of the Tinnsjøen lake where the steep valley sides rise to 1 000 masl. Over a horizontal distance of 15 km from Gaustatoppen (1 883 masl) to the floor of Tinnsjøen lake, there is a height difference of 2 150 metres. **Vestfjorddalen** with Rjukan and the **Måna** river ends in Vestfjorden, a westerly inlet of the lake.

The surface soils in the valleys mostly consist of morainic and fluvial deposits. In many places the glaciers have dug deep into the ground, forming lake basins, with late Glacial morainic and fluvial deposits (sand and gravel) forming natural dams (e.g. Norsjø lake in

Telemark). What is peculiar to Skiensvassdraget is that the low-lying lake system extends from the coastal area and far into the mountain world of the interior. Skiensvassdraget (the Telemark watercourse) has a total catchment area of 10 772 km^2. The watercourse consists of three parts that converge in the Norsjø lake (16 masl). Tinnelva forms the eastern branch – the East Telemark watercourse. At the point where Heddalsvatnet lake overflows into the Sauarelva river, the catchment area of this watercourse is 4 073 km^2.

The **Måna** river has a total fall of 726 metres over a distance of approximately 30 km from Møsvatn to Tinnsjøen. Much of the fall takes place approximately 10 km below the Møsvatn Dam, where the river cascades down into a gorge. **Rjukanfossen** has a total fall of 238 metres, including a vertical drop of 104 metres. The name of the waterfall, which in translation means 'the smoking waterfall', can be ascribed to the shape of the gorge which 'pulverises' the water and gives it the appearance of rising smoke. From that point on, until it reaches Tinnsjøen lake, the Vestfjorddalen valley is in the shape of a U valley with an even and gentle fall and with high and steep valley sides prone to occasional rock slides and avalanches. Some alluvial plains have been formed, and in the lower part of the valley they transition into a small fluvial delta at the head of the Vestfjorden inlet. **Tinnsjøen** lake is shaped like a fjord and is extremely deep. With a depth of 460 metres, it is the third deepest in Norway and in Europe. It has an area of 51 km^2, and is long and narrow with steep shores. It lies 191 masl.

The water from Tinnsjøen flows into the **Tinnelva** river, and runs through a narrow valley with occasional wider sections. There are extensive morainic deposits in the valley, which form several terraces at the lower end towards Heddalsvatnet lake. It is on these terraces that we find the built-up areas of Notodden. The Tinnelva river travels 32 km from Tinnoset to **Heddalsvatnet** at 16 masl. Over that distance the river falls 173 metres, including 88 metres during the final 5 km. The river moves through rapids and cascades over ledges as it falls. The 43 metre high **Svelgfoss** waterfall accounts for the steepest drop. At the lower end of the valley, approximately 2 km from the mouth of the river, the **Tinnefossen** waterfall is inside the town of Notodden.

Climate

Southern Norway has a favourable climate compared with areas at the same latitude in Alaska, Greenland and Siberia. This is due to its position in the western wind belt to the east of a large ocean area and to the major, warm (7–9 °C) and stable ocean current (the Gulf Stream) that flows along its coast. The western winds bring humid air and precipitation as the air is pushed up over Southern Norway's mountain range. Western Norway gets most of the precipitation and is the wettest area in Europe, while the amount of precipitation gradually diminishes as the low-pressure areas move east. The Hardangervidda plateau has plenty of precipitation all year round, and the summer season is often not long enough to melt all the snow that falls in winter. On the western side, there are also permanent ice sheets and glaciers.

Because of the ample precipitation and the many small and large lakes, the watercourses that have their source on the plateau are naturally self-regulating. As a consequence of these factors, the Hardangervidda plateau represents a significant energy resource. **Together with the topographical conditions, the climate conditions provide optimum conditions for hydroelectric power production**.

Cultural conditions in general – the nominated area in a local and regional context

Settlement and community development

Settlement in the area is sparse and concentrated around the industrial communities, which in the municipalities of Notodden and Tinn have developed into towns with central urban functions. The municipalities cover a wide geographical area, much of which lies above the tree line. Except where the buffer zone includes urban areas developed after the towns were established (particularly since World War II), the buffer zone is sparsely populated.

As industrial communities, Notodden and Rjukan share important historical features. The pre-industrial communities were quite different, however. In pre-industrial times, Notodden was closely linked to and geographically a part of the rich agricultural communities of Telemark. Vestfjorddalen, the Tinnsjøen shoreline and the Tinnelva river valley, on the other hand, were outlying marginal areas of the villages to which they belonged. These were hilly areas with poor soil in which not many people settled and where forestry and marginal land were more important resources than cultivated land, in contrast to the old parishes if Tinn and Heddal. 'Tinn' was originally the name of the lake, but the name rubbed off on a collection of rural communities.

The industrial development was based a completely different view of what constituted natural resources than that of the rural community. The cultural heritage and environments from the rural communities that were based on traditional farming and outfield activities that existed before Norsk Hydro got a foothold in the area, have thus been only moderately preserved in the buffer zone. Cultural heritage from the partly marginal farming communities that were characteristic of the area prior to its industrialisation, stand in stark contrast to the nomination proposal's attributes and help us understand how unique and adventurous the new industries were at the time.

Since pre-historic times, the areas close to the big inland lakes and rivers have attracted settlement and other human activity wherever the natural conditions were not too harsh. While the Tinnelva river from Notodden to Gransherad largely featured strong rapids and steep gorges prior to the time of watercourse regulation, the river banks and lake shores between Gransherad and Rjukan, not least the shores of the Møsvatn lake, have attracted settlement as far back as the Stone Age. Along the Tinnelva river, between the centre of Gransherad and Tinnoset, we know of around ten settlements from the Neolithic Period. These settlements were never along the shoreline, but inland and close to the river where there was access to ample and varied resources. The shores of Tinnsjøen were also home to a number of known settlements from the Stone Age and later, but none of these have been investigated.

The **Heddal** valley west of Notodden is wide and extensively cultivated with several large farms. The long history of settlement on the good soil of marine sediments has contributed a rich cultural heritage stock with a long time line. The wooden Heddal stave church from the first half of the 13th century is the biggest of Norway's 28 preserved stave churches and stands out as the valley's most prominent cultural heritage monument.

Gransherad in Tinnedalen valley and Hovin on the eastern shore of Tinnsjøens lake formed a separate municipal district until they were amalgamated with Notodden in

1964. Gransherad translates as 'spruce district' and was, as indicated by the name, a typical forestry district. The church from 1849 is situated by the river. Further downriver stands Lisleherad Church, built in 1873. This is also the site of an older church. All the above-mentioned churches were built of wood.

Settlement in **Tinn** was concentrated in the narrow valleys separated by forest-clad hills at the northern end of the Tinnsjøen lake. At Atrå, a number of tombstones bear testimony to early settlement. This was the site of Atrå stave church, which was demolished when a new church was built in the 1830s (drawn by Hans Ditlev Franciscus von Linstow, the architect behind the royal palace). Tinn Austbygd got its own church in 1888. Mæl has also had its own stave church, assumed to have been built in the 12th century on a site that lies below the present church from 1840. Some way up the Vestfjorddalen valley stands Dale Church from around 1750, which was refurbished in 1845.

Population trends

Industrialisation brought a rapidly increasing population to the area. First of all came the workers known as navvies, who travelled to different parts of the country and took work where it was found. Next came the families that populated the towns in step with the housing developments. These two phases overlapped, and many working families had navvies as lodgers. Following the culmination of the processing industry, the population figures dropped, not least in the towns, but the population is now stable.

Rjukan in particular was a one-company industrial town with Norsk Hydro as the dominating company, and the population figures have always fluctuated as a consequence of economic fluctuations. Because Hydro was producing for an international market, the town was vulnerable in relation to circumstances far beyond its control. After an explosive growth during the first two decades after Hydro first set up business, a growth that was boosted by World War I, came the first downturn in the 1920s. After ups and downs in production in the years that followed, Hydro finally made the strategic decision in the 1960s to wind up its fertilizer production in Rjukan. Based on this decision, a continuous and controlled period of cutbacks followed until production was finally closed down at the end of 1991.

Except on the energy side, Hydro has now pulled out of Rjukan and also Notodden. Both towns continue as industrial towns, however, since a significant part of the population works in industry, now employed by a wide range of smaller industrial enterprises.

A modern phenomenon is holiday settlements in special 'cabin towns', where the holiday homes have attained a standard on a par with ordinary residential homes. This means that many more people are present within the municipal borders during certain seasons and at weekends than on ordinary weekdays. The Gaustablikk – Kvitåvatn area in Tinn is a very good case in point.

Population trends in the municipalities of Notodden and Tinn and in the industrial towns of Notodden and Rjukan.

Year	Notodden (the town)	Notodden Municipality	Rjukan (the town)	Vestfjorddalen	Tinn Municipality	Telemark	Norway
1900	849	4 917[3]	–	369[8]	3 237[3]	99 052	2 239 880
1910	4 918	8 963[3]	2 375	2 679	5 464[3]	108 084	2 391 782
1920	6 533[1]	11 180[3]	8 530[4]	9 277	12 170[3]	125 245	2 649 775
1930	6 192[2]	10 937[3]	7 881[5]	8 642	11 977[3]	127 754	2 814 194
1946	6 062	11 188[3]	5 460[6]	6 181	9 440[3]	131 679	3 156 950
2001	8 321	12 343	3 616[7]		6 490	165 732	4 520 947
2011	8 762	12 396	3 277[7]		6 037	169 185	4 920 305

Municipal amalgamations 1964: Heddal and Gransherad were amalgamated with Notodden (Jondalen in Gransherad became part of Kongsberg). Hovin was amalgamated with Tinn, with the exception of Rudsgrend which became part of Notodden. Figures from the population censuses carried out between 1900 and 2001.

1) Plus Svelgfoss: 166

2) Plus Svelgfoss: 140

3) Population figure in accordance with the municipal borders of 2002

4) Plus Vemork and Våer: 179, and Mæl (Rollag): 209. Total population in the Hydro settlements: 8 918

5) Plus Vemork: 289, and Mæl (Rollag): 248. Total population in the Hydro settlements: 8 418

6) Plus Vemork and Frøystul: 199, and Mæl (Rollag): 189. Total population in the Hydro settlements: 5 848

7) Plus Våer: 65, and Mæl (Rollag): 171. Total population in the Hydro settlements: 3 852

8) Dal parish in Vestfjorddalen

Following Hydro's decision in 1968 to wind up production in Rjukan over a period of time, Notodden feared that it would suffer a corresponding outward migration, but Notodden was able to restructure more successfully, based on organised initiatives. From 1960 to 1987, the population in the town centre dropped from 1 446 to 511, but most of those who left moved to the new housing developments east of town in the 1970s. In the course of the 1970s, however, Hydro implemented several rationalisation measures whereby employees were moved to Eidanger/Herøya or offered early retirement. Some professionals also left to take employment with Kongsberg Våpenfabrikk.

Business and industry

Today, **Notodden** is an important centre for commerce, the service industry and education. The town has varied industries, with an emphasis on the workshop, plastic processing, metallurgical and food industries. Some of the industry is concentrated in the industrial park that was established on the industrial site left behind by Norsk Hydro when it moved its core business out of Notodden in 2001. Notodden Industrial Park is home to around 50 enterprises.

When Norsk Hydro celebrated its 75-year anniversary in i 1980, 600 persons were still employed by Notodden Fabrikker AS in Notodden. At that time, it was largely the packaging department that generated a profit. A laminate factory established in Hydro Industrial Park in 1968 moved into a new building at Tuven and was taken over by Norske Skogindustrier AS in 1984. The workforce employed by Hydro's factories in Notodden reached its lowest level in 1984 with 230 employees. In 1985, the packaging factory was also sold – to Isola Fabrikker AS. The Tinfos ironworks (ferrosilicon production) were closed down in 1987. An industrial estate has been established at Tuven, approximately 2 km west of the town centre at the lower end of the Heddal valley. The area features workshops and industrial enterprises, but is dominated by retail showrooms for cars, as well as other car-related retailers, warehouses and various service enterprises. The retail trade in Notodden's town centre has suffered as a consequence. Heddal is one of Telemark's most fertile agricultural communities, while Gransherad in the north is based on forestry. Notodden has Telemark's second biggest logging industry (after Skien), with a total felling volume of 69 900 m^3 in 2003 (14% of the total for the county).

Throughout the 20^{th} century, **Tinn Municipality** depended on Hydro's industries in **Rjukan** for employment. After World War II, the number of employees remained stable at almost 1 700 until the 1960s when Norsk Hydro increasingly transferred its activities to Porsgrunn. Today, Tinn has approximately 25 industrial enterprises employing around 400 people. Most of these enterprises are located within Hydro Industrial Park in Rjukan, with the chemical industry (employing 41% of the total for the industry, including rubber and plastic, in 2004), workshop industry (37%), metallurgical industry, graphics and food as the dominant industries. Another industrial estate has been zoned and established at Svadde in Vestfjorddalen, which is located east of Rjukan but is connected to the newer parts of the town. Tinn Municipality is one of Norway's most important power-producing municipalities, with the power obtained through regulation of Møsvatn and Mår/Gøyst on the Hardangervidda plateau representing an average annual production of 4 TWh, or 3.2 % of Norway's total hydroelectric power production.

Tinn also has some agriculture and forestry. Logging forms the basis for some timber industry. In 2004, the felling volume totalled 48 100 m^3, consisting mainly of spruce.

Hydroelectric power production

Today, the **East-Telemark watercourse** is important for hydroelectric power production and as a waterway. The lakes and rivers are no longer used commercially except by tourist vessels on the mountain lakes of Møsvatn and Mår. Timber floating was an important part of the forestry industry, and was carried out using tugs on Tinnsjøen and Heddalsvatnet lakes, on the Tinnelva river and in timber flumes past the power station. Floating to Union Bruk AS in Skien continued until the saw and planing mill closed down in 2006, when floating on the Telemark watercourse stopped, marking the end of all floating in Norway. During the final period of floating the logs were stacked to form cross rafts ('soppe'). Notodden had a tipping station for logs carried by lorries: One lorry load of 20 m^3 was equivalent to a 'soppe'.

Some of the power plants in the Telemark watercourse are very old and have not been subject to concessions. Timber floating, which is the oldest business associated with the East-Telemark watercourse, was organised via the local forest owners' association ('Øst-Telemarkens Brukseierforening' – ØTB). It is ØTB that is responsible for water level regulation in relation to Rjukan – from the Møsvatn and Mårvatn lakes down to the mouth of the Tinnelva river in Notodden. That is why Norsk Hydro has ownership interests in ØTB, together with Tinfos AS and Statkraft SF, among others. Statkraft SF owns some big plants in the mountain areas near Mår in Tinn Municipality. Power stations and dams over and above those that are covered by the nomination proposal's attributes, are those that were built by someone other than Norsk Hydro, or that were built by Hydro after the second world war. These plants may be located inside the water string or be connected to it via a tunnel, and are seen as being within the world heritage buffer zone. Where a new plant has been built to supplement or replace the original plant as part of a modernisation process, the new part of the plant is described below.

The approximately 30 km long **Måna** river between the Møsvatn and Tinnsjøen lakes has 5 power plants that make up what is known as the 'Rjukan String'. The Frøystul, Vemork, Såheim, Moflåt and Mæl plants are all owned by Hydro Energi. Between 1990 and 1996, all these power plants were modernised and the mechanical equipment and waterways were upgraded to the current standard. At the same time, production was increased by approximately 8%. Over the whole distance, there is a total fall of just over 700 metres. The two more recently built power plants downstream from Såheim utilise the modest remaining fall of 92 metres down to Tinnsjøen lake. The water in the Måna river is routed from the dam into a headrace tunnel with the power plant at the lower end. Several ledges have been arranged to provide water surfaces in Måna's dried out riverbed.

The old **Frøystul power plant** from 1926 has been demolished. It was closed down and replaced by a new power plant in 1995, when the Rjukan String was being modernised. The plant is in a rock cavern and utilises the fall of 61.5 metres between the Møsvatn Dam and the Skarsfoss Dam in the Måna river. The plant has one Francis turbine, with an installed output of 47 MW and an average annual production of 217 GWh. It belongs to Hydro.

The **New Vemork power plant** was built in 1971 inside a rock cavern behind the old station on the eastern side of the river. The exterior part is a Brutalist-style concrete structure, drawn by the architect Geir Grung. A new headrace shaft has been blasted from Vemorktopp for supplying water to the underground plant. Two Francis turbines have replaced the 11 turbines in the old power station building. When the old Vemork plant was phased out, the installed output was 132 MW, while the new plant has an installed output of 203 MW and an average annual production of 1 143 GWh.

Moflåt power plant was built in a rock cavern approximately 5 km below Såheim, and utilises the Måna river's fall of approximately 46 metres from there. The water is routed through a tunnel from the dam at Mæland below Såheim. The plant was put into operation in 1954 and is equipped with one Francis turbine. It has an installed output of 30 MW and an average annual production of 162 GWh. The portal in front of the station is made of natural stone, echoing the old Vemork.

Mæl power station was built in a rock cavern near to where the river Måna runs into Vestfjorden in Tinnsjøen lake. It utilises the fall of 47 metres from an intake dam downstream of the tailrace from Moflåt power station, and also receives tailrace water from Mår power station which is collected in a dam at Dale. The plant was put into operation in 1957 and is equipped with one Francis turbine. It has an installed output of 38 MW and an average annual production of 219 GWh.

Mår power station is situated at Dale, east of Rjukan's town centre. It does not belong to the Rjukan string of power plants as it does not utilise water from the Måna river, but rather the fall of the rivers Mår and Gøyst that run into Tinnsjøen lake at Åtrå. The catchment areas of these rivers on the Hardangervidda plateau have been connected by building a dam across Kalhovdfjorden in the Mår watercourse and the Strengen Dam across Gøystvatn lake at Gøyst. Work on the regulating facilities was started by the German occupying power in 1942, with a view to supplying electric energy for the production of aluminium and magnesium at Herøya, intended for use in *inter alia* German aircraft production. The construction work was stopped following the American air raid on Herøya on 25 July 1943. When the war ended, the Norwegian state took over the partially constructed plant. The two first generator sets were put into operation in 1948, followed by the final three between 1949 and 1954. The five Pelton turbines have an installed output of 200 MW and an average annual production of 1 145 GWh. The hall for the generator sets and transformers was blasted out of the rock. This plant was one of the world's first big power plants to be established inside a rock cavern. The plant utilises a head of 823 metres. The 250-metre-long penstock shaft has 3 875 wooden steps forming one of the longest stairs in the world. The power plant is owned by Statkraft SF.

Of **Tinnelva's** total fall of 175 metres from Tinnsjøen lake to Notodden, 140 metres are currently being utilised by five power stations. The two waterfalls at Årli and the Grønvollfoss, Svelgfoss and Tinnfoss waterfalls have been developed to provide a total output of 182 MW. Hydro's first power station Svælgfos I, and the Svælgfos II and Lienfos power stations with which it was supplemented, have all been demolished and replaced by the new underground Svelgfoss power plant belonging to Hydro Energi.

Årlifoss power plant is a river power plant without a regulating reservoir. It utilises the energy of the two waterfalls at Årli in the Tinnelva river approximately 7 km below Tinnoset. The plant was built between 1912 and 1915 based on the drawings of Olaf Nordhagen, who had also drawn Vemork Power Plant. The plant was rebuilt in 1989, with the construction of a new power plant on the eastern bank of the river holding one Kaplan turbine. It has an installed output of 22 MW and an average annual production of 131 GWh. The old power plant on the western bank of the river had four generator sets. It was the first power plant built by the municipal power company Skiensfjorden kommunale kraftselskap (SKK). It was phased out when the new plant was completed. It is currently owned by Skagerak Kraft AS.

Grønvollfoss power plant is a river power plant in the Tinnelva river without a separate regulating reservoir, utilising the fall of the Grønvollfossen waterfall and the rapids above. It was built between 1931 and 1933, based on drawing by Thorvald Astrup, who had also drawn Såheim power station among others. The power plant was put into operation in 1933. It was modernised in 1985. It has an installed output of 26 MW and an average annual production of 162 GWh. The power plant is currently owned by Skagerak Kraft AS. The flood capacity of the dam was increased in 1997.

The current **Svelgfoss power plant** is a reservoir plant that uses water supplied through a tunnel from Kloumannsjøen. Since 1958, it has replaced the three former Svælgfos I and II and Lienfos power plants, utilising a total head of 70 metres. The plant has two Francis turbines, with an installed output of 92 MW and an average annual production of 523 GWh. It is owned by Norsk Hydro (70.8%) and the Hjartdøla Group, and is remotely operated and managed by Hydro Energi from its control centre in Såheim power station in Rjukan.

New Tinfos I power plant from 1955 is a Functionalist-style building typical of its period, with wide surfaces and simple cubist volumes. The building is of painted concrete and lacks ornamentation. The plant has two Kaplan turbines that handle a total water flow of 160 m^3 per second, and an installed output of 2 x 27 MVA, with an average annual production of 210 GWh. A control station building has been erected just south of the power station building. It is an unpainted concrete building from 1992. The power plant utilises the total fall of the Sagafossen and Tinnfossen waterfalls of 29.5 metres. The station is owned by Tinfos AS.

2b. History and Development

Development of cultural history

The places and the region before the industrial era, general overview

This map, Episcopatum Stavangriensis, Bergensis et Asloiensis, was drawn and coloured by hand in 1636–1642 by the famous Dutch cartographer Johannes Janssonius (1588–1664), known as Jan Jansson in English-speaking countries. Telemark is the white area in the middle of the map.

For a long time, the innermost parts of Telemark county were regarded as something of a closed world. A map called *Episcopatum Stavangriensis, Bergensis et Asloiensis*, which was drawn and coloured by hand in 1636–1642 by the famous Dutch cartographer Johannes Janssonius, illustrates the public's perception of this area. Historically, 'Tellemarck' can be understood to mean the inner part of the county, the land of the 'Telene' people, while Grenland and Vestmar were names for the coastal areas, which were also more accessible, fertile and open landscapes. Grenland and Telemark are both place names that may date back to the Migration Period (the Iron Age) and that refer to the 'Grener' and 'Teler' tribes. Ever since the medieval times, the people of Telemark were seen as quarrelsome, and their merits included murders of bailiffs and peasants' revolts.

The inner part of Telemark, in which the nominated area lies, has a rich cultural history. It was largely dominated by independent farmers, and Telemark is regarded as a core area for Norwegian building traditions and Norwegian folklore in general. This is where the cog-joint technique and the Western Norwegian stave and trestle-frame technique come together in wooden architecture. In the Norwegian context, Telemark has by far the most preserved buildings from the pre-Reformation period, i.e. the Middle Ages. In terms of numbers, it is primarily timber farm buildings for housing and storage (*stabbur* and *loft*), but also wooden stave churches (Eidsborg stave church and Heddal stave church), of which Heddal is the biggest in Norway, as well as a number of stone churches. In the six-volume work on Norwegian timber houses from the Middle Ages by Arne Berg ('Norske tømmerhus frå mellomalderen'), two of the volumes are dedicated solely to Telemark. More specifically, they refer to the upper parts of the county, which, together with the neighbouring villages in the upper part of the Numedal valley and the inner part of the Agder area (the Setesdal valley), constitute a distinct focal point for medieval buildings in Norway. Tinn and

Traditional Telemark architecture, loft & bur (storage buildings) at the farm Mo Øvre in Vinje. Photo: Unn Yilmaz © Riksantikvaren.

Notodden (and Hjartdal) are situated in the centre of this area, and all contain a significant number of automatically listed buildings, most of which are storehouses ('stabbur and lofts') in farmyards. There are also small cottage-like buildings. The building traditions, which partly date back to the Middle Ages, seem to have been kept alive well into the modern age.

Telemark has long been involved in mining because of its geology, with a large number of deposits of usable rock, metals and minerals. From the Migration Period onwards, Telemark was an important supplier of whetstone, which was transported from quarries near Eidsborg in the inner part of the county to Skien and then on to Europe. Mining operations started as early as around the Reformation, when the King sent German miners to Norway to develop the mines. Mines were set up in several places, including in Fyresdal (chalcopyrite) and Seljord. Privileges for mining were given in the form of royal privilege letters, in which farmers were also ordered to carry out driving work and other work, at a price set by the King.

There was also mining in Hovin, now a part of Tinn Municipality, probably from the first part of the 17th century, when Fosso was the centre of Telemarkiske Kobberwerche's (copper works) activities, including a stamping mill, smelter and bellows by the Masomnfossen waterfall. The copper ore came from scattered mines, and the miners were German. By around 1660, the works had been closed down. In 1903, Tinnsjø Kobberminer (copper mines) started operating a new copper deposit. A laundry building and workers' huts were built. The level of activity was high for a few years, but transport was awkward. The ore was transported down to Tinnsjøen lake and shipped on barges to Tinnoset, where it was reloaded onto the railway. Operations slowed from 1913 and were eventually discontinued. The remains of buildings, mine galleries and deep shafts can be found in several places. At Tinnsjøen, the quay was blasted out of the rock.

Mining and good access to hydroelectric power led to the early establishment of industry in Telemark. One example is ironworks, of which Ulefos Jernværk from 1657 is Norway's oldest running company, now operating as a iron foundry. Sawmills also became widespread after the gate saw was taken into use. The formation of Norsk Hydro in 1906 marked the start of modern industrial history in Norway, and Telemark is still one of the most important industrial counties in the country.

Historical preconditions for the industrial success story; the national context

Three historical conditions in Norway played a decisive role in why the large factories for the production of calcium nitrate, and consequently also the industrial towns, were set in the inner parts of Telemark:

- **The Telemark Canal**: the fact that the river system was canalised and connected to the open sea through the locks at the Skotfoss waterfall (Løveid canal) and in Skien (Klosterfossen);
- **Tinfos AS and the Tinfos I power plant**: the fact that in Notodden, which lay by the inland route to the sea, electric power was available from the power plant that the industrial company Tinfos had already built;
- **The Rjukanfossen waterfall**: the fact that it was possible for Sam Eyde to buy the rights to Rjukanfossen.

These conditions all have their own historical background. Because they affect the unique event represented by the formation of Norsk Hydro's calcium nitrate plants, a more detailed account of these conditions is required. This is provided in the following sections.

The use of the watercourses

The rivers and lakes have been used for transport for as long as the areas they run through have been inhabited. This transport has included migration and goods transport, by boat and other vessels in summer and by sled and other means when the water has frozen over. Flood situations, especially meltwater floods in spring, have been exploited for timber transport in the form of log driving. Adaptations have been made in the rivers and lakes to ease all these transport services, such as canalisation for boat transport and dams, timber flumes, guiding walls and other devices for timber floating. Timber floating on the East Telemark river system was practised in a modernised form using tugboats up until 2006, as the last place in Norway and the second last in Europe.

Timber floating. Erik Werenskiold for Norwegian bank note, 1938.

Timber floating. Trouble beneath Tinnfossen waterfall. Photo: Notodden Historielag.

The power of water has been exploited for many centuries. Running water has been the source of energy for crafts and industry. The waterwheel ran mills, saws and bellows for ironworks. Small and large waterfalls have run gate saws and mills all around Telemark. The first gate saws in Norway were used in the 16^{th} century. The gate saw revolutionised the timber trade. The new technology that made it possible to cut materials into planks in larger quantities using hydro power meant that timber could be exported. Several towns along the coast grew and prospered because of this trade, including Skien. Hydro power is also used for pulp mills, ironworks and other industry. In the mid-19^{th} century, the steam engine burst onto the industrial scene. Several saws were now powered by steam, and the steam engine made it possible to develop new industry. The steam engine meant that the factories no longer had to be located by the waterfalls.

The history of Skiensvassdraget watercourse is the story of how the floating associations, the canal company, the plant owners, the steamboat companies, the municipalities and the big industrial companies viewed how the watercourse should be regulated and the water be used. The interests could be concurrent or highly diverging.

There were sawmills in the Tinnelva river, as well as in Sagafoss, and the Tinnfossen wa-

Tinnfossen waterfall with Myrens Dam and saw mill to the left. Postcard from around 1900.

terfall was used for mills at an early stage, and then gate saws and a stamping mill. In order to exploit the fall, a manageable part of the water had to be diverted. A 55-metre-long tunnel was therefore constructed by fire-setting through the rock past the waterfall between 1790 and 1807. Timber floating down Heddalsvatnet lake is as old as the sale of timber to Grenland and abroad. There were tipping stations by the lake, including one at Tinnesand, to which some timber was transported, but most of it was floated down the rivers. By the mouth of the Heddøla and Tinnelva rivers, the logs were made into log rafts and hauled or sailed down the water.

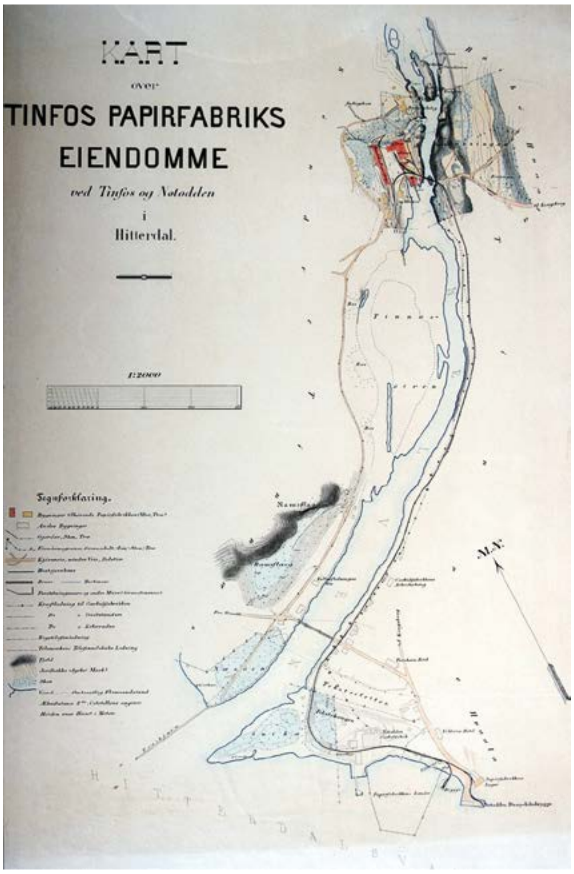
Timber floating on the Tinnelva river was particularly difficult. Svelgfoss was especially difficult when the water level was low, as was Tinnfoss when it was high. Improvements were made to the watercourse following a convention of 1843. It mentions extensive works that it recommended be carried out, especially at Tinnfoss and Sagafoss, concerning retention dams and blasting. The timber floating was not adequately secured until the 20th century, however, when the waterfalls were developed into power plants.

Tinnsjøen was regulated in 1889–1890, and Tinnoset dam created a regulating reservoir of 110 million m^3 of water. This way, the plant owners in Skien secured a more even flow of water. The regulation also opened up new perspectives for the owners of the waterfalls in Tinnelva, and with regard to regulation of the lakes on the mountain plateau; Møsvatn and Mår.

Industry before 1900

A background for the development in Notodden is the establishment of pulp mills at the lower end of the river system, near Skien, around 1870. They based their activities on the export of wood pulp. One of the pulp mills, Laugstol Brug, also became the first electricity company in the country in 1885, when it installed a Francis turbine for electricity production to provide better and less hazardous lighting for its own premises. It was here that the electric incandescent lamp was introduced to Norway. The company then started supplying electric power to customers in the surrounding area.

In Notodden, **AS Tinfos Træsliberi (pulp factory) was founded in 1872**. The company leased the waterfall under an irrevocable contract. The enterprise was a product of the boom period during and after the Franco-German war, an investment object offering high, rapid returns on capital. The founders were mainly people from Kristiania (Oslo). However, the plant did not come into operation until 1875, by which time the price of wood pulp had fallen. The plant was sold in 1877, and the new owners modified and expanded the business. Bigger turbines were installed, a paper-making machine was put into production, and the name was changed to Tinfos Papirfabrik (paper mill). When the waterway to Skien was covered in ice, the products were exported by horses over the Meheia hill to the railway at Skollenborg (siding on the Randsfjord Line to Kongsberg, opened in 1871). Because the Tinnelva river was not regulated, the water flow was uneven. Activity at the



This croquis shows the paper mill and the power plant below Tinnfossen, the horse-drawn railway and the power line down to the carbide plant and the quay at Tinnesand by Heddalsvatnet lake.

plant often ceased for parts of the summer, and also often in winter. Part of the workforce was employed in both industry and agriculture at cotters' farms. Workers who moved from other places were housed in special wooden huts at Tinnesmoen, which were later burnt down. The number of workers varied from an average of 59 in 1885 to as many as 140 in 1890.

The factory built a horse-drawn railway from the pulp mill down to a loading place by the quay (1882). The line was on a slight downhill incline and could also be used to transport timber upwards. An electric dynamo was installed that provided light for the company. Another used paper-making machine was bought and a new factory was built next to the old one in 1888. However, the old factory burnt down, and transport links were awkward, so the owner gave up. Tinfos Papirfabrik was sold as a bankrupt estate in 1894. The winning bid came from a partnership of five gentlemen, two of whom were the Holta timber trading brothers from the neighbouring village of Sauherad.

The waterfall was developed immediately afterwards. The wooden dam from 1873 was demolished and a stone water inlet was built. A pipe ran from this reservoir that could carry water equivalent to 8 000 horsepower to the turbine down in the factory. The paper mill from 1888 was closed down, and the new owners expanded operations. In addition to the old pulp mill with two pulp stones, a new mill with three pulp stones was brought into use in 1898. In addition to the pulp mills, there were sawmills and planing mills, and the factory was surrounded by the manager's and engineers' houses as well as houses for the workers – 30 houses in all.

Industry builds power plants

The owners who took over Tinfos Papirfabrik quickly started expanding in order to utilise the waterfall power more effectively. In 1894, the factory's water turbines had an output of approximately 700 horsepower. This was increased to approximately 2 000 horsepower when the new pulp mill started up in 1898 and the diameter of the tunnel had been increased. Plans were immediately made to create a new electric power plant and a new industry to use this power. The choice was **carbide**, a young branch of industry that had just been introduced in Norway. The company built the **Tinfos I** power plant in 1900, also with a view to supplying power to the calcium carbide plant in Notodden, for which it was also responsible. Tinfos I went through two expansions in its first nine years. The latter was not completed until the decision regarding a new power plant, **Tinfos II**, had been made. The company's plan to establish an ironworks in Notodden triggered the need for more power.

When Sam Eyde and the company Norsk Hydro were ready to set up a testing plant for nitrate fertilizer, they began operations using available electric power purchased on contract from the first power plant by Tinnfossen. The Tinfos Company's activities were affected by cyclical fluctuations, which at this point had resulted in low prices, and it needed revenues. The power contract was conditional on the interests behind Hydro being allowed to buy the rights to Svelgfoss; these were controlled by Tinfos but expensive to develop.

Transport and communication

Notodden is located approximately 70 km (as the crow flies) from the coast, but only 16 metres above sea level. People from the villages to the north and west used to come down to Heddalsvatnet lake, where, in summer, they could row roughly 50 km to the southern tip of Norsjø lake (Fjærekilen). In winter, the ice was used for sledding. In addition to the traffic routes that come together at the north end of Heddalsvatnet, there is the road connecting the east and west, the road across Meheia to the mining town of Kongsberg and the low-lying areas around the Oslofjord. Notodden was at a crossroads of many different routes. It was not a tourist destination, however, but a place where goods could be unloaded from land-based transport and onto sea-based transport.

Upstream of the Lienfoss waterfall, a ferry crossed the Tinnelva river, on an old route that went via Lisleherad and Bolkesjå to Kongsberg. Road construction in the area did not pick up pace until the 1820s and 1830s. A road was then constructed from Skien along the west side of Norsjø and the east side of Heddalsvatnet to Tinnfossen, where the bridge was completed in 1832. Construction of the carriage road across Meheia had begun at the same time, and it opened in 1839. Work in the silver mines had been discontinued for some time, but had now resumed, and Kongsberg went through a prosperous period with increased trade. In addition to this competition, the tradesmen in Skien saw that the number of village shops had increased in the surrounding area, and realised that something had to be done.

The Telemark Canal and the steamboats

In the 1840s, the long-standing idea matured of making transport between the town of Skien and Norsjø lake easier by building a canal past the Skotfoss waterfall. A steamboat service was set up from Fjærekilen to Gvarv and to Tangen in Heddal from 1852, with a paddle steamer that carried passengers and goods and hauled timber. The canal route that was agreed on (1854) went from the Klosterfossen waterfall where the Skienselva river was navigable, and up into Norsjø. The canal was officially opened in 1861. At the north end of Heddalsvatnet, the landing at Tinnesand was replaced by a new quay, called Kanalbryggen (the 'Canal Quay') (see *supporting values* in 2.a), which was completed in around 1876. From 1894, traffic that had previously used the Tangenbrygga quay near the mouth of the Heddøla river began to call at this quay instead, and **Notodden thereby became the gateway to both Heddal and Tinn**.

A steamboat service was also set up at Tinnsjøen in 1864. Traffic then increased from the Skiensfjord up to Tinn and the Rjukanfossen waterfall and Gausta. Traffic increased further when Skien got a railway connection to Kristiania (Oslo) in 1882. The Sauarelva river between Norsjø and Heddalsvatn was deepened, so that bigger boats could operate the service on the eastern lakes and the season be extended when icebreaking started in 1880. In 1890, there were as many as 13 steamboats in service on Norsjø. Two boats went each way every day during summer. The journey from Skien to Notodden normally took five hours, which was reduced to 3.5 in 1896. Big hotels were built in Notodden, including the Victoria in 1876 and the Furuheim in 1879, which later also comprised a posting station, postal service and a telephone exchange. Telemarkens Telefonselskab (telephone company) started operations in 1889, and the first main line went from Skien via Ulefoss to Notodden and onwards to Bolkesjø and Tinn.

Historically, the settlements by Tinnsjøen had been isolated from the communities further out, with Tinnsjøen acting as a barrier between the high mountains. The steamboat traffic changed this. At **Sigurdsrud** near Atrå, a village centre developed around the quay and trading houses. Until the car took over in the 1960s, this was the 'urban centre' for the people of Tinn, with a shop, bakery, bank, telephone exchange, sheriff's office, blacksmith, taxi service and petrol station. The cluster of houses and the quay still clearly speak for themselves. In the lake outside lies the 'D/S Tinn', which, after having been built at Sigurdsrud, sank during its launch in 1910.

Sigurdsrud village centre by Tinnsjøen Lake. Photo: Trond Taugbøl.

Travel and tourism

Telemark is one of the cradles of modern tourism in Norway. The reasons are related to both European cultural history and some of the magnificent natural phenomena in Øvre Telemark, particularly the Rjukanfossen waterfall, but also Mount Gaustatoppen. The date can be set in the early 19th century. Europe had just seen the Age of Enlightenment, advances in natural science and changed conceptions of man's place in nature. This led to the Romantic Era, and in turn National Romanticism. National uprisings partly based on cultural individuality took place in several countries, including Norway. In addition, a bourgeoisie had emerged in several countries and cities, with the financial means to engage in leisure travel.

Rjukan and Gaustatoppen were visited in 1810 when the naturalist (geologist, chemist, surveyor) **Jens Esmark** (1763–1839) went to Telemark together with the botanist **Christen Smith** (1785–1816). Esmark was of Danish origin, but was sent to Kongsberg to study mineralogy in what was then the country's biggest mine. In 1802, he started teaching at the Mining Seminar (Bergseminaret). Several of the mines were starting to become exhausted, so the mine was closed down for a time from 1805. During this period, Esmark travelled to Telemark, including to the former copper mines in Hovin, driven by commercial interests, i.e. the desire to find new mineral deposits. At the same time, however, he took a professional interest in surveying and had heard rumours of an enormous waterfall just below the summit of Gaustatoppen, a mountain that no one had climbed. The mountain towered so high that people wondered whether it was the highest in Norway, but no one knew for certain.

Esmark is considered the first person to have climbed Mount Snøhetta in August 1801, and by using a barometer to measure pressure differences, he estimated it to be 'just over 8 000 Rhineland feet', equivalent to about 2 510 metres. The current designation is 2 286 metres. Together with Christen Smith, he was the first person to climb **Mount**

Gaustatoppen in 1810. By measuring its height to 1 911 metres (compared with the current designation of 1 883 metres), he was able to ascertain that it was lower than Snøhetta, and therefore could not be the highest mountain in Norway. **What was to become important for Norway, however, was Esmark's measurement of the height of Rjukanfossen's vertical drop.** The result was 432 ells, equivalent to 271 metres. The measurement was based on telemetry using a barometer, because the gorge below the mighty waterfall was completely inaccessible. Esmark reported to Vice Governor Friedrich of Hessen-Kasel in Christiania of *'the tallest of all known Waterfalls, not only in Europe but even in the World'*. King Frederick VI in Copenhagen took an interest in the discovery, and in 1812, he signed a royal degree in which Hessen Kasel at Akershus castle was requested to investigate the possibility of using Rjukanfossen for the public benefit. It was not until the late 19th century that the correct height of the waterfall's vertical drop was set at approximately 105 metres, out of a total fall of 238 metres.

Johannes Flintoe: The biggest waterfall in the world (1821).

Drawing of Rjukanfoss waterfall by Chr. Tønsberg from the book 'Norge fremstillet i Billeder' (Norway in images) from 1848.

Copenhagen's and Christiania's great interest in 'the world's tallest waterfall' meant that the Vestfjorddalen valley attracted a horde of tourists. The waterfall was a tourist destination that, together with free Norwegian farmers, was in tune with the interests of Europe's and the USA's upper classes, adventurers, artists and scientists, and it became a huge tourist attraction in the pre-industrial period. **Telemark has consequently played an important role in the development of tourism in Norway**. The inner parts of Telemark and the mountains were made famous by the National Romantic painters Johannes Flintoe, W Carpelan, J C Dahl and Joachim Frisch. In the decades after 1814, the conditions for tourism were poor in Norway, and these areas were inaccessible to most people. Food and accommodation services were needed. Several farms eventually began to offer such services, including Håkanes, Miland, Dale and Ingolfsland in Vestfjorddalen. Ole Torjerson Dahle

(1798–1884) recognised the need and started offering guided mountain walks and accommodation when he took over his father's farm in 1830. He was the first person to erect a house solely intended for tourists. In the 1850s, the famous British travel guide publisher John Murray created a dedicated route to Rjukanfossen using Dale as the accommodation. Thomas Bennett, who later set up a successful tourism enterprise, also secured his own route on which the entrepreneur at Dale was host: 'Route 20 from Christiania (Oslo) to the Rjukanfos'. When steamboats were put into service on Tinnsjøen lake in the 1860s, hotels were built by Tinnoset and Fagerstrand (by Vestfjorden on the north side).

Among the travellers was French author **Jules Vernes** (1828–1905), who came to Vestfjorddalen in 1862 and stayed at Dale posting station for an extended period. In the novel 'The Lottery Ticket' ('Un billet de loterie', 1886), the depiction of the setting takes place in Vestfjorddalen. In Jules Vernes' own words: *'All this is indescribably beautiful and comes across as the most charming country in the world. To put it briefly: Dale is in Telemark, Telemarken is in Norway, and Norway is Switzerland with thousands of fjords where the sea breaks against the foot of the mountain.'* Many other famous people from Norway and abroad have registered their names in the guest book at Dale posting station, including authors, painters, linguists and historians. Crown Prince Oscar (1829–1907) and Crown Princess Sofie (1836–1913) of Norway and Sweden visited the waterfall before they were made King and Queen in 1872. Examples of foreign names from the visitor's book are: August Moritz and Albrecht Pancritius from Germany; Alfred, Lord Tennyson (1809–1892, poet), Charles, 2nd Baron Teignmouth, (1796–1885, politician) and James Randell from the UK; Bayard Taylor (1825–1878, poet) and Alfred Corning Clark (1844–1896, school and business man) from the USA, and Paul Riant and Jules Leclercq from France.

The Norwegian Trekking Association (DNT) was founded in 1868. The same year, it bought the farm **Krokan** in order to 'ease access to places of particular distinction because of their natural beauty'. The price was 400 *spesidaler* paid over 10 years. The steep, upper part of Vestfjorddalen had no roads at that time, with the cascading Rjukanfossen in the background and Mount Gausta towering majestically to the southeast. A more dramatic, scenic place could hardly be found. Krokan was a cotter's farm under the Fosso farm until it became a separate farm in 1856. Fosso was situated at the top of **Rjukanfossen's** canyon, and access to Krokan some hundred metres further down was via the steep and dangerous rocky path called **Maristigen**. Krokan was opened as a trekking association cabin in 1871 and is considered to be the first of its kind in Norway. The fact that this happened in Telemark is down to Rjukanfossen and Gausta, but first and foremost the steaming waterfall, because 'people seemed to be smitten by waterfalls'. Historian and geographer Yngvar Nielsen, who was president of DNT for a number of years around the turn of the last century, and who published the popular 'Reisehaandbog over Norge' (Travel handbook of Norway) from 1879, otherwise writes about the scenery of Telemark that it is romantic and appealing with 'grace and variety', 'in several places, it is also characterised by grandeur.' Hymn writer M B Landstad wrote in 'Norske Folkeviser' (Norwegian folk songs) (1853) about Telemark that *'its remote location...when you come across Medheien to Hitterdal or Gransherred, any stranger will be surprised by the antique scenery that suddenly appears before him in the form of houses, costumes, language and ways of life'.*

The number of visitors at Krokan was never very high, because, although relatively many people stopped by, far too few stayed the night, which generated little money. With time, the number of tourists to Vestfjorddalen increased so much that the investments needed far exceeded DNT's capabilities, at the same time as tourism took a clear commercial turn. When the road from Våer to Krokan was constructed in 1892, access to the waterfall became easier. Then, in 1896, the state blasted away Maristien to make a carriage road from Krokan to Fosso, and the footpath disappeared. Fosso farm had been purchased in 1895 by bankers from Skien who wanted to turn it into a tourist hotel. DNT did not see it as its task to run competing tourism enterprises, but to be pioneers. The board of the association had no interest in keeping a tourist cabin that was now situated right next to a 'high road' and discontinued its activities at Krokan the next year. Krokan was then leased to a consortium that built **Rjukan Hotel** by Fosso on the edge of the Maristijuvet gorge. The hotel opened in 1897, and it was a sophisticated and fashionable place. The waterfall itself was floodlit in 1898 using electric power generated by a dynamo, and the hotel was supplied with power so that guests could play billiards in electric light in the billiard hall and on tennis courts right on the edge of the gorge. This meant that Rjukanfossen became one of the first waterfalls in Europe to be lit up by electricity it had produced itself.

Rjukan hotel at the top of the waterfall. The main building now stands at Mæl and is used as an inn (Tinnsjø Kro). The hotel is on the right. Photo: Directorate for Cultural Heritage.

Developments in traffic were the reason why the thriving tourism in Rjukan took a different turn. In 1892, the Telemark Canal from Skien to Notodden was extended with a western course to Dalen, the Bandak Canal. Dalen hotel with its extravagant 'dragon style' opened in 1894, when the mountain road across Haukelifjell to Odda in Hardanger was constructed. Hotels were built at Seljestad and in Odda. The fjords of Western Norway took over as the ultimate tourist destination in Norway. In the years before industry arrived in the area, Tyssedal and Odda were the biggest tourist destination in the country. It was visited by the British aristocracy, Arabic sheiks and Kaiser Wilhelm II every year on his yacht, the 'Hohenzollern'. The area was packed with fjords, mountains, glaciers and waterfalls, and the most spectacular of all were Ringedalsfossen and Tyssestrengene, the two waterfalls in the Skjeggedal valley. The latter of them was deemed to be the tallest waterfall in Europe.

Rjukan Hotel had been a huge attraction, but it went bankrupt after only four years. The property then went back to DNT, which the association ran at a loss. The waterfall was then the object of a speculative acquisition involving several parties, only to finally be bought by the company **AS Rjukanfos**, founded by Sam Eyde in 1903 for entirely different purposes than tourism. DNT's conditions for the sale were that the hotel be included. The purchase price was NOK 8 000. In 2003, DNT (represented by the Helberg foundation) bought back Krokanhytta cabin for NOK 1, with the intention of presenting the cultural heritage of the mountain and the association's own role in its history. The Krokan cultural environment at Rjukanfossen is described under *supporting values*, page 213-215.

Waterfall acquisition

Norwegian hydroelectric power has certain characteristics that differ from other countries with extensive hydroelectric power. Some of these characteristics could bring great comparative advantages. Initially, interest focused on the wide, slow rivers of Eastern Norway, with short waterfalls that were very similar to rivers in Europe. However, the majority of Norwegian hydroelectric power is not found in the rivers of Eastern Norway, but is associated with the watercourses in the west, which have less water but much higher falls. If Norway were to become an electricity country based on its own sources, there had to be ways of exploiting waterfall power in smaller and more remote watercourses. This entailed a financial risk for waterfall buyers. One advantage is that the many high-lying lakes of the Norwegian mountain plateaus can, with relatively modest regulation, serve as reservoirs for hydroelectric power plants. This distinguished Norway from countries like Switzerland, where the mountains are steeper and reservoirs often require huge dam structures to be erected. Also Swedish hydroelectric power required far more regulation in order to be exploited efficiently. By exploiting the natural reservoirs and the high fall from the plateau, it was possible to produce some of the cheapest power in the world using Norwegian watercourses. This is despite the fact that the best waterfalls are often located in inaccessible places where there are hardly any people and infrastructure is poor. The other advantage was the fact that, pursuant to Norwegian law, watercourse rights could be held by private individuals. Developers in Norwegian hydroelectric power experienced less involvement from the authorities than in other countries.

Waterfall acquisition became a speculative enterprise towards the end of the 19th century, when technical innovations and vast social changes provided opportunities for a quick gain or forward-looking investments. Previously, large rivers and waterfalls had been too wild and unmanageable to be exploited. Saws, mills and stamping mills were therefore usually situated beside waterfalls in small and medium-sized watercourses. Rivers often formed the boundary between landed estates, and long waterfalls and cascades could have many owners. Allodial rights and various easements on the properties made the legal circumstances even more complicated. The waterfall buyers attempted to make land acquisitions without letting the individual owners realise what value their property could represent for the buyer. They rarely had plans to develop the watercourses themselves, but speculated in reselling the rights at a better price than what they had paid for them. Watercourse rights had often passed through several people before they came into the hands of someone with a genuine interest in developing the watercourse. Politically, this was problematic. The original land owners, who did not know the value of the watercourses, were often tricked into selling their rights at very low prices. The speculation may also be regarded as an obstacle to the development of the watercourses, as the speculators were driving up the price of the waterfalls.

Sam Eyde becomes involved

Foreign investors were interested in Norwegian waterfall power, but they often did not find their way to Norway by themselves. They usually worked with Norwegian and Swedish entrepreneurs who knew the local conditions. Engineer and industrial entrepreneur Fredrik Hiorth was one of the first to recognise the opportunities and to form consortiums for the acquisition of high waterfalls. He was also the one who made the young engineer Sam Eyde so interested in waterfall development. The many companies that were formed by the people involved with entrepreneur **Sam Eyde** (1866–1940) are archetypal examples of this type of collaboration. Sam Eyde had international contacts from his time as an engineer in countries like Germany and Sweden, and he combined these with huge ambitions for how to exploit the power in Norwegian watercourses. Later, Norwegian lawyers also became an important link between foreign investors and Norwegian authorities and businesses.

Sam Eyde was to play a key role in waterfall acquisition in Norway. Initially, his role concerned assignments for his engineering office, but he quickly realised that there was more to gain from speculative buying and selling than from engineering assignments. At the same time, he was keen to take part in developing the waterfalls he speculated in. With the help of Swedish financial circles, he bought a stake in Vammafossen in the lower part of the Glomma river in 1902. Given the waterfall's central location, this was a question of competing to supply the capital itself with power. Big waterfalls could not be developed until the owners had secured a market for a substantial part of the power. At the same time, the electricity was cheapest when the developers built on a large scale, because there are economies of scale associated with power production. Eyde planned to sell Vamma to a group of developers of several other large waterfalls in Glomma (Kykkelsrud, Rånåsfoss/Bingsfoss), in order to create a constellation that could manage the whole of South-East Norway and be sole supplier to the capital. During this period, Eyde developed features that characterise financial entrepreneurs. When he had a resource and wanted to exploit it, he was quick to think in terms of bigger solutions where he combined one resource with another and linked them together in bigger projects.

In 1903, Eyde faced the important step that was to secure him a place in history. The waterfalls were the stepping stone, while capital, technology and labour played a decisive role in the development of an energy-intensive industry, in which, around the turn of the century, the electrochemical industry had just become a new opportunity. Of the above-mentioned factors, there was only one over which Eyde had little or no control: capital. Capital on the scale needed to build an entirely new industry and develop the hydroelectric power needed to supply it did not exist in Norway; it would have to come from abroad. From his engineering activities, Eyde had made connections with financial circles in several countries, including Germany and Sweden, and he helped to raise capital for the waterfall and industrial projects. The foreign capitalists nonetheless played a decisive role as independent parties. This was something that made a lasting impact on Eyde's career. Soon after Vamma, he began to take an interest in **Rjukanfossen**. The acquisition of large waterfalls in such a remote location had to be seen in conjunction with the development of the new

Freeholder Ole Halvorsøn Sem and Sam Eyde in a trade for waterfalls.

industry if the power were to be exploited. Everything was therefore in place for a project of unprecedented magnitude, requiring all of Eyde's skills and available financial factors.

In Notodden, Tinfos Papirfabrik had acquired the rights to the west side of **Tinnfossen** as early as 1873, and to the east side in 1885, in exchange for a modest annual fee. In the course of the 1890s, the other waterfalls in the Tinnelva river came into play. **Svelgfoss** is a good example of the process from the acquisition of an option to a final sale. The transactions can be traced from 1895, when a bank cashier in Hitterdal Sparebank (savings bank) handed over his option to a timber floating inspector, who in turn handed it over to a newly formed company, AS Svælgfos. Behind the scenes were the stakeholders in Tinfos Papirfabrik. The company then acquired the waterfall from the two landowners in 1899, while the landowners retained the timber floating rights. In reality, this meant that a timber flume had to be built in order to exploit the waterfall. In 1904, the waterfall was sold to **Sam Eyde, backed by the Wallenberg brothers of Stockholms Enskilda Bank**. At this time, Eyde was looking for electric power for a testing plant in which the Birkeland/Eyde method for extracting nitrogen for artificial fertilizer could be tested on a large scale. Together with the Wallenberg brothers, he travelled around Norway in March 1904, which resulted in power contracts by the Nidelva river near Arendal and with Tinfos Papirfabrik. This company had already built a power plant in Tinnfossen that was put into operation in 1901, and set up a new company for carbide production, Notodden Calcium Carbidfabrik AS, in 1899. **The Tinfos I Power Plant** (*object 1.1*, described on page 84-85) was completed in 1900. It sold power to the carbide factory based on a German patent and German machinery. The furnace system was not built for continuous operation, however, and did not yield a satisfactory result. The company was awarded compensation, which did not cover the loss. The company therefore leased the plant to a British company (The Albion Products Co. Ltd) in 1903, which rebuilt it but had to agree to a lower price for the electric power from Tinfos I. However, the quantity of power was increased. This meant that a new generator set had to be installed at Tinfos I in 1904. **The power plant had sufficient capacity to supply power to Eyde's first test factory.** The company was still heavily indebted at the time Sam Eyde was exploring power options in Southern Norway, and it made the leased power conditional on the purchase of the rights to **Svelgfoss**. Sam Eyde did so, together with the Wallenberg brothers and Tillberg in person, in April 1904, for a sum of NOK 240 000 of which roughly half was paid in cash. Later, the new owners sold the waterfall for approximately NOK 1 million to the company in which they themselves had an interest, **Norsk Hydro**.

The Rjukanfossen waterfall

Director Sætren of the Norwegian Canal Authority had made Eyde aware that it was possible to buy **Rjukanfossen**, because the owner, the Norwegian Trekking Association, needed to sell it after Rjukan Hotel had gone bankrupt. Rjukanfossen was originally split between the farms Fosso Suigard and Vemork. During the 1890s, the rights to the waterfall had been acquired from the landowners and the rights to Rjukanfoss and Skardfoss were now all in the hands of businessmen in Skien, for the sum of NOK 1 100. They were the same people who in 1897 had facilitated the building and operation of Rjukan tourist hotel by the waterfall. This meant that a lot of the work of turning the waterfall into a speculative object was already done. When the hotel was declared bankrupt in 1901 and put up for sale along with the waterfall, Sam Eyde seized the opportunity together with Hiorth and the canal director. It was the rights along the Måna river and not the hotel they were interested in. In 1902, they took over the hotel and the pertaining water rights for NOK 40 000 and immediately set up a new company to resell the waterfall. Together with his business associates, Eyde formed a partnership (Maaneelvens Fossecompagnie) that had an option on the waterfall, and at the same time, he systematically acquired properties along the watercourse downstream of the waterfall and upstream to Møsvatn. In 1903, the time was ripe for the formation of AS Rjukanfos, the objective of which was to exploit the properties through resale or power development. Developments thereafter were complicated. The fact that the company AS Rjukanfos was formed in Stockholm reflected the fact that most of the share capital was in Swedish hands. AS Rjukanfos's bid of NOK 220 000 for the waterfalls in Måna was accepted.

In other words, the purpose was initially speculative, as it was for Vamma, since it was not yet clear what the power would be used for, neither at Vamma nor Rjukan. Vamma was near Eastern Norway's concentration of populations and could provide a general power supply. That was not an option for Rjukanfossen due to its location, so the purpose would have be industrial. The power potential of Rjukanfossen was far greater than that of Vamma, estimated at 250 000 horsepower compared with Vamma's 40 000, and it represented a large-scale supply. Eyde first thought about the metallurgic industry, and aluminium was considered. The factors of uncertainty involved in setting up an industry were partly technological, i.e. power loss associated with transmitting electric power over long distances, and partly political, related to possible state concession requirements for such transmission. The battle between different systems for power transmission was still ongoing elsewhere in the world, but, although the battle had in reality been settled to the advantage of alternating current, **long-distance transmission of electricity was still not possible without losing a substantial amount of power.** During the period between the turn of the century and about 1920, waterfalls close to fjords deep enough for seagoing vessels were the ideal location factor for many big enterprises.

Sam Eyde had seen Rjukanfossen once, in 1888 as a tourist, and he was also impressed by the mighty sight, but perhaps even more by its power: *'Imagine if this power could be used for something'.* As the trade was initially speculative on the part of the investors, and Eyde himself was not clear what the waterfall would be used for other than something industrial, the question was where the industry was to be located. Transferring power to the coast was a theoretical possibility. It would prove possible to solve the technical aspect, but in practice, it would lead to too great a loss of power and be too expensive. The work of exploring the relevant development solutions got under way. Eyde's engineers participated, but advice was mainly sought from foreign experts. British engineer C Austron strongly recommended transferring the power to a central location for industrial purposes. He estimated the development costs at NOK 24 million, a third of which for the transmission system, which would also lead to a loss of power of 20%. The Swedish consultancy company Vattenbyggnadsbyrån also concluded that development of the Rjukan power would be very profitable, even when taking the power loss and costs for the transmission line into account. The considerations resulted in the decision to **build the industrial centre of Rjukan under the waterfall,** and to construct a transport system, 70–80 km in length, down to the lake with a canalised connection to the sea.

The year when Måna and Rjukanfossen were secured for a major development, 1903, was also the year when Eyde met **Professor Kristian Birkeland** and learned about the industrial experiments that were being carried out in Germany and the USA regarding the production of artificial calcium nitrate as fertilizer. Subsequent developments were to be rapid, in Notodden and in Vestfjorddalen.

The establishment of large-scale industry

Compared with other Western European countries, Norway was an underdeveloped country in the 19th century. At the start of the new century, as a result of the exploitation of hydroelectric power, it nonetheless became the centre of an unusually large industrial investment. Throughout the centuries, the country's economic foundation had been based on the utilisation of rich natural resources; in chronological order fish, iron ore and timber. It was now the turn of the highly diverse waterfall power. Throughout the 20th century, cheap, abundant waterfall power was used to process raw materials that have been shipped in from countries abroad, and then exported as finished or semi-finished products. Typical examples include aluminium and ferrous alloy. Hydroelectric power has been called 'the white coal of Norway' and it has enabled an industrial development that, together with an active state and distribution policy, has made the country prosperous.

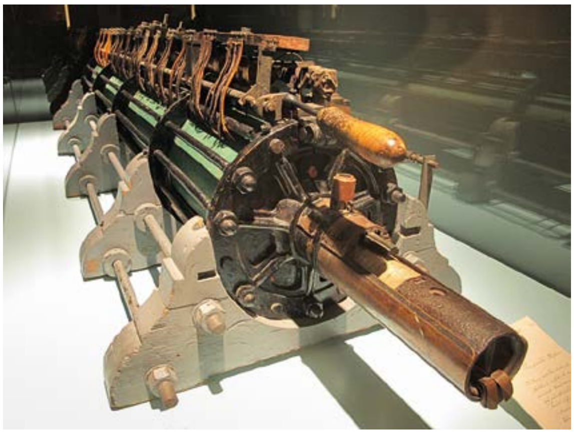
The **establishment of Norsk Hydro** in Telemark in 1905, the year of Norway's full independence, is a particularly interesting case. In many ways, it is representative of the era and phenomenon, yet it also represents something unique. In this case, one of the essential raw materials for the processing was plain air. The story of how the company came about is as fantastic as Norsk Hydro's success as a large-scale manufacturer of artificial fertilizer in a remote mountain valley below Hardangervidda. The story has a mythical quality to it and it has been the subject of professional and lay interpretations. The myth was partly created by the entrepreneur Sam Eyde, but there is also reliable documentation of the course of events.

Birkeland/Eyde's electric arc process

The meeting between Birkeland and Eyde at a dinner party held by Minister Knudsen adds a mythical dimension to the story of Norway saltpetre. Photo from exhibition at the Norwegian Museum of Science and Technology

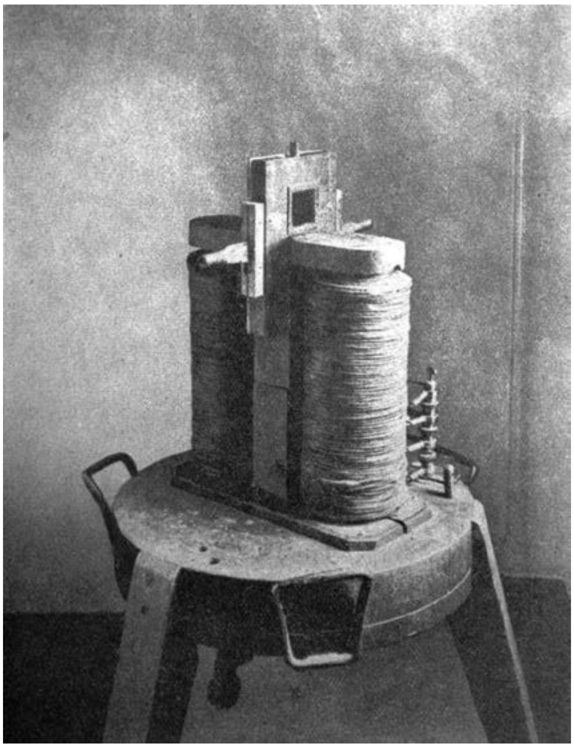
The meeting between engineer and industrialist Sam Eyde and researcher and scientist Kristian Birkeland was a decisive moment for Norwegian industry and for the company Norsk Hydro. It took place on 13 February 1903 at a dinner party hosted by Minister Gunnar Knudsen. Gunnar Knudsen was himself an industrialist and a believer in the possibilities of electricity. One of the companies he was involved in was Laugstol Brug in Skien, which was the first power producer in the country that sold energy to consumers. Sam Eyde had recently secured the rights to the mighty Rjukanfossen in Telemark and was trying to find alternative ways of exploiting the 250 000 horsepower produced by the waterfall. Ordinary power supply was out of the question, because the valley was practically empty and the nearest population concentration was miles away. The solution would have to be industrial. Eyde was also familiar with the international race to fix nitrogen from the air into an industrial fertilizer product for the global agriculture industry, and with Americans Bradley and Lovejoy's ongoing attempts at Niagara Falls using electric arc furnaces. During the dinner, he allegedly answered Birkeland's question of what he was occupied with at the moment by saying: *'What I want most of all is the most powerful electrical discharge on earth'.* In reply to which Birkeland exclaimed: *'That I can get for you!'* This is how Sam Eyde later described the incident, and with his sense of dramaturgy, he said that *'the idea hit me like a bolt of lightning'*. Birkeland later claimed that Eyde had been referring to thin electric arcs and small amounts of energy, like those used by Bradley and Lovejoy.

A few days earlier, Professor Kristian Birkeland (1867–1917) had rented the old banqueting hall at the university in Kristiania (Oslo) to demonstrate his invention, the electromagnetic cannon. As a researcher, Birkeland was primarily interested in basic research, and his many research projects in natural science required far greater means that the modest budgets allocated to the university from the state. At a physicists' congress, one of the notables in physics, Lord Kelvin, had given him the following advice: *'If you do like me, young man, make an invention and earn a million, then you can think about science'*. Around the turn of the century, Birkeland dedicated his time to finding practical solutions to technical problems in order to obtain more resources for basic research. The electromagnetic cannon was his first patent. He had succeeded in forming a limited company (Birkelands Skydevaaben) with participation from politician Gunnar Knudsen and military leaders, among others. At a gala lecture in the old banqueting hall on 6 February 1903, the cannon was demonstrated to an audience that included representatives from foreign companies (Armstrong and Krupp) as well as of the Government and the military. Earlier in the day, Birkeland and his associates had fired two successful shots using ten-kilo projectiles, but during the demonstration, it went wrong. A short circuit (of approximately 10 000 amps) occurred when the transformer broke down, resulting in a deafening bang, but also long flames out of the cannon's muzzle. The professor noticed that the electromagnetic field affected the shape of the flames.

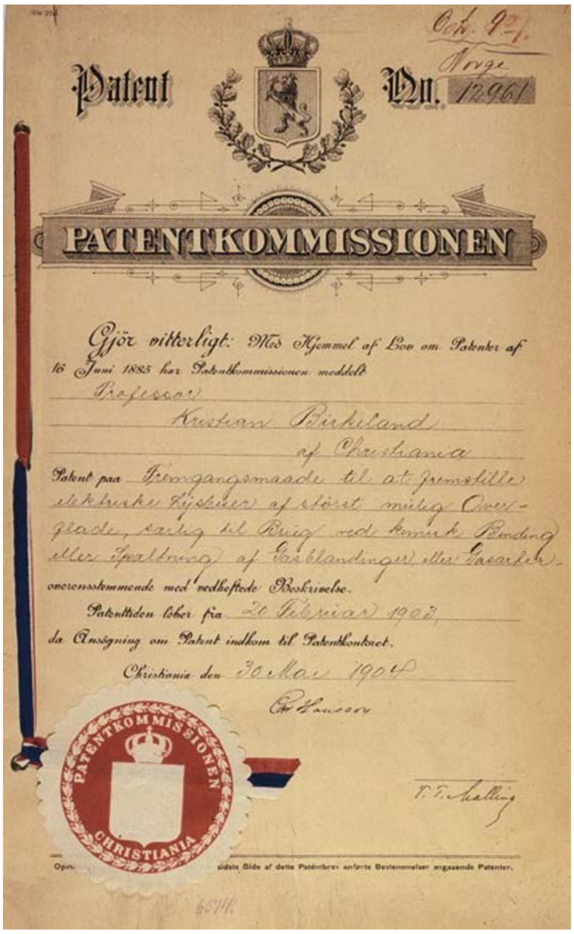


The electromagnetic cannon invented by Professor Birkeland, now displayed at the Norwegian Museum of Science and Technology. Photo: Trond Taugbøl.

Four days after the party at Gunnar Knudsen's, Birkeland and Eyde met and signed a written partnership agreement. Birkeland had the ideas and main responsibility for the development of an electric arc furnace based on electromagnetic forces, while Sam Eyde linked the furnace to the production of nitrogen-based fertilizer and understood the market perspective. As early as 20 February 1903, Birkeland filed the first patent application for the use of the electric arc to extract nitrogen from the air. This indicates that Birkeland already knew of the electric arc's most important properties from his advanced experiments. The first experiments were conducted using a miniature furnace in Birkeland's laboratory at the university. Several documents indicate that Birkeland was already producing nitric acid. The experiments were quickly moved to Frognerkilen Fabrikker (factories) in Kristiania (Oslo), since these provided more room and a greater electric output. The company N Jacobsens's



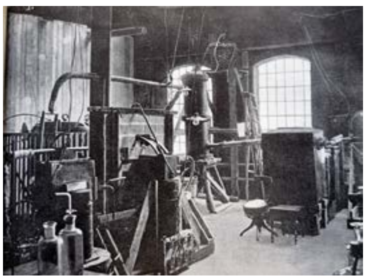
Professor Birkeland's first test furnace from 1903. The size was compared to a cigar box.



The patent from 1903 in the name of Professor Kristian Birkeland on the method for decomposing of gas mixtures by the use of electromagnetic arc, considered to be the patent no.1 of Norsk Hydro Company.

electrical workshop in Kristiania (Oslo), which had produced electromagnetic cannons for Birkeland, cast casings for the test furnaces. Iron, copper and brass were tested in the shields around the combustion chamber. Birkeland and his assistants worked day and night, with increasingly powerful magnets, to increase the diameter of the electric arc. In August, they managed to produce nitric acid in a gas balloon. In October, the enterprise moved to Ankerløkken, where there was more space, and it was here that the first proper Birkeland/Eyde furnace was taken into use; an iron furnace with a diameter of one metre and an output of up to 50 kW. They achieved continuous operation over several days when they started to use U-shaped electrodes made from copper pipe cooled with running water. One year later, in October 1904, the test activities moved to Vassmoen in Froland near Arendal.

In summer 1904, the decision had been made to build a dedicated testing plant, and Notodden was chosen as the location. Presumably, a number of factors spoke in favour of



Experiments scaled up at the industries Frognerkilen Fabrikker in Kristiania (Oslo).

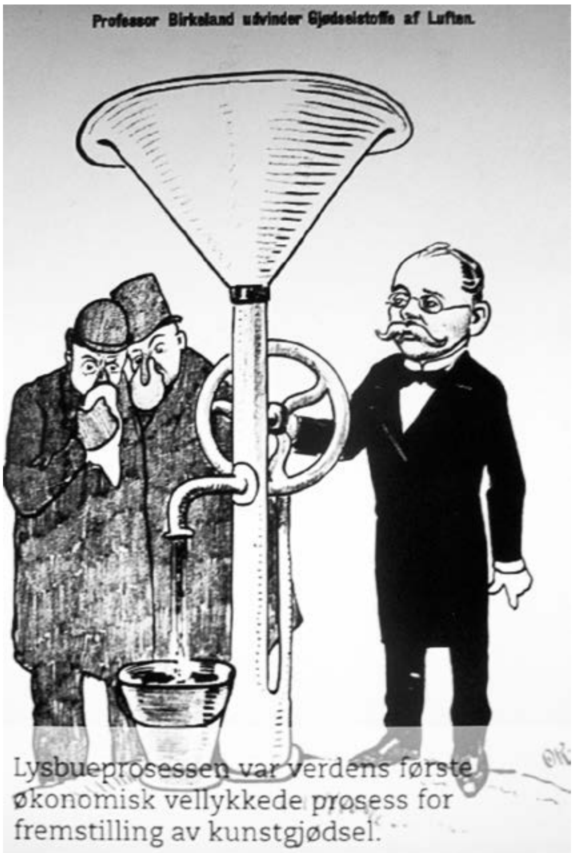
Ankerløkken testing station in Kristiania.

Vassmoen near Arendal, birthplace of Sam Eyde and where he was involved in the harnessing of waterfalls in Nidelva river.

The Testing Plant as built early in 1905, with furnace house, tower house and boiler house
Photo: Norsk Hydro.

this choice: the presence of available power that had already been developed, the potential for bigger developments in the vicinity, both in Tinnelva river and the acquired Rjukanfossen with possibilities of regulating Møsvatn lake on Hardangervidda, and the canal to Skien. The calcium nitrate factories in Notodden were built; the fifth and last testing plant used by the staff in the course of two years. The company moved there in May 1905. When the company *Norsk Hydro Elektriske Kvælstof Aktieselskab* was formed on 2 December 1905, Birkeland was elected a member of the board of directors, but at his own request, he was appointed consultative director the next year, in order to be able to concentrate on his own research interests.

The electric arc furnace – 'the most important invention ever made in Norway'



Birkeland, the Professor who 'produces fertilizers from the air', was seen as a magician by the general public.

It was Norwegian Kristian Birkeland who solved the problem of how to produce nitric acid from the components of air in the electric arc. His method was completed in 1904. Internationally at that time, there was hectic activity to find a scientific solution to a predicted food crisis, by industrial production of fertilizer that could increase crop yields and replace the world's natural deposits of nitrate, which would soon be exhausted. In 1898, the British chemist **Sir William Crookes** made an ominous appeal to the British Association in which he warned that the 'civilised world' was on the brink of a resource disaster unless it could find a way of producing artificial nitrogen fertilizer. The quest for an effective, cost-efficient method of producing nitrates was among the biggest challenges for the chemical industry at the start of the 20th century. It turned into a veritable race between players in different countries. The nitrogen issue was an important international concern.

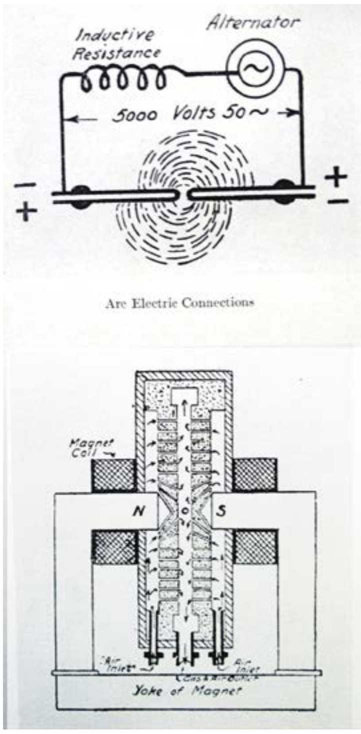
Birkeland and Eyde's collaboration started at about the same time as the emergence of calcium cyanide and the testing of the electric arc by Niagara. The type of furnace developed by Birkeland together with engineer and entrepreneur Samuel Eyde was scaled up based on the use of alternating current produced from hydroelectric power plants

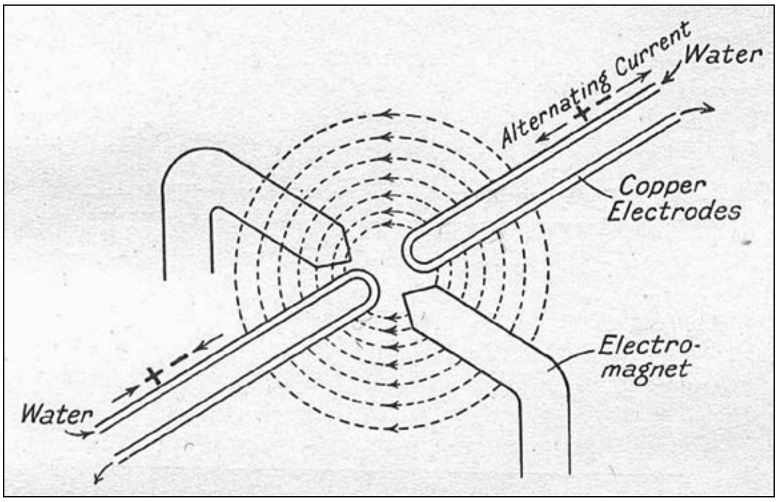
The electric arc under magnetic influence in the chamber inside a Birkeland-Eyde furnace.

that were constructed for the purpose. At that moment in time, waterfall power was easily available for development, at prices that seemed low in relation to the profit that was to be expected. **The Birkeland/Eyde process** was a commercial success and had a great impact on the supply of artificial fertilizer, known as **'Norway saltpetre'**, to the global market during a period of approximately 30 years. The commercial success of the process, and its weaknesses, the most significant of which was that it was highly energy-intensive, encouraged further development work in the electrochemical field in several countries, particularly Germany.

On occasion of the 100th anniversary of the Norwegian Industrial Property Office in 2011, Birkeland's invention of the electric arc method was named the most important invention ever made in Norway. The reason is the importance the invention would have for the global food supply. Birkeland and Eyde were nominated for the Nobel Prize in chemistry several times, and Birkeland was nominated on his own (1912). It is said that Eyde worked against Birkeland's candidacy and promoted his own. Whether this is why they did not win is impossible to say, the German Otto Schönherr was not found worthy either. Efforts were later made to win a Nobel Prize in physics for Birkeland, but his relatively premature death in 1917 put a natural stop to this.

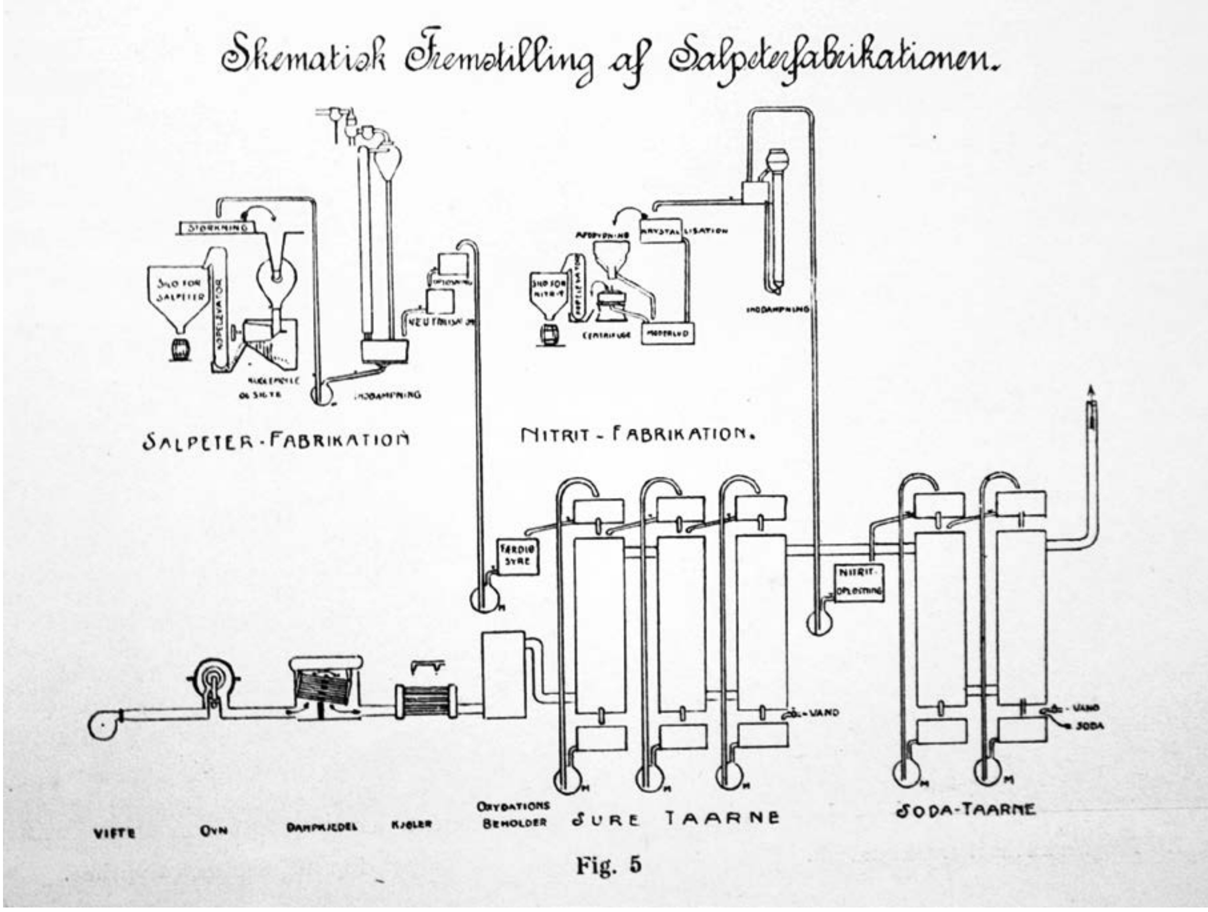
The principle behind Birkeland and Eyde's method is that the *electric arc* that flashes between two copper electrodes is affected by a strong *electromagnet* so that the direction





Schematic presentation of the Birkeland/Eyde furnace's mode of operation, the way Sam Eyde presented it to international journals and congresses.

of the electric arc is perpendicular to the connection between the electrodes. The electric arc spreads outwards in a semi-circle, forming and breaking 50 times in the course of a second. *The alternating current* changes the polarity of the electrodes and causes the electric arc to flicker from one side to the other so quickly that it appears to be a constant, circular, disc-shaped flame. Ordinary air is pumped through the arc. The size of the contact surface between the flame and air is significant. At 5 000 volts, the flame disc achieves



Scheme illustrating the flow of operations in the production of nitrate of lime.

a diameter of approximately two metres. The copper electrodes are hollow and are kept cool by internally circulating water. In the completed furnace, the magnets are shaped like shields that surround a circular combustion chamber that is 6–8 cm in width and two metres in diameter. Refractability is achieved by lining it with customised chamotte brick. A stream of atmospheric air is fed into this combustion chamber. When it comes into contact with the flame produced by the arc at a temperature of approximately 3 000 ºC, nitrogen in the air combines with oxygen into nitrogen oxide, which after cooling absorbs more oxygen and forms a brown, gaseous nitrogen dioxide. This is then turned into nitric acid in towers where water is percolated from above. The nitric acid is saturated with limestone and thereby produces *calcium nitrate*, also known as *nitrate of lime*. This solution thickens until it become so concentrated that, after cooling, it sets into a solid mass that can be ground into the grainy product called 'Norway saltpetre'. The commodity contains about 15 % nitrogen.

The finished product nitrate of lime in sacks and barrels, under Hydro's brand 'Norgesalpeter' (Norway saltpetre).

The Birkeland/Eyde furnace was developed and built in Norway, where it was found in Norsk Hydro's factories in Notodden and Rjukan. It was energy-intensive and used cheap Norwegian hydroelectric power. Hydro had major French ownership interests, and the only place outside Telemark in Norway where the Birkeland/Eyde furnace was put into production was at a factory in Soulom by the Pyrenees in France that produced nitrogen fertilizer on a licence from Hydro. This factory was relatively short-lived until it was closed down in the mid-1920s (see section 3.2, comparative analysis, page 338).

Historical preconditions for the industrial success story; the international context

What happened in Norway in the years after 1900 in terms of the establishment of the heavy electrochemical industry for the production of artificial fertilizer based on the use of the newly developed large scale hydroelectric power industry depended on a set of international factors. These did not only include the need for international capital to form the company that directed these events in Norway, Norsk Hydro, but also historical preconditions in developments and international events in relation to fertilizer as a commodity, and in relation to the use of electricity. A meaningful context for understanding the connections is the **industrial revolution** in the Western world, and its specific consequences in terms of international trading and market formation. This industrial era was based on **coal-fired power** as the primary source of energy, and the mechanical processing of raw materials from mining and agriculture. Typical products were iron and steel, textile, cellulose/paper and tinned food. Electricity was something of a curiosity until it formed the basis for **the second industrial revolution**. Research into the phenomenon had benefited from fewer barriers to the international exchange of findings and results in the wake of the more open global community that followed the development of free trade in the 19th century. **Electricity** as a source of power and a factor in new chemical industrial processes, driven by science, capital in new constellations and with the public sector playing an active role, characterise the new industrial stage at the beginning of the 20th century. More details on this are provided in the following section.

Electricity as an energy source of universal importance

In addition to the muscle power of animals and humans, wind and water in movement have been mechanically exploited in various forms since time immemorial, in order to run devices for various types of production. Man's knowledge of electrical phenomena dates back a long way, but it was some time before it had any practical use. Waterfall power, on the other hand, has been utilised for a long time, everywhere that it was available, for devices such as mills, sawmills, stamping mills, helve hammers and other early-stage industrial activities. Where water was not available, windmills could supply power for some of the same purposes, but they were not suited for operation on an industrial scale. Wooden waterwheels were used for the direct mechanical exploitation of waterfall power, and then later metal turbine discs, which operated the machinery with the aid of belts and pulleys attached to the turbine shaft. The system had its clear limitations in that, if the amount of water and the fall was too great, the water pressure could cause the wheel or turbine to break. In other words, the big waterfalls and watercourses could not be used. Nonetheless, the industrialisation of the 19th century tended to use watercourses as the localisation factor, in that the watercourse was the power source and transport route, if necessary in canalised form.

Industrial revolution based on coal power

The industrial revolution that started in England in the mid-18th century brought about a fundamental change in that energy became available as a transportable commodity, in the form of coal that could be used in traditional and new industries, thanks to steam engines. Coal power represented a predictable, stable energy source that could be supplied in large quantities and at a low price. Coal-fired steam engines could be used both in the transport sector and for many types of production in large factories. The steam engine meant that factories no longer had to be located beside rivers or waterfalls. A massive industrialisation took place, with rich deposits of coal and iron as an important basis. Such deposits are found in many countries, where they form the basis for chains of industrial towns, based on the pattern from England. *Coal mines, ironworks and canals in several countries in Western Europe and North America have been inscribed on the World Heritage List as industrial heritage from this era*. Spearheaded by the English industry, various types of machinery were developed, cast and exported. New industries could transform old towns into industrial towns, or establish new urban areas. In the Nordic countries, which are lacking in coal but rich in forests, new machinery was used in sawmills and pulp mills. Although they were also located near important watercourses, which both served as the source of power and as the means to transport the raw materials to the factory, these new enterprises represented an important introductory phase in the industrialisation of countries like Norway.

The biggest waterfalls could not yet be exploited for production. They attracted attention as tourist destinations, however, when a wealthy urban bourgeoisie emerged in Europe and North America, with the time and money to go on leisure trips. This coincided with the idea of the romanticism of nature that was a reaction to the hideous consequences of industrialisation, both visually and socially. Unspoilt nature was 'discovered' and explored, not least mountains and untamed waterfalls. As long as the amount of energy in extreme waterfalls could not be utilised, tourism developed into a significant industry. This included Niagara Falls in North America with its massive volume and spectacular shape, as well as Rjukanfossen and Tyssestrengene in Norway with their great height.

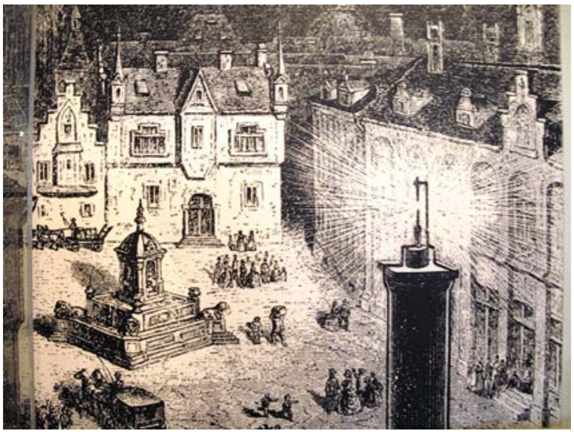
Electricity – from curiosity to source of power

Electricity as a physical phenomenon had been studied by scientists in many countries since the 17th century. It was long regarded as sort of a separate substance, 'electric fluidum', which is deposited on the surface of electrified bodies. Around 1730, the Frenchman Charles du Fay discovered that the phenomenon was caused by two types of electric charge; unlike charges attracted each other while like charges repelled one another. According to the Englishman Robert Symmer's theory (1759), this was explained by the fact that there were two such kinds of fluids, namely 'positive' and 'negative' electricity. His fellow countryman Stephen Gray discovered that certain elements conducted electricity, while others conducted it poorly. He called the substances conductors and insulators. The first experiments were carried out that showed that electricity could be stored in a condenser (capacitor) called a Leyden jar. The American *Benjamin Franklin* conducted a famous experiment (1752) where he, using a wire and a condenser, proved the connection between lightning and electricity. Franklin also claimed the hypothesis of only one kind of electricity (1747), where the terms positive and negative meant a surplus or a lack of electricity. Later, in 1799, the Italian *Alessandro Volta* invented a device that became the first battery. Volta based his research on Doctor L Galvani's discovery of the effect of electric power on dead animals, which Galvani ascribed to an animal quality called 'galvanic electricity'. Volta found that two different metals became electrified when they both touch a conductive fluid. He constructed the voltaic pile, a battery consisting of galvanic elements with poles of copper and zinc. It could generate a continuous electric current, unlike the condenser, which lost all its power when it was connected to something.

Volta's discovery opened up new opportunities in that researchers could advance from studies of static electricity to electricity in motion, with electrical power now under their control. The physicists then discovered new, unexpected qualities of electricity. *Electrochemistry* arose as a separate field. It quickly resulted in many other proven effects, such as the current's ability to precipitate metals. Using the voltaic pile, potassium and sodium were discovered by the Englishman Humphrey Davy in 1807. Another discovery was made by the Dane H C Ørsted when he proved the effect that galvanic electricity had on a magnetic needle in 1820. The Englishman *Michael Faraday* then discovered *electromagnetism* in 1831, i.e. that electricity could be produced with the help of a varying magnetic field; electromagnetic induction. He also discovered *electrolysis* in 1833 and the quantitative laws that apply. Following experimentation, he developed a theory of magnetic lines of force in the surrounding space, and in 1845, he discovered that magnetism can cause the plane of polarisation of light to rotate. A complete theory of electrodynamics was developed by the Scot J C Maxwell in 1865. The German H Hertz finally proved the theory in 1888, when he proved electromagnetic waves and the electromagnetic field. Older theories of electricity as one or two kinds of weightless fluids or substances could then be abandoned for good.

The discoveries of the physical regularity of electricity and how various substances react to electrical charge and current paved the way for **inventions** that utilised the potential of electricity. Nevertheless, we had to wait until well into the 19^{th} century before we can talk about inventions that had a material impact on society. Initially, attempts were made to replace optical telegraphs with electrical apparatuses. An electrochemical telegraph was constructed by Sömmering in Munich in 1809, but it did not achieve any importance. The first *electromagnetic telegraph* was constructed by Cooke and Wheatstone in England around 1840. It was a needle telegraph limited to 20 letters. In the USA, Samuel Morse achieved an international breakthrough with his telegraph and the Morse code that came with it. Telegraph lines were then stretched between cities and countries throughout the world. *The telephone* was invented by the Italian Antonio Meucci in 1849. In 1871, he patented a device that could transmit audio signals across great distances with the aid of electricity, but when he could not afford to renew the patent, the American A Graham Bell, who worked in the same laboratory, patented the telephone in his name in 1876. *Electric light* was developed in two forms, of which the *arc light* is the oldest, dating back to the early 19^{th} century when H Davy discovered it by sending electric power from a galvanic battery through two pieces of coal, which caused a bright flame to occur. *The arc lamp* was first used in individual buildings such as lighthouses, using a dynamo around the middle of the century, and also in some cities for street lighting. In the 1870s, Hefner von Alteneck made a differential lamp with a mechanism that allowed several lamps to be powered from the same electric source. At the same time, the carbon arc lamp was developed for indoor use. The first practical form of *incandescent lamps* was Thomas Alva Edison's carbon filament lamp, which was fist presented on New Year's Eve in 1879. The definite victory of the incandescent lamp over the arc lamp would not take place until well into the 20^{th}

century, however, when first Siemens and Halske in Germany and then General Electric Co in the USA patented the production of lamp filaments made of metal, in the latter case wolfram, which became dominant.

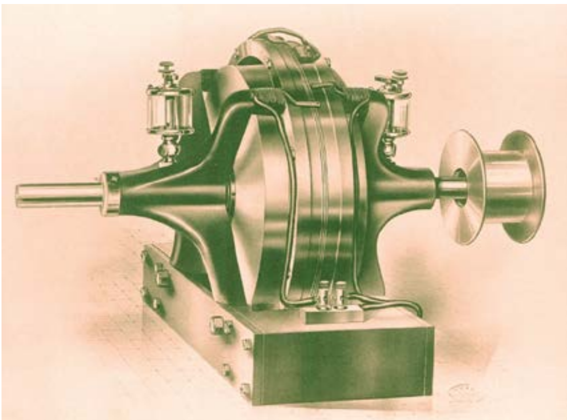


Not until late 19th Century did electric arc lamps lit the streets of old cities.

A new illuminated world was made possible by Thomas Edison's revolutionary incandescent bulb lamp.

The problem of power transmission: the War of Currents

The beginning of general electricity distribution started in New York and London in 1882, and can be explained by *Thomas Edison's* invention of the incandescent lamp. In 1878, Edison founded the company Edison Electric Light Co with the backing of major investors, which became General Electric in 1892 following mergers. In 1880, Edison patented a system for the distribution of electric energy. The same year, he founded another company, which in 1882 erected the world's first commercial power plant, Pearl Street Station in New York, in order to reap the profit of the invention of the light bulb. The power plant was powered by coal and distributed 110 V *direct current* to 59 consumers on Lower Manhattan. The power plant at Holborn Viaduct in London was powered by steam and supplied private homes in the vicinity and some street lighting.



Electric dynamo patented 1889 by Nikolau Tesla.

The distribution of electricity is related to the development of the transmission technique. Edison's adversary was his fellow countryman *George Westinghouse*, because of Edison's marketing of direct current for electric power distribution. The Serbian-American inventor *Nikolau Tesla* had developed a technique for power transmission using three-phase *alternating current*. This enabled voltage in the transmission system to be raised and lowered using transformers, which was not possible with direct current. The power loss that occurs during transmission is

Serbian banknote commemorating Nikolau Tesla.

reduced at higher voltage levels. Alternating current can be transformed into high voltage, and then back again for distribution to end users after being transported over great distances. Tesla's patent rights to alternating current motors, dynamos and transformers were acquired by Westinghouse Electric Co in 1885.

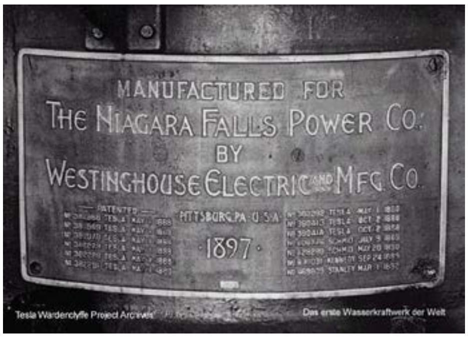
In 1887, Edison's companies were distributing direct current to customers from 121 coal-fired power plants in the USA. When the public began to take an interest in the limitations of direct current, Edison launched a campaign against alternating current with the aim of convincing people that high-voltage alternating current was too dangerous to be used. The problem with direct current was that it was only financially profitable to distribute power over a radius of approximately three kilometres from the power plant. When Westinghouse suggested using high-voltage alternating current instead, since it could transport electricity for hundreds of kilometres with a minimal loss, Edison launched a 'war of currents' to discourage the use of alternating current. Animals were killed as part of the campaign in order to demonstrate how dangerous alternating current was. As late as 1903, the circus elephant Topsy was electrocuted, an incident that was filmed for propaganda purposes. It is worth noting that, at this time, Birkeland and Eyde had already started their work with a view to using large amounts of electricity in the processing industry.

Niagara Falls: from tourism to industry

Niagara Falls was electrically illuminated by the tourist industry, first in 1881 by 16 direct current carbon arc lamps of a type invented by C F Brush and adopted for use in Cleveland in 1875, then in 1883 using Tesla's alternating current. The power was supplied by a generator in a turbine house for Schoellkopf's tannery beside a canal built for hydraulic power, which the year after was rebuilt into a regular hydroelectric power plant. Niagara Falls Power Company was founded with a view to the commercial utilisation of the waterfall energy on a larger scale. In 1894, the company announced a contest with a big prize to the person who could develop the best system for transmitting electricity over long distances. Tesla's three-phase alternating current system was thereafter chosen as the international standard at an experts' meeting held in London. This led to greater efficiency and safety in the distribution of electric power, and a huge expansion of the power distribution. Tesla's invention of an induction motor powered by a rotating magnetic field and multi-phase systems paved the way for the utilisation of the potential of Niagara Falls. In 1895, George Westinghouse and Nikolau Tesla installed the first power plant at Niagara Falls. The plant delivered more than 15 000 hp, and was able to supply nearby towns and industry from 1896.

Also significant were Werner von Siemens' discovery in 1866 of the principles of the dynamo and the American Charles Parsons' invention of the steam turbine from 1884, which he connected to a dynamo. The turbine generates rotating movements, which in itself was an improvement in performance in relation to a piston-driven generator, but it is especially suitable for running an electric generator. The patent was further developed by George Westinghouse, who scaled up the turbine to the equivalent output of hundreds of thousands of horsepower.

Power plants and factories by Niagara Falls. Photo: Library of Congress.



Plaque on generator at Adams Power Plant (1895) listing 13 of Nikola Tesla's patents, which were all used in the world's first big power plant by Niagara Falls.

At the same time, two Americans named *Bradley and Lovejoy* were attempting to generate nitric acid through oxidation of the nitrogen in the air at high temperatures. Based on their method, an industrial enterprise was set up at Niagara, where they had access to considerable amounts of power at a reasonable price from what was then the world's largest hydroelectric power plant. However, their method and equipment would prove not to be up to standard. The furnace technology consisted of a rotating drum with 138 electrodes supplied with *direct current*. Electric arcs were formed during rotations when electrode tips (made from platinum) on the inside and outside of the furnace meet, while nitrogen oxide was formed by feeding air though the electric arcs. The output corresponded to 453 kg HNO_3 per hp/year of applied energy. Due to its high number of electrodes and high-voltage connections, this type of furnace became very expensive to operate and maintain. Operations were discontinued as early as 1904. The plants and the pioneering work at Niagara are also discussed in Section 3.2, Comparative analysis, p. 347-349.

Norway on the international stage

Norway was one of the first countries to have an electricity supply. An electric light was lit for the first time in Norway in 1877, an arc lamp connected to a dynamo at Lisleby Brug (sawmill) near Fredrikstad. Other factories were quick to follow with small in-house lighting systems, initially run by steam engines. The first hydroelectric power plant was built by the mining company Senjens Nikkelverk in Troms county in 1882, a small power plant, allegedly the first in Europe. In 1885, Laugstol Brug in Skien became the first electricity company in the country to sell power to consumers. It was a hydroelectric power plant with two dynamos that each could supply 150 incandescent lamps, which was more than the wood-processing company needed for its own use. A pioneer was Hammerfest, which built the first municipal hydroelectric power plant and *in 1891 became the first town in Europe to have electric street lights*. The capital got its first electricity plant in 1892. In 1900, Hammeren power plant was put into operation with six water-powered generator sets, which was assumed to be enough to cover the city's power requirements indefinitely. The first small, private plants only required modest engineering knowledge, but more professional skills became necessary as the installations got bigger and the areas of application increased.

The new processing industry that was starting up in the USA, Germany and other places was energy-intensive and used advanced technology. It required very extensive technical skills. The investments that were needed to build big dams, tunnels and penstocks, power plants and factories required a type of concentration of venture capital that at that time had to come from investors in already industrialised countries with advanced economies. Norway was lacking in these factors, but it was rich in waterfalls available for exploitation.

Norsk Hydro and international financial capital

At the time the company was formed, Norsk Hydro's financial ownership structure was strongly dominated by foreign interests, mainly Swedish and French but also German. Only about 7% of the shares were owned by Norwegians. Norway was in union with Sweden until 1905, and Swedish citizens had rights in Norway that did not apply to other foreign nationals. Speculation in waterfalls gave rise to a Swedish-Norwegian circle of entrepreneurs, including Norwegian engineers such as Fredrik Størmer and Fredrik Hjorth, who brought Sam Eyde into the game. Eyde on his part was a diploma graduate and had worked in Germany for seven years through the engineering firm he ran alongside the German engineer C O Gleim. The firm carried out railway stations and port projects in Germany and the Nordic countries, with the main emphasis on Norway and Sweden, and Eyde built up a wide network of associates through this work. With his bourgeois background and social skills, Eyde also gained admittance to and socialised with the upper classes in both Germany and Sweden. In Germany, this included Werner von Siemens, founder of the industrial corporation. Through his marriage to Swedish Countess Ulla Mörner of Morlanda, Eyde gained entry to Swedish high society. In Stockholm, Eyde met lawyer Knut Tillberg, who was also a county governor and a politician with strong business interests. As managing director of Gällivarre Malmfelt, he had formed ties with brothers *Marcus and Knut Wallenberg* and their Stockholms Enskilda Bank, one of Sweden's most important financial institutions.

Sværgfos Power Plant and Rjukan I factories. The photos are from an expedition made in August 1910 by French financier Albert Kahn (1860–1940) and photographer Auguste Léon. Kahn was a globally-oriented philanthropist, but also a banker with interests in Norsk Hydro. Norway was one of the first countries he documented in his project 'The Archives of the Planet' ('Archives de la planète'), because it gave Kahn a chance to inspect his investments in Rjukan. The photos were taken as autochrome photographs, a process invented in 1907 by the Lumière brothers as the world's first colour photography technique. Kahn documented 30 countries before he went bankrupt as a result of the stock market crash in 1929.

Several routes to foreign capital

Eyde started a collaboration with Tillberg and Swedish finance that speeded up Eyde's projects in Norway; first Vamma and then Rjukanfos (waterfall companies), connecting technology with hydroelectric power. The Wallenberg brothers represented a type of financial player that did not exist in Norway. Backed by the bank in which they themselves were the most important shareholders, they assumed overall responsibility for developing the companies or industries they got involved in. The electricity company ASEA was among the companies they controlled. They had been convinced by the potential of Birkeland/Eyde's electric arc process and got involved in the nitrogen issue in autumn 1903. Eyde and Tillberg's big plans nonetheless represented such a huge project that the financial responsibility had to be divided between more parties. For a number of years, the Wallenbergs had raised capital for their projects in France. *Paribas (Banque de Paris et des Pays-Bas)* was Enskilda Bank's biggest foreign lender and an important part of the brothers' European network.

While the Wallenbergs were making an assault on Paris, Eyde was working on a German lead. Through a German consultant, Otto Witt, Eyde had made contact with the big chemical company *BASF*. The German electrochemical industry was leader of the field in Europe; the Germans were on the verge of a breakthrough in the production of carbide-based nitrogen (represented by A Frank and N Caro), while chemist Otto Schönherr and electrical engineer Johannes Hessberger under the auspices of BASF had come a long way towards developing an electric arc process similar to the Norwegian one. Eyde offered BASF a share in the holding company he was planning to set up with Tillberg. BASF would then discontinue the development of its own process but recognised the potential in the Norway process. In exchange for a small shareholding, however, BASF demanded that the process be licensed in Germany and that it got to test and develop the process in its own laboratories. This would give BASF considerable control without contributing significant capital. This led to a breakdown in the negotiations. For the Germans, the breakdown meant that work on the Schönherr process was resumed, and just a few years later, Hydro would have to deal with German interests on a new basis.

The Swedish Wallenbergs contributed the majority of the financing of Eyde and Tillberg's plans. Several companies were set up, first AS Det norske Kvælstofkompagni in which Eyde and Tillberg were the main shareholders, together with Birkeland, as compensation for the electric arc process. The company owned the rights to the process and its further development. The value of the electric arc process was thereby decided by the company's share price. A buyer of such shares was then created when *Det norske Aktieselskab for Elektrokemisk Industri (Elkem)* was formed in early 1904. Elkem took over the majority shareholding in Kvælstofkompagniet and the shares in the waterfall companies Vamma and Rjukanfos, and the Wallenbergs subscribed for the shares in Elkem. The nitrogen issue was thereby driven by the interaction between a dominant holding company and subordinate technology and waterfall companies. By keeping the different assets apart, the total risk in the project was reduced. The structure was advanced for its day, and unparalleled in Norway. However, Elkem had spent almost all its capital on buying shares in the subordinate company and on paying founders' profit to the original participants. In the short term, it was a question of continuing to develop processes on an increasingly bigger scale, which in the long term meant finding investors with enough financial muscle to take the project to the industrial phase.

Upscaling to large-scale industry

It was Norsk Hydro Elektriske Kvælstof Aktieselskab that was to be responsible for the industrial initiative. Before that, a **test factory** had to be built to test the process on a larger scale and under more realistic conditions than laboratory experiments, in order to be able to present a relatively well-founded project to external investors. By now, Elkem and the circle of entrepreneurs behind it possessed a number of waterfalls that could be relevant for the project's industrial phase, of which the biggest, Rjukanfossen, was selected. **The location of the industrial plant** was still undecided, and the choice would make a difference to the project's profitability. Expert statements initially supported a location by the coast, despite an estimated power loss of 20 % and high costs for building a transmission facility. A new assessment carried out by Professor Reichel of the Berlin Technical College raised the importance of both power loss and costs, and proposed Notodden as a suitable alternative solution. One of Eyde's own engineers, Olav Heggstad, launched the radical idea of building the factory beside the waterfall, which meant that the finished products, not the power, would have to be transported down to the coast. The costs associated with a transport system to Rjukan were then calculated to be lower than the costs of transmitting the power, and in order to reduce the number of loose ends in the project to a minimum, the final decision was **Rjukan**. Notodden was chosen as the location for a test factory rather than the Elkem-owned Vamma, because there it would be possible to use power that had already been developed. A separate company, *AS Notodden Salpeterfabrikker*, was set up in 1904, the object of which was exploratory operation. The lessor, the Tinfos power company, was in need of money and demanded that Elkem take over Svelgfoss a few kilometres upstream of Notodden, at a favourable price.

In 1905, the Wallenbergs made a new assault on Paribas. At this time, the political situation between Norway and Sweden was unclear, and the bank's management was hesitant about getting involved in a country that was at a risk of war with its Swedish union partner. In addition, the project was huge and related to a new, untested electrochemical process. Paribas demanded that the project be scaled down, and that the development in Rjukan had to take place in stages. A *commission of independent experts* was given the task of visiting Notodden and investigating the process further. The bank's participation depended on the commission's conclusions. If it was positive, the involvement was to take the form of a gradual investment programme in which the electric arc process was initially to be based on the development of Svelgfoss, then Bøylefoss by Arendal, and finally maybe Rjukan and Vamma. The commission of French, British and German experts visited Norway in summer 1905, just after the dissolution of the union. At that time, the test factory in Notodden had three electric arc furnaces, each of 520 kW, which supplied nitrous gases to eight large granite acid towers. The result was to be compared with

Birkeland's experiments ended in 1905 at Notodden, where a test factory quickly was built. Here the furnace house and the tower house under construction in 1906. Photo: Norsk Hydro

The commission of international experts gathered at Notodden in 1905. Photo: Norsk Hydro.

the American process that had been used at Niagara, where a production of up to 600 kg of water-free nitric acid had not been sufficient to achieve profitable operations. A week before the commission arrived, the test results were poor, as low as 400 kg, but the engineers at the test factory then expanded the absorption system with a temporary wooden acid tower, filled with dry lime. This proved to be a fortunate move. The experts concluded positively in the chemical area and described the electric arc process as a 'sure success', but remarked that the absorption process was not yet complete, as only two-thirds of the nitrous gases were being captured. The bank made its decision in September 1905, and an agreement was signed with Norwegians and Swedes in Paris. At the same time, political negotiations were taking place between Norway and Sweden, in Karlstad, where the Swedes' reaction to the unilateral dissolution of the union was still unknown. Paribas got involved in the construction of a calcium nitrate plant in Notodden and a power plant by Svelgfoss. It was a minimum solution, but it was a start. In December 1905, the company Norsk Hydro was formed in Sam Eyde's office in Kristiania (Oslo), dominated by French and Swedish capital, in addition to German, Swiss and Norwegian capital.

Duels with French, German and Norwegian players

In order to get started on the even bigger projects in Rjukan, Hydro made another attempt at securing German capital. The German company BASF was in a leading position in the international chemical industry. The company was working on a separate type of furnace based on an invention by *Otto Schönherr*. In the Schönherr furnace, the electric arc is extended into a five-metre-long cylindrical string that burns calmly in a tube into which air is fed tangentially to oxidise. The method was able to compete with Hydro's Birkeland/Eyde furnaces, but unlike Hydro, BASF did not have access to cheap hydroelectric power. In autumn 1906, BASF was interested in collaborating with Hydro and entered the negotiations based on a perception of its own strength. The company was set to obtain options for Norwegian hydroelectric power, had plans to build a calcium nitrate plant by the Alz river in Bavaria, and had further developed its furnace type. In 1907, a testing plant for the method was erected in Kristiansand. The parties were to set up a production company together that had access to both electric arc processes, as well as a power plant, and BASF and Hydro were to own equal shares in both. Because the Germans reserved the right to bring in their own waterfalls, Hydro was unable to finance the collaboration through waterfall sales. Nor had the value of Rjukanfossen been decided yet.

At the same time, problems with the absorption system meant that the Birkeland/Eyde furnaces were producing poor results at the plant in Notodden, and the possibility that the German furnace was better suited for the projects in Vestfjorddalen raised enthusiasm for the next stage, not least on the part of Paribas. In order to balance out the German holding in the new companies, Hydro would have to raise NOK 17 million in fresh capital. Following disagreement with the Wallenbergs on the distribution of this burden, involving parties such as French banker Aron Rotschild, the French ended up taking financial responsibility for the partnership with the Germans. Hydro's Swedish ownership share was then reduced, while the French shareholding was close to 70%. French historians point to the foreign policy context behind it; the strategic importance of the calcium nitrate industry meant that French authorities would not leave the development of this industry to Germany. The Hydro share was listed on the Paris stock exchange in 1908.

The complicated company structure around **the Rjukan project consisted of companies at three levels**. At the top were Hydro and BASF, with respective French and German majority shareholding, under which were two jointly owned subsidiaries, A/S De norske Salpeterværker and Norsk Kraftaktieselskab, which in turn had a number of subsidiaries in which assets such as waterfalls and technology were kept separate. The companies at the lowest levels only had Norwegians on their boards, which meant that they could count on more favourable concession requirements from the Norwegian state. Concession legislation did not yet exist in its final form. Leases for power were entered into between companies at the lowest level. Control of the waterfall power could be moved up in the system by shares in a company with the formal right of ownership being taken over by another company. Buying and selling waterfalls was subject to a concession obligation, but not buying and selling shares. *Hydro and BASF divided the work so that the Germans would have responsibility for the factories through A/S De Norske Salpeterværker, and the Norwegians for the hydroelectric power development through Norsk Kraftaktieselskab*, which was headed by the skilled engineer *Sigurd Kloumann*. Within this framework, *Norsk Transportaktieselskab* was to be set up as a subsidiary to build and operate the transport line from Notodden to Rjukan. Also on the transport side, it was unclear what concession conditions were to apply. The legal infrastructure around the Rjukan development was almost as demanding as the engineering challenges.

The cooperation agreement between Hydro and BASF of December 1906 included the utilisation of up to 500 000 horsepower for the manufacture of calcium nitrate based on Norwegian and/or German technology. The amount of power was twice the potential of Rjukanfossen, so if the plans were to be realised, calcium nitrate plants would have to be set up in locations connected to the parties' waterfalls. Initially, it led to gradual development in Rjukan, starting at the top of the valley. The agreement meant that the companies were to compete for the most rational electric arc process; in reality, it was more of a battle than a partnership. Hydro was involved in two parallel development processes; the calcium nitrate plant in Notodden on its own, and the facilities in Vestfjorddalen, where responsibility had to be shared with the Germans, and where Hydro was the subordinate party, industrially and financially as well as organisationally. In Notodden, 36 industrial-sized Birkeland/Eyde furnaces from 1908 were running round the clock at the plant. The furnace itself was now in principle completed, while there was still uncertainty regarding the absorption system for nitrogen gas. Norwegian engineers looked abroad for suitable technology from external suppliers, but ended up developing a new type of *granite and sandstone absorption tower* that was filled with quartz, through which water was percolated. Towers up to ten metres in height were erected in the tower house in Notodden. Testing of the furnace types was conducted in Notodden, in dedicated buildings erected for the purpose. The Germans also had problems with the absorption system for their Schönherr furnaces. It became impossible to conclude on the final choice of furnace technology. For the first part of the facility – Rjukan I – the majority of furnaces were to be German (96 to 8), while the decision was still open in relation to Rjukan II. BASF's absorption system failed, Hydro's granite tower system from Notodden was to be used, and 32 such towers were erected for Rjukan I. Based on an overall assessment, Hydro's engineers decided in 1913 that the Norwegian Birkeland/Eyde furnaces were to be used for Rjukan II.

The collaboration between Hydro and BASF nearly came to an end in 1910. Sam Eyde's obstinacy and extravagance was a topic that would cost him the job as director general of the Rjukan companies, but he also brought Kristian Birkeland into the work of improving the Norwegian process by constructing a furnace in which the load was increased from

Tower house for the Rjukan I plant emerges on former grassland. Photo: Neupert.

750 kW to well over 3 000 kW. Because of uncertainty associated with the technology and profitability, as well as major cost overruns in the project, BASF chose to sell its shares in the Norwegian business in 1911. Eyde then played the role of financial strategist, as he brought the American businessman Fred Stark Pearson into the matter and got the French bank Paribas to buy out the Germans. NOK 35 million was needed in order to complete the Rjukan facilities. Paribas set up a syndicate in which the bank itself contributed half the money. BASF also participated in that they accepted Hydro shares worth NOK 5 million as part of the settlement. When Pearson suddenly withdrew, capital had to be raised through a share issue in Hydro and large loans that were initially covered by the French bank Société Générale and Swedish banks. The jointly owned Rjukan companies – the calcium nitrate plant and the power company – were dissolved, while the subsidiaries – including the transport company and A/S Rjukanfos – were transferred to Hydro as wholly owned subordinate companies. The Norwegian triumph, in which Eyde was perceived as the nation's saviour, unlike five years earlier when he was portrayed as a lackey for foreign speculators, meant that Hydro continued to use Birkeland/Eyde's energy-intensive electric arc technology for many years. BASF, on its part, devoted its efforts to the development of an alternative technology, physicist Fritz Haber's ammonia synthesis where coal could be the energy carrier, a raw material that the Germans controlled.

The French connection is of a specific interest for the nomination of Rjukan- Notodden, in that the French investor Albert Kahn was involved. He was a shareholder in Norsk Hydro since 1907, when the base for collaboration with BASF was to be provided, and his relationship to the Rotschild Frères and Banque Paribas convinced these brothers to widen their engagement from 1911 and onwards, as BASF sold its stake in the company. Kahn was at the same time an idealist, who through 60 years had a close friendship to Henry Bergson, with whom he shared views and interests in philosophy and politics. In 1922, Bergson became the first director of *L'Institut Internationale de Coopération Intellectuelle,* which was established by the *League of Nations*, and is thus regarded to be a predecessor of *UNESCO*. Kahn was the creator of Archive de la Planète, a project intended to document and preserve the memory of human life and activities in its diversity. With his photographer, Auguste Leon, Kahn made a journey to Scandinavia in 1910, in order to test out the method of autochrome photography for this great project. Decisive for starting in Scandinavia was that he at the same time could make an assessment of the industrial establishing that took place in Rjukan and Notodden. Kahn's positive report to baron Edmond de Rotschild in turn gave way for the sevenfold increase of French investments in Norsk Hydro.

Industrial revolution, free trade capitalism and the global market

The industrialisation of Europe started in the latter half of the 18th century and accelerated during the 19th century. Industrial towns and cities absorbed much of the labour that became superfluous following the mechanisation of agriculture. Disease control, health services and nutrition also improved. The population of Europe therefore grew substantially, which resulted in emigration. The growth in the number of industrial workers forced agriculture to produce far more than the farmers needed themselves, in order to meet the consumption requirement. A more specialised economy arose, organised in a type of free trade capitalism, with markets for industrial goods and agricultural produce. With the UK as the leading global power, this form of capitalism came to prevail through free trade and global markets in the course of the 19th century.

The ideological ideas of Adam Smith coincided with the rise of capitalist economy.

One of the factors that permitted this development in the 19th century was less restricted trade between the countries of the world. With England as the driving force, a new economic policy was introduced whereby old mercantile privileges were abolished, rates of duty lowered or abolished, and *free trade agreements* signed between states, the first one with France in 1860. At the same time as the new technology made it possible to communicate and transport goods quicker and on a larger scale than before, it also became simpler and safer to engage in business activities across national borders, since the countries' currencies were linked to an international gold standard with a stable value. England had a particular interest in this development because the country's industry, which was leading from a technological point of view, needed new markets for its products. In order for the countries that imported British goods to be able to pay, they also needed an opportunity to sell something back. Import of raw materials from the colonies was no longer sufficient to cover the needs of industry. Ideologically, the policy was based on the ideas of economists like *Adam Smith, David Ricardo and John Stuart Mill*, who claimed that through increased specialisation and by utilising natural comparative advantages, free trade would be advantageous to all parties. Their liberalist economic theory claimed that minimal political control of business and industry would lead to a more efficient use of the resources and thereby increased material wealth for all, without taking into consideration the fact that power is unequally distributed between the parties in an unregulated market. The idea of free competition has spread from the UK, Europe and North America.

The development stages of capitalism illustrated by the examples of Norway and Hydro

The proposition of an investment in Norway had challenged the French bank Paribas's strategy of financing public infrastructure projects by issuing long-term bonds, often with the public sector as guarantor for the loans. It led to an internal confrontation on the bank's board between 'traditionalists' and 'modernists' who wanted to move in the direction of the German investment banking model and become involved in more risky industrial projects. Paribas had pursued a different strategy to German investment banks, which, by playing an active role in the industry in which they invested, exemplified the personal union between financial and industrial capital in the imperialistic phase of capitalism, in the words of *Vladimir Iljitsj Lenin* in a famous book from 1917. The book is based on Nikolai Bucharin's analysis of how big business gained control of investments on the periphery of Europe, referring to Norsk Hydro as an illustrative example.

V. I. Lenin referred to the Norsk Hydro Company in Norway as an example on the imperialistic phase of capitalism, characterized by the union between financial and industrial capital.

From an impartial viewpoint, the industrialisation of Norway was not a question of building the country, but a race to secure a piece of cheap Norwegian hydroelectric power. Germany took the lead in a new, organised form of capitalism, in which the economy was coordinated in close cooperation between businesses, and in which the state pursued an active facilitation policy, while big investment banks played key roles. The liberalistic economy of the 19th century that was based on individuals was replaced by a more organised cooperative capitalism. This was an archetypical contrast to the British 'personal capitalism', which dominated the economy during the first industrial revolution. A typical British capitalist was an individual who first and foremost was looking for profit. British companies were led by people representing the ownership interests, not by professional managers recruited on the basis of professional criteria. The banks played a lesser role; when a company needed fresh capital, it was mobilised on the basis of the personal wealth of the owners and their families. Investing in packed finished products, the way that British industry did towards the end of the 19th century, did not leave as much room for economies of scale and innovation as the electrochemical industry in Germany and the USA. In 1910, the British Foreign Service concluded that the UK was losing its long-standing dominant position in Norwegian industry. It was referring to German industry, which was on the offensive in Norway at the time. Leading industrialist Carl Duisberg of the Bayer chemicals group had visited the calcium nitrate plant in Notodden and the construction site in Rjukan in 1907. Duisberg was one of the initiators of the partnership between three of Germany's leading chemicals companies; Bayer, Agfa and BASF. Often referred to as *Dreibund*, the three companies undertook to finance the development in Rjukan, together with Hydro's French main shareholder, the bank Paribas. This was not least due to the fact that the Germans had succeeded in establishing connections with the right circles in the Norwegian middle class, and Duisberg himself described Eyde as 'appropriate and suitable for our purpose'. **The development of Rjukan and Notodden illustrates the new form of economy that coincided with the second industrial revolution**.

Sam Eyde portrayed himself and his role in a national context. The name Norsk Hydro and the logo evoked national associations. After the formation of the company, which was founded using foreign capital, both Eyde and Birkeland presented themselves to the Norwegian public with the invention they had made together – as they both put it – thereby solving the nitrogen issue. The stage was now set on which events could unfold that would be of importance to the national economy; future investments that would use hundreds of thousands of horsepower to run large factories in poor, undeveloped valleys. Nationally, the focus was nonetheless on waterfall acquisition and foreign owners' control of Norwegian companies as a threat to the political independence and economic sovereignty of the recently independent nation state. A prolonged political struggle arose concerning concession legislation, which was intended to limit foreign interests' ownership of Norwegian natural resources like waterfalls and to ensure that the ownership of foreign investments would revert to the Norwegian state after a certain period.

Concession and national control

Norway's full independence in 1905 was the result of political processes. Nation building was an issue both before and after the country became an independent state. The development of hydroelectric power and the energy-intensive industry in Norway triggered a heated debate about who had the right to own and control Norwegian natural resources. Among the issues of the day was the question of speculative acquisitions of waterfall rights. Foreign investors' control over Norwegian hydroelectric power, together with domestic players and major ownership interests in Norwegian industry created unrest in the Norwegian population. Some of the investors were only investors, which was the case for Norsk Hydro's French and Swedish owners. But some of the foreign investors that took an interest in Norwegian hydroelectric power were big, powerful, vertically integrated companies that often controlled both the exploitation of raw materials as well as production and sales, and had operations in several countries. Some of the companies were veritable giants by Norwegian standards. The German chemicals giant BASF, which was involved in Norwegian hydroelectric power on several occasions, had an equity of NOK 250 million in 1905 – which corresponded to 52% of all the capital managed by all of Norway's 83 commercial banks put together.

Several people pointed to the danger of large international cartels and their ability to affect the Norwegian economy and undermine free competition in the market. Many were particularly concerned that foreign companies could obtain a monopoly position in private electricity distribution and then charge unreasonably high prices that would damage small Norwegian businesses and Norwegian households. As the debate evolved, other issues began to eclipse the fear of private power monopolies and expensive universal power supply, such as labour rights and security polity. With reference to the Boer Wars (1899–1902), where Norwegian public opinion had largely sided with the Boers against the British-owned interests in the gold mines, which dragged the British empire into a war to conquer the Transvaal Republic and the Orange Free State, the question was raised as to whether there was a risk that the superpowers might intervene in Norway.

Scepticism regarding the new energy-intensive large-scale industry materialised on several levels. Parts of the Norwegian population were sceptical because of the social consequences. Large-scale industry challenged the position of Norwegian independent farmers, who were often portrayed both as bearers of the Norwegian culture and as the foundation of Norwegian democracy. Christian Michelsen, who was the Norwegian Prime

Minister at the time the union was dissolved in 1905, feared that large-scale industry would result in an 'unhappy proletariat' with the same divisive class conflicts that were visible in other European countries. The most suitable waterfalls were often located in narrow mountain valleys where there were few opportunities for other employment. A company that set up business in such a place would gain an immensely strong position in the local community, where the workforce would largely be completely dependent on the company. A shutdown or temporary halt in production would have enormous social consequences, such as poverty and political unrest. An expansion of export-related industry would also make the country more vulnerable to cyclical fluctuations in the international economy – completely beyond the control of the country. Some individuals, especially the most conservative farmers, used this as an argument against all forms of large-scale industry. On the opposite side stood the wish for modernisation and economic progress. The population in Norway was growing, and many people were emigrating to North America. New industry could help to create new jobs and new opportunities for the many young people who were unable to find work in traditional industries. But with modernisation backed by foreign investors came the fear that the lion's share of the revenues from the Norwegian watercourses would find its way out of the country. This was more a question of principle as to who would have the right to own natural resources, and not necessarily an argument against large-scale industry *per se*. Norwegian watercourse could in fact be owned by private individuals, unlike watercourses on the European continent, which were mostly public property. The difference between Norwegian and continental legislation was largely due to the fact that for centuries, rivers on the continent had served as important transport routes for shipping traffic, which was less relevant in Norway. In practice, this meant that private companies were basically given free rein to buy and develop Norwegian watercourses without the authorities getting involved.

The need for Norwegian authorities to get involved grew in parallel with the acquisition of waterfalls by entrepreneur Sam Eyde and his companies, such as Norsk Hydro with its foreign majority shareholding. In 1902, Eyde gained control of Rjukanfossen in Telemark and also bought strategic properties along the watercourse, until in 1903 he formed a company with a view to utilising the properties through resale or power development. His intentions were speculative; it was not yet clear what the waterfall power would be used for. The Norwegian Parliament introduced new legislation that linked concession obligation to conditions for waterfall acquisition. After 1906, it was initially a question of rushing through legislation in order to get a grip on the situation. The **concession acts** were finally passed in 1917. They extended the Norwegian State's authorisation to stipulate conditions for the development and utilisation of Norwegian watercourses and made it possible to discriminate against foreign investors. Perhaps the most controversial principle in the concession legislation was the *'right of reversion'* – i.e. that watercourses and hydroelectric power plants would fall to the State free of charge when the concession period expired. At the same time, the public got right of pre-emption to all Norwegian watercourses.

The financial importance of being able to use the hydrological cycle for electricity production, which in turn could be used for the new energy-intensive industries, far exceeded the financial importance of the waterfalls as tourist attractions and of some of the watercourses as important transport routes for timber floating. The struggle for the new resources meant that the Norwegian people had to face completely new challenges in relation to modernity, where both the future of the young democracy and the nation's independence were core issues. The solutions that were presented introduced completely new principles to Norwegian politics and created a *unique democratic system for the management of natural resources*. Despite the fact that concession legislation got part of the blame for reduced investments in Norwegian hydroelectric power in the interwar period, the laws were upheld and later became an important source of inspiration for the management of petroleum resources on the Norwegian continental shelf. This again affected the company Norsk Hydro, now as a participant in the recovery of oil and gas. The principle that Norwegian natural resources should first and foremost be owned by the Norwegian state or in other ways be subject to stringent democratic control is still a distinctive feature of Norwegian policy.

Commercial fertilizer as a commodity of universal importance

Historically, the development of human civilisation has largely been associated with technological advances in agriculture. Progress in other sectors has depended on increased efficiency in the agricultural sector, among other things by freeing up labour for other work, and in society in general through increased purchasing power and higher living standards for the population at large. In the early 19th century, a vast majority of the European and global population were employed in agriculture, while the urban population was small. In Norway, agriculture employed almost 90 % of the population. As the century progressed, a development took place from primitive to more efficient tools and farming systems. The use of different forms of fertilizer is an example of how the natural capacity of the land was manipulated for food production. Because robust, viable societies rely on a stable and sufficient food production, seedcorn, and later artificial fertilizer, became strategic resources that formed the basis for both conflict and trade.

Commercial fertilizer from natural sources

The industrialisation of the 19th century meant that the need for larger crop yields became urgent in many countries. Western European agriculture was made more efficient through the import of nitrates, especially from South America. The west coast of South America was an area with huge populations of seabirds, whose excrements had deposited in thick layers of **guano** over the years. The favourable qualities of guano were well-known to the Incas, but not to Europeans until the German explorer Alexander von Humboldt analysed the substance in 1804. Guano was easy to dig out and ship, and it became a commodity on the global market. Initially, it was an important raw material for the production of gunpowder and explosives. Guano was considered so strategically important that the United States Congress adopted the Guano Island Act in 1856, which gave American citizens the right to take possession of any island with considerable deposits of guano. On the basis of the act, the islands of Jarvis and Midway came under American control. Its fertilising properties were discovered by Europe in the 1830s, and demand for guano steadily increased as new land was put to the plough, and as fertilisation paved the way for the spread of wheat cultivation to areas such as the USA, Canada, Argentina and Russia. Peru in particular experienced a short period of wealth based on this resource. In 1880, nearly all guano had been recovered.

At the same time, another natural source of nitrate was ready to take over, namely the unique **deposits of sodium nitrate (saltpetre) in the Atacama Desert**. The area went from being uninhabited and insignificant to becoming a source of great wealth. The

Chile saltpetre was for decades the most important fertilizer available on global markets, but was in the end replaced by artificial electrochemical products. Photo: Skyscrapercity.com

question of who was to control and enjoy this resource quickly became a source of conflict. In the period 1879–1884, a war was fought between Chile and an alliance of Peru and Bolivia, which ended with Chile annexing the whole Atacama, leaving Bolivia without a coastline. The commodity was sold under the name **Chile saltpetre**. As representatives of the phenomenon, *two of the mining towns in Atacama were inscribed on the World Heritage List in 2005*, cf. ***Humberstone and Santa Laura Saltpetre Works***.

Chile saltpetre is a natural resource and as such limited. Towards the end of the 19th Century, it was clear to the industrialised countries in Europe and North America that alternative sources of nitrate were needed. The countries had somewhat different motives. As war was often used as a means of resolving conflict situations, on the European continent and elsewhere, nitrates were of strategic importance to the arms industry. In the event of a European war, Great Britain with its powerful fleet could secure supplies from Chile, while Germany risked being cut off from supplies for its war industry. Although the security policy dimension was considerable, the need for a stable, sufficient fertilising resource was nonetheless a prime motive. The appeal held by British chemist *Sir William Crookes* in 1898 warned of a resource disaster that would soon hit Western food supplies. Synthetic production of nitrogen fertilizer became a key topic at international congresses over the following years. It developed into a veritable race between players in different countries to find a method that was successful from both a financial and a chemical perspective.

Advertising for the Chile Saltpetre.

International race to resolve the artificial fertilizer issue. Competing methods.

The idea of binding free atmospheric nitrogen in an artificial fertilizer product had occupied chemists and physiologists since the late 18th century. The question of whether nitrogen in the air could benefit plants was answered in 1888 at a German research station in Bernburg by agricultural chemists Hellriegel and Wilfarth. By ploughing certain nitrogen-fixing plants (especially legumes) into the soil, the soil can be enriched by introducing nitrogen that non-nitrogen-fixing cultures can thereby use. The German Adolph Frank was the first to succeed in the industrial transfer of atmospheric nitrogen into artificial fertilizer. He presented the results of many years of experimentation at the fifth international congress for applied chemistry in Berlin in June 1903. By passing a stream of nitrogen gas, achieved through the fractional distillation of liquid air, over **calcium carbide** at around 1 000 °C, this will largely convert into *calcium cyanamide* ($CaC2 + N2 = CaCN^2 + C$). Calcium cyanamide can be used as a fertilizer because, in contact with water, it decomposes into *potassium carbonate* and *ammonia* ($CaC_2 + 3H_2O = CaCO^3 + 2NH_3$.) The same process takes place in the soil, partly influenced by certain bacteria. Sam Eyde participated in several of the international congresses for applied chemistry in the early 20th century.

Carbide factories had already been built in several countries, as part of the newly developed industries at the very end of the 19th century. The principle behind the production of carbide had been known since 1863, but it was not until 1892 that the American Thomas L Wilson and Frenchman Henri Moissan, simultaneously and independently, discovered a practical way of manufacturing it. The substance is made by subjecting burnt lime (calcium oxide) and coke (carbon) to a strong current so that the coke reaches a temperature of 2 000 °C. When carbide comes into contact with water, it produces the gas acetylene, which burns with a very clear flame. Carbide was initially manufactured as fuel for lamps, for use in mines, trains and cars, and it competed with petroleum, gas and even electricity for regular lighting. Acetylene gas is also manufactured for the welding industry as welding gas.

The Germans *Adolph Frank and Nicodem Caro* patented the cyanamide process or **Frank-Caro process** in 1903 as a commercial process for making artificial fertilizer. Nitrogen fertilizer from carbide (calcium cyanamide) was thereby established as one of the alternatives in the race to find an efficient way of producing artificial fertilizer. As with fertilizer, it must be used with caution, as it may have several unfortunate side effects; if it is applied too early for example, it can kill the germination. The first full-scale cyanamide factories were established in 1905 in Italy (Piano d'Orta) and Germany (Westeregeln). From 1908, the calcium cyanamide synthesis was applied at **Odda Smelteverk** (smelting plant), established by British capital in Norway (North Western Cyanamide Company). With an annual production of 12 000 tonnes in 1909, the plant in Odda was the world's biggest calcium cyanamide producer. At this time, there were seven first-generation plants in the world; in France, Switzerland, Poland (then Prussia) in addition to the countries mentioned above. At the cyanamide plant in Odda, calcium carbide was crushed into a powder and placed in upright, cylindrical furnaces that were then heated on the inside using carbon electrodes, adding and pressurised nitrogen. It took 36 hours to get cyanamide with a nitrogen content of at least 20%. The content of the furnaces shrinks and forms a solid that can easily be removed from the furnace walls. Other cyanamide factories, especially in Germany and Italy, used horizontal furnaces that were heated from the outside. The reaction temperature in these furnaces was more difficult to control, and the cyanamide had a tendency to stick to the furnace walls. Calcium cyanamide from Odda was sold under names such as 'Kornet Norsk Kalkkvælstof'. The commodity usually contains approximately 20 % nitrogen.

Internationally, the cyanamide process was to become the most important method of producing artificial nitrogen fertilizer until after World War I, when the **Haber-Bosch process** became dominant. After World War I, most industrialised countries also introduced a policy of self-sufficiency, which resulted in more competition on the export markets. In order to meet this challenge, alternative raw materials, processes and production methods were sought. At Odda Smelteverk, chief chemist *Erling Johnson* was given an opportunity to switch production to new types of fertilizers, which led to the development of *the Odda process* in the period 1927–1928. (Odda Smelteverk is also described in section 3.2 Comparative analysis, page 325-329.)

Around the year 1900, however, the picture was not clear. As early as 1785, Cavendish had proven that, when electric sparks flash over through air, the oxygen and nitrogen in the air will bond and, when mixed with the humidity in the air, will form the nitric acid that is always present in the atmosphere, and that will pass into the soil through precipitation. This was the starting point for an alternative track. William Crooke, who in 1898 warned of an upcoming food crisis in 'the civilised world', had himself described a solution: When a powerful electric current is passed between two poles, the air 'catches fire' in an electric arc, i.e. it continues to burn with a mighty flame while producing nitrous gases, in which nitrogen is bound. Many people worked theoretically and industrially on the question of how to **fix the nitrogen in the air**, which turned into an intense technological competition. Patents were taken out in a number of countries, and experiments with **electric arcs** carried out in countries including Germany, England, Switzerland, France and the USA.

In *1902*, Americans *Charles S Bradley and D Ross Lovejoy*, with the company Atmospheric Products Co, had carried out an industrial trial of electric arc furnaces at *Niagara Falls*, where huge amounts of electric energy were available from the world's first big power plant. The method was not sufficiently developed, however; the apparatus was too complicated and had many deficiencies, including technical problems with materials, which meant that it proved so impractical and financially unsatisfactory that the effort was discontinued in 1904. (See also *Niagara Falls, from tourism to industry* on page 254-255, and 3.2 Comparative analysis, the USA on page 347-349.)

'Norway saltpetre' on the global fertilizer market

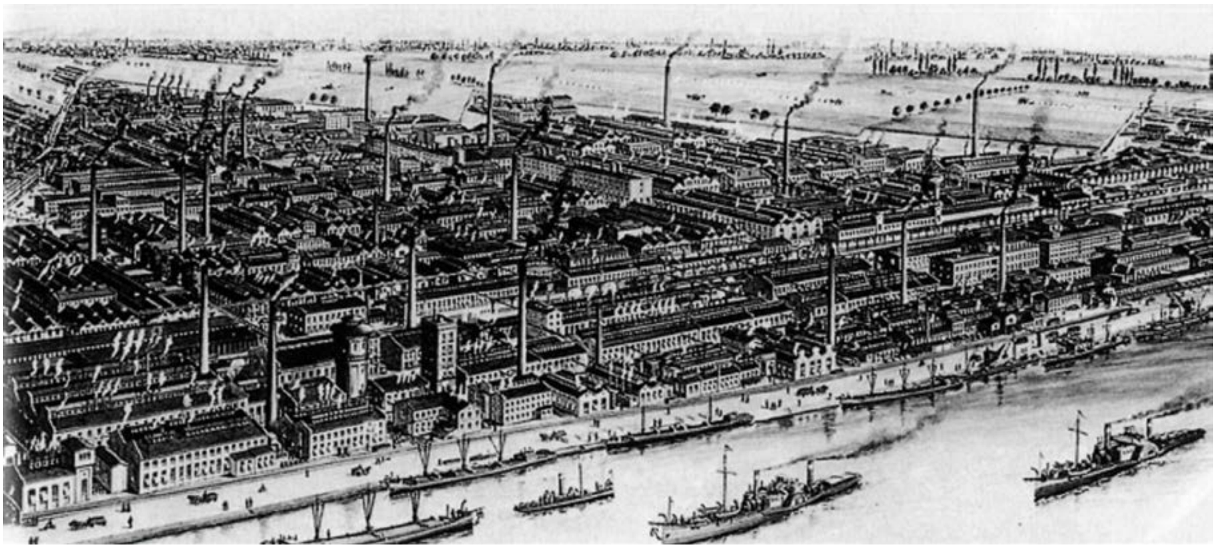
Nitrate export from Chile increased from 1905, and Chile saltpetre had the biggest market share. Of the alternative fertilizer products, sulphate of ammonia – a by-product of the coal industry – and the carbide-based cyanamide sold well because they were inexpensive, but as plant nutrients they were also of a lower quality. Hydro's product was of an equivalent quality to Chile saltpetre and went for the same price. During the first years, Hydro's production accounted for a small part of the sale of fertilizer in Europe; in 1911, the plant in Notodden produced 15 000 tonnes of 'Norway saltpetre', but when Rjukan I was completed in 1912, Hydro was able to send 71 000 tonnes to the market. At the same time, Hydro decided to pursue a more aggressive brand-building strategy. The emblem with the Viking ship was introduced, a brand that would allude to the product's Norwegian origin.

World War I changed the framework conditions. Hydro strengthened its position by supplying nitrate to the arms industry in warring countries on both sides. Exports to France accounted for a third of the country's nitrate requirement. Supplies to Germany secured the technical components and equipment that were required to complete Rjukan II. At the same time, Germany was taking steps to increase its domestic nitrate production, in which BASF and Haber's ammonia process became important. During the war, **ammonia nitrate** became the most important product. Unlike 'Norway saltpetre', it could be used directly to make explosives. Hydro built its own ammonia nitrate plant and ammonia water plant in Notodden (*object 7.15*, described on page 120-121). When Rjukan II started up in 1916, Hydro's production amounted to 80 000 tonnes of ammonia nitrate and 11 000 tonnes of 'Norway saltpetre'. When the war ended, 'Norway saltpetre' once again dominated production: in 1920, it amounted to 135 000 tonnes. Total production using the Birkeland/Eyde furnaces during the period in which they were in operation, 1905–1940, totals 580 000 tonnes of bound nitrogen, which corresponds to four million tonnes of finished product (nitrate of lime). The production volume consistently doubled every ten years, and

Norway saltpetre (Norgesalpeter) produced by Norsk Hydro in Telemark, Norway, conquered a big share of the global market.

Hydro became the biggest nitrogen exporter in Europe. In 1931, Norsk Hydro alone accounted for 10 % of the country's total exports to France. In 1952, exports amounted to 80 % of Hydro's production. On a global basis, approximately 16 % of the fertilizer produced was exported. Hydro's share of the world's total fertilizer production was 3.3 % in 1955, which meant a share of the global market of 18 %. 'Norway saltpetre' was a high-quality product on which Hydro had a monopoly, and which farmers in many countries preferred.

Its primary competitors were the British-owned ICI, the American company Du Pont, the German BASF and subsequently IG Farben.



The Baden Aniline & Soda Fabrik (BASF) factory at Ludwigshafen in Germany around 1890.

Hydro's changeover to the ammonia process and hydrogen electrolysis

World War I had intensified the international technology competition. In Germany, BASF had achieved success with its Haber-Bosch method, and, although the victors of the war gained access to the German patents, Germany regained its strong position on the international nitrogen market. The Haber-Bosch process was improved, but it came in different versions, and there were also other ways of making ammonia. The most important elements of the **Haber-Bosch method** were the reaction between hydrogen and nitrogen in large furnaces under great pressure and high temperatures achieved with the use of a catalyst. In Germany, coal was used to make hydrogen. The costs of this hydrogen production amounted to about half of what it cost to make synthetic ammonia. Hydrogen could also be made through *electrolysis of water*, however, which was cleaner than coal-based production. Depending on the price of electricity, it could also be a lot cheaper. The inexpensive Norwegian hydroelectric power was again emphasised as a resource of interest.

Hydro pursued its electric arc method for as long as possible, and engaged in extensive testing to improve it. Sam Eyde left the company's management in 1918, following disagreements based on how Hydro was balanced between the warring countries and Eyde's business involvement in competing companies. In 1925, BASF managed to make calcium nitrate based on the ammonia process. It was then clear that it would be able to compete with Hydro's method. Eyde saw this more clearly than the board of Hydro, and got Wallenberg and Paribas involved with a view to a changeover. Hydro's board then ordered the company to make a comparison of the processes. The expert committee that was appointed concluded that the Haber-Bosch method was superior, and *the changeover decision was made in 1926*. As in 1911, Eyde wanted a collaboration with BASF where the German method and Hydro's inexpensive power could mutually benefit each other, but Hydro's management wanted to keep BASF away and instead use a similar ammonia process that had been developed in the USA. The hydrogen plant that Hydro set up in Notodden for the purpose of the US collaboration was called 'the tactical plant' (*object 7.10,* described on page 115), with reference to the position that was taken in the negotiations with the German cartel of chemical companies (including BASF), which in 1925 became the industry conglomerate IG Farben. In 1927, Hydro and IG Farben nevertheless entered into a close, contractual collaboration, in which Hydro left the sale of its production outside Norway to the Germans and let them have 25 % of the shares in Hydro and a place on the company's board. The place that they got was Eyde's; he had to leave the company he had helped to set up because he had received payment from the Germans prior to the agreement and was accused of acting on their behalf in the negotiations.

Although Hydro controlled large amounts of inexpensive hydroelectric power, the energy need was related to the alternative electrochemical processes of importance to the competitive situation. In 1926, the Frank-Caro process for cyanamide required approximately 12 000–14 000 kWh to produce one tonne of fixed nitrogen. By comparison, Birkeland/Eyde's electric arc process required as much as 61 000 kWh, while the Haber-Bosch process only required 4 000 kWh. In 1926, 24 % of the annual production of fixed nitrogen was produced using the Frank-Caro process, only 6 % using the electric arc process and the remaining 70% using the Haber-Bosch process.

The changeover to a production method based on electrolytic hydrogen, in which Eyde's role must be acknowledged, became the biggest milestone in Hydro's history in the interwar period. Both Notodden and Rjukan were prioritised for continued operation, and production quickly started at the *New Production Facilities* that were built during the period 1928–1929, with ammonia production in Notodden and continued fertilizer production using the Haber-Bosch method in Rjukan. The new production facilities in Rjukan meant that *Vemork and Såheim had to be modified* to supply direct current. Hydro had acquired *the Herøya peninsula near Porsgrunn* ten years earlier, where the *Eidanger calcium nitrate plant* was built in 1929, which would become the company's biggest facility. (See also 3.2 Comparative analysis for a description of Herøya.) Here, ammonia was made into the main product nitrate of lime. During the German occupation, the German interests secured the majority shareholding (53 %) in Hydro, by a share issue in December 1940 from which the French owners were excluded. After the forced dissolution of IG Farben in summer 1945, the Norwegian state took over the German shares in the company.

Just a few days after the start-up of the new production facilities in 1929, the New York stock market crashed. This led to an international crisis that had consequences for the entire international nitrogen industry and thereby led to new rationalisation requirements for Hydro throughout the 1930s. Hydro's finances seen in relation to the potential consequences for the industrial towns of Notodden and Rjukan in the event of a move to Herøya were continuously assessed until most of the business was moved in the late 1960s.

Heavy water

Heavy water was discovered in 1933 when chemist Gilbert Newton Lewis was the first to isolate a pure sample of deuterium oxide. Hydro used electrolysis of water to produce artificial fertilizer by ammonia synthesis. From 1934, the hydrogen plant in Rjukan, which was the world's largest water electrolysis plant, produced heavy water on an industrial scale as a *by-product of hydrogen electrolysis*. In chemical terms, deuterium oxide D_2O is relatively similar to ordinary water, H_2O, but it is 10 % heavier because both the common hydrogen isotopes are replaced by the deuterium isotope, which is twice as heavy, its nucleus containing a neutron in addition to the proton that is found in all hydrogen atomic nuclei. The substance was used in technical and medial experiments to curb growth processes. It can be used in nuclear reactors as a moderator to slow down the neutrons to the correct speed, but also as a heat exchange medium. Used heavy water from reactors is slightly radioactive because of the formation of tritium. *In spring 1942, scientific tests proved that it was possible to make plutonium in heavy water reactors*.

Barrels with heavy water lying close to the wreck of D/F Hydro at the depth of 430 m i the Tinnsjøen lake, as result of sabotage action in 1944. Photo: Thor Olav Sperre.

Heavy water from the Rjukan factories Photo: Teknisk Ukeblad.

Heavy water from the Rjukan factories

During World War II, the Germans occupied Rjukan and took possession of Hydro's products. During the war, the barrels of heavy water were shipped to Germany, where they would be used to control nuclear fission. Following new installations in accordance with a German method, production increased to 100 kg a month from the start of 1942. No other place in Europe produced that much high-concentration heavy water. Towards the end of the war, Germany saw the production of nuclear weapons as the key factor that could decide the outcome of the war in its favour, which meant that it became vital for the Allies to prevent such a scenario. The strategic importance of the substance as a component in the development of nuclear weapons made Rjukan the centre of renowned, important acts of war. Allied forces and Norwegian saboteurs carried out actions that succeeded in their objectives, in the form of Allied attacks and acts of sabotage against production plants and transport systems. As a consequence of the outcome of the war, the Norwegian state took over the German shares in Hydro as war indemnity in 1945. This meant that the majority shareholding was finally in Norwegian hands. (Objects relating to hydrogen synthesis are described under *object 7.10*, page 115, *object 8.6*, page 127-128, acts of war under *object 11.15*, page 165, and *Supporting values* on page 209.)

Conditions and ideals for architecture, urban planning and the art of building

Sam Eyde was very important to the new engineering profession in Norway. Norsk Hydro hired young engineers who were given challenging tasks and a good salary. Eyde and Hydro also wanted to provide employment opportunities for young Norwegian engineers. The Rjukan facilities and the town were planned from scratch in a remote area with dramatic scenery. Many of these professionals were still in their 20s, as young as the nation, but they still managed to handle ground-breaking projects that by their nature and genre were in many ways world-class. The entrepreneur's systematic acquisition of building sites meant that, during the zoning work for Rjukan, the site could be planned as an integrated whole. With the exception of some properties in the commercial centre of the town, all other private parties were excluded. The topography, with the deep, narrow Vestfjorddalen valley and its east-west orientation leaving just a narrow strip in the bottom of the valley suitable for development, formed the basis for Rjukan's town plan. In places, extreme conditions had to be overcome, such as the danger of landslides and avalanches, and sunlight conditions where the mountain massif left the valley in the shadow for up to six months of the year. At the time the industrial towns in Telemark were being built, urban planning as a discipline was becoming professionalised in Europe, Norway and North America. **The concept of zoned towns** crystallised from a professional, ideological discussion of the town plan as a tool for social design.

Foreign-educated architects in a national context

Sam Eyde himself was an engineer, holding a diploma from a German university college in Berlin, and his studies had also included architecture. At that time, the German university colleges were considered to provide the best education an engineer could get. Norway had no equivalent institutions. There were 'semi-technical' colleges in Bergen, Trondheim and Kristiania (Oslo); it was not until 1910 that the Norwegian Institute of Technology opened in Trondheim. The institute also trained architects, and for many years, architects and engineers formed a joint expert community in the country, with backgrounds from foreign university colleges, especially in Germany, and to a lesser extent Sweden.

Most of the professionals who started working for Norsk Hydro in Telemark were educated abroad and were well versed in international tendencies and trends. At the same time, the nation's struggle for independence and nation-building after 1905 influenced the period's style, in architecture as in other aspects, so that the formation of Norsk Hydro was perceived as archetypally Norwegian on the rhetorical level even if the ownership was in fact foreign. The town of Rjukan, large parts of Notodden, and a number of buildings used for power plants and railway transport are typical examples of that period, both in terms of an integrated social and industrial environment and as individual buildings. The work was largely carried out by architects employed by Norsk Hydro or the sub-department ***Rjukan Byanlæg***. The predecessor to this office was called *Architektführung*, which was only operational during the period from 1908 to 1911, when BASF, pursuant to the cooperation agreement with Hydro, was to be responsible for the production plants in Rjukan.

The inner villages of Telemark are deemed to be a central area in terms of Norwegian building traditions. In the 19th century, the tourism industry had penetrated these rural villages with stylistic whimsies in the European fashion, such as the Swiss chalet style that romanticised the rural architecture of the Alps. It differed greatly from the rural architecture of Telemark, not just stylistically in expression and size, but also in terms of the building method. The sawmills now delivered timber sawn and planed to standard dimensions, at the same time as college educated engineers and architects began to appear in Norway. These skilled academics argued in favour of the new building method; among other things, they claimed that high ceilings and large windows were healthier than the dark farmhouses. As the Norwegian nation building project matured, architects developed the 'dragon style' as a Norwegian variant of the Swiss chalet style. The 'dragon style' was used not least for tourist hotels, some of which could be huge, and with their towers and spires, they represented something new in an old building environment.

Several architects were employed by Norsk Hydro and Rjukan Byanlæg, but for certain categories of buildings, especially the biggest and most prestigious, external architects were hired. In most cases, this was **Thorvald Astrup**, who designed several power plants, all the railway stations, some factory buildings, the Admini building in Rjukan and the engineers' mess hall, and some houses in Rjukan. For the two most important power plants, the assignment went to cathedral architect and professor **Olaf Nordhagen**. The large, prestigious buildings were individually designed and are of high architectural quality. The style varies from historicism to bordering on functionalism. When the company later switched to an alternative production method (Haber-Bosch) just before 1930, functionalism was at its height and the preferred choice. In Notodden, the Tinfos company also hired skilled architects for the power plant, administration building and houses, in order to assert itself – influenced by Norsk Hydro.

Large-scale industry entailed new building assignments and types of buildings of a completely different character and dimension. The architects were to some extent inspired by traditional architecture when they designed the Hydro projects. This applies in particular to **Magnus Poulsson** and **Ove Bang** (houses, villas) and Thorvald Astrup (Tinnoset railway station building etc.). Local and national elements are nonetheless given a place in schemes based on international trends. Earlier *industrial architecture* only acted as a model to a limited extent. Pulp and paper mills had been set up near Norwegian watercourses to utilise the energy of falling water, and these had to accommodate many new types of machinery that required large halls and fireproof walls. *Brick, iron and glass* were the preferred materials. When electric power plants and the electrochemical industry appeared on the scene, developments in iron and steel production had resulted in new technical properties that opened up new possibilities in terms of construction technique. Combined with cement, there was now *reinforced concrete*, a flexible new building material that could handle dimensions and loads that were previously impossible. Developments in construction technique, from Portland cement (1820), iron-reinforced concrete (1857), Gilchrist-Thomas and Bessemer's methods for iron and steel processing, to modern reinforced concrete (around 1900, JL Lambot and F Hennebique), are an important background to the engineering and building feats that could not otherwise have been accomplished during the industrial boom in Notodden and Rjukan.

In terms of architectural history, the period when Hydro's industrial development took place covers developments in style from variants of historicism and Art Nouveau to the neoclassicism of the 1920s and the onset of functionalism as we approach 1930. The material used for industrial buildings went from traditional brick to reinforced concrete ('ferroconcrete' as it was called then). This follows international trends in industrial architecture with the use of steel, glass and concrete. Together with the use of reinforced concrete, the use of iron and later steel frames for warehouses and factory buildings was a key step in the direction of modern architecture. It paved the way for a freer, more functional design. The nation-building process before and after 1905, the year of Norway's full independence, often meant that the architecture used for symbolically significant building projects was given a national flavour. For example, Norwegian railway architecture was not as influenced by the Gothic style as in countries such as England. Wood and natural stone were often used to reflect the general national connection. Rough-hewn stone cut from the Norwegian bedrock was characterised as a national style at the time.

Although the architecture is characterised by the contemporary styles, it also has a homely and local character that means that Rjukan and part of the buildings in Notodden are distinctive and suitable for the landscape in which they were situated. As regards private houses, around 140 types of house were taken into use by Hydro in Rjukan, including individual houses erected for directors and administrative staff. This diversity covers both differences in rank in Hydro's internal hierarchy and a range of styles influenced by national and international trends.

Progressive impulses. The German connection

In the period from 1906 to 1911, Hydro and BASF collaborated on the development in the Vestfjorddalen valley, where BASF undertook the financing together with Hydro's French main shareholder Paribas. A certain amount of German influence on the industrial architecture in Rjukan can be traced from this collaboration. Through the joint venture with Norsk Hydro, *the Germans were to be responsible for the production plants, while Hydro was to handle the power development.*

The Germans had a staff of engineers at work in Rjukan during this period; (see the area called Tyskerbyen (the 'German town', object 13.12) in Rjukan, page 182) and it is likely that architects, or at least engineers with a knowledge of construction and contemporary German industrial architecture, also took part in the work. In Germany, **Peter Behrens** created new highlights in industrial architecture in this period, with the power plant (1905–1908) and turbine factory (1909) that he designed and constructed for the company AEG in Berlin.

Peter Behrens created a new language for industrial architecture by bringing together ancient classical typology with modern parameters like the absence of decoration. His works for AEG in Berlin (1909 – 1912) showed monumentality, and had great impact on younger architects.

The managements of the big German industrial companies, including BASF, AEG and IG Farben, with which Hydro collaborated at times, were concerned with industrial design and wanted to impress their workforce with spacious, good-quality factory premises. With the help of skilled architects, they wanted to show the workers that they cared. With their aesthetic design, the buildings also served as symbols of the industrial company's resources and demonstrated faith in industry and industrialism. This also characterised Hydro's way of thinking. It centred on an expressed wish to add architectural and stylistic quality. In the same way as the German companies, Hydro employed skilled, recognised architects for all its building projects. Several of these architects had obtained their degrees in Germany; Thorvald Astrup, Christian Morgenstierne and Bernt Keyser-Frølich at Technische Hochschule Charlottenburg in Berlin, where Sam Eyde also got his engineering diploma; and Helge Blix from the university college in Neustadt.

The factories and residential houses became part of the reform movement in architecture. In addition to German progressive design, architects were also influenced by modern American construction and Russian structuralism trends during the decades when Hydro was building its factories and towns in the inner parts of Telemark. Morgenstierne had also studied in Chicago. He studied at the university college in Charlottenburg in the period 1898–1900 before he took a state exam in the USA, and he worked for four years in Berlin and five years in Chicago before he moved home to Oslo. He was therefore well versed in the development of industrial architecture from two of the most prominent cities in the world in that field. Thorvald Astrup, who designed several of the buildings in the Hydro parks in both Rjukan and Notodden, represented Norway as one of the country's leading industrial architects at the 12th international congress of architecture in Budapest in 1930. The topic was the architect's role in relation to industrial buildings. Astrup addressed the ideas mentioned above. He expressed the opinion that a change had taken place, whereby industrial buildings, which had previously been neglected from an aesthetic point of view, had now become the subject of attention and requirements. He believed that architects had to be hired by the management rather than by the contractors, that they had to give priority to practical considerations for industrial operations and make an effort to get engineers and industrialists interested in architecture. At this time, Hydro was again collaborating with German industry, because of the changeover to the German Haber-Bosch process, which meant that a number of new buildings had to be erected in both Notodden and Rjukan.

The labourer issue

In his many talks about the Norwegian calcium nitrate industry, Sam Eyde often directed attention to the workers' living conditions. He stated to many different audiences that

Workers homes in the Krupp Siedlung Altenhof in Essen, Germany, pictured in 1902, from Wikipedia.

he believed the thousands of people who would come to Rjukan would get a life that was far better than that of workers in the big cities. The first neighbourhood Hydro built exclusively for its workforce was 'Grønnebyen' (the 'Green Town') in Notodden, and slides of the houses accompanied Sam Eyde's talks until building in Rjukan was finished. At the same time, he often commented that the conditions in Chile – at the sodium nitrate mines – 'are not quite as favourable'. Rjukan would get 150 double workmen's houses with a small garden patch for each apartment, in addition to several services. Eyde stated that experience from *BASF's industrial complex in Elberfeld in Germany* had served as a model for him. There, large amounts had been spent on providing housing for the workforce that was suited to their needs and taste, and that they eventually would be able to buy. The purpose was not only to show appreciation for the workers' contribution to industry, but to create a sense of solidarity and fellowship between the company's blue-collar workers and engineers. German model towns for workers are inextricably linked to *Alfred Krupp*, who built what were considered very good houses for his workers as early as in the 1860s. In Essen in Ruhrgebiet, Krupp competed for labour by offering the workers dwellings in beautifully designed areas. In 1865, Krupp concluded that *'is it clear.......what advantage we will have in relation to others if we provide safe housing for our people'.* Eyde was familiar with these aspects of German industry. He undoubtedly saw expenses for the workers' social and material welfare as investments towards a contented workforce in the company. Big thinking was also needed to get the new industrial communities to work. Offering work was not enough on its own; in order to provide stable conditions, the company had to make it attractive for families to settle down there.

Workers homes on Vitalistrasse, Braunfeld, Germany, built 1902-03 by the gasworks on Widdersdorfer Strasse. Photo: www.Braunsfeld.info.

Built from scratch with high-standard infrastructure, well laid-out streets and beautifying parks, **Rjukan** was to be presented as the most modern town in Norway. The high standard of living was based on a wish to offer the workers a good quality of life, but also to attract and retain labour. Bathrooms with hot water, a flush toilet and electric lighting in every apartment were sensational in terms of comfort. Rjukan was a leading example in this field. As in Germany, the workers would get an opportunity to buy their own home, being granted loans on favourable terms that were repayable to the company in reasonable annual instalments, while Hydro provided all the amenities of a modern town with: *'schools, bathing facilities, village hall, sports ground, hospital, infectious diseases hospitals, boarding house for unmarried workers, grocery, bakery, butchery with freezer, fire service, a large mains water plant etc., etc.'* Eyde stresses that these *'arrangements have been completely voluntary on the part of the company. We have no concession obligation, no orders to do anything other than what any employer should have; that he should ensure the well-being of his subordinates, if he is to demand that they perform their job satisfactorily.'* And further: *'To me, the labour issue is one of the most important we have; as no one is more aware than the workers of who is concerned with their well-being and understands them. Without understanding and solidarity, it will be difficult to solve the major tasks. You can never demand that the struggle between worker and employer should end. But one must seek to create trust among the workers and gain their sympathy. That way, we can achieve a better balance.'*

Trends from Europe formed the basis for Eyde's attitudes. However, the workforce was also internationally aware, and Rjukan was not without labour conflicts. In 1912, there was a major strike in Rjukan led by workers inspired by syndicalism. The workers were also concerned with becoming part of the bourgeoisie, bound by the company's interests and fate, which meant that the idea behind the **'Own Homes'** movement did not catch on in Rjukan. The workers in Rjukan built their parallel society as the company and town grew. They set up and ran their own cooperative societies, a newspaper, library, holiday home, clubs and associations. The *Folkets Hus* (People's House) (*object 13.10,* described on page 179-180) that was finally erected is a marked manifestation of the labour movement's independent role in Rjukan.

The modernity and investments in quality of life that were made in Rjukan are to a lesser extent part of the overall town structure in Notodden, but are clearly visible in the housing areas near the factories, such as in Grønnebyen (the 'Green Town') (*object 12.1*, described on page 166-167) associated with Hydro, and Kanalbyen ('canal town') and Hyttebyen ('cabin town') associated with Tinfos.

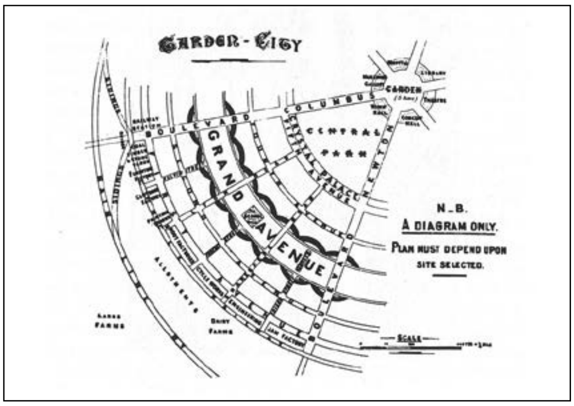
Model towns and the garden city movement, 'company towns'

The urban planning was also based on international ideals and principles. Rjukan is the first planned company town in Norway and it builds on ideals from England, based on the *garden city concept* as the foundation for a high physical standard for the workforce. The influence from English garden cities and German model towns is clear. 'Company towns' were built during both the first and the second industrial revolutions, and leading industrial nations such as the UK, Germany and the USA were also leading in the development of this phenomenon. An important part of the basic idea behind company towns is the desire for a better quality of life for the workforce.

The term 'company town' is originally American, while 'model village' is often used in the UK, 'Arbeitersiedlung' in Germany and 'cite ouvrière' in France about the same company-controlled urban development. In Russia, towns built under the dominance of a single company are called 'monotowns'. The Oxford Dictionary defines 'model village' as a *'village providing a high standard of housing, typically built by an employer for the workforce'.* Another definition was provided in connection with the inscription of New Lanark on UNESCO's World Heritage List: *'The company town may be defined as a settlement created by a single enterprise and run in such a way as to attract, retain and control the workforce.'*

Urban planning in the 1800s was largely characterised by practically oriented grid plans. Baroque ideals also came into play, however, such as in Georges-Eugène Hausmann's rebuilding of Paris, commissioned by Napoleon III, where avenues cut diagonally through the streets of old Paris. This continuation of the baroque planning ideals served several purposes. In part, it was a symbolic, political act, an expression of the ambition to highlight France as a superpower and turn Paris into the leading city of the industrial age. The drastic changes to the city also fulfilled a practical political aim, however; to ensure increased control for the government by making the city easier to defend than the old Paris with its narrow, twisted streets. At the same time, Hausmann managed to make the city more efficient by linking the new railway stations to the main business areas in the city.

Reactions to authoritarian, geometrical planning, which barely considered the needs of the population, came around the turn of the century and were brought forward by Austrian **Camillo Sitte** (1843–1903), who became the leading urban planner of his day with the book *Der Städtebau nach seinen künstlerischen Grundsätzen* ('City Planning According to Artistic Principles') (1889), which emphasised the importance and impact of urban spaces. He wanted to return to the medieval city structure, with cities that had developed by themselves with an organic connection between streets and spaces and important buildings. The problem consisted of adapting these goals to the tremendous population growth and providing alternatives to the big cities' self-developed slums. **The garden cities of England**, initiated and launched by urban development theorist **Ebenezer Howard** (1850–1928), were one solution. His book *Garden Cities of Tomorrow* (1898) became very important to European urban development. Howard was self-taught and had been inspired to further his own ideas by Edward Gibbon Wakefield's *View of the Art of Colonization* (1845).



Ebenezer Howard: Garden-City. Grand Avenue, 1902, in Garden Cities of Tomorrow.

Howard's strength was a combination of idealism and a businessman's realism. The garden city was formalistic, organised in concentric circles around a centre, until it petered out into the outer circle of farmland, a pattern that had roots all the way back to the Renaissance. The garden city concept promoted variation in house designs, spaces and front gardens, organic structures and curved streets.

Model towns arose in the 19th century when industrialists recognised the need for *improved living conditions* for poor working class families, and for the purpose of exercising *social control* over these families. It was also assumed that improved housing and sanitary conditions in particular would benefit the company in the form of increased productivity. This typically concerned a *philanthropic, paternalistic owner* who achieved his ideas for the company in a social context. Sam Eyde learnt all about the German industrial groups' model towns for their employees. An important part of the fundamental idea behind company towns was the wish to improve the quality of life for the workforce, which also led to the garden city movement initiated by Ebenezer Howard.

A **company town** is described as a town or urban settlement where real estate, buildings for both housing and commercial purposes, retailers, buildings for health and social purposes, infrastructure, etc. are owned and run either wholly or mostly by a single enterprise, the cornerstone company that is also the town's biggest employer. The purpose of building a company town is often related to the decision to locate a large industrial enterprise in a small, undeveloped area with access to natural resources that then generates the need to provide housing and infrastructure for the workforce. In all respects, ***Rjukan*** is a company town. Notodden is to a certain extent, but only because it was already being developed on the basis of general transport and communication and service when the industry came to the town, and because, when it started to grow, there were two separate industrial companies that built in parallel on the basis of their needs and made their impact on different parts of the town. (Notodden Hydro Town is described on page 68-70, and Rjukan Hydro Town on page 70-79.)

People of importance to the nominated places; brief biographies

Sam Eyde (1866–1940), engineer, industrialist and entrepreneur



Sam (Samuel) Eyde; engineer, gründer within industries, member of the Storting (Parliament), Norwegian Minister to Poland, receiver of the Danish Dannebrog order and the Swedish Vasa order.

Sam Eyde was the son of a ship-owner from Arendal. He achieved a degree in engineering in Berlin, and went on to work for a number of years in Germany, Sweden and Norway on railway station and port facilities. In Lübeck in Germany, Sam Eyde made a breakthrough in bridge construction. Together with a German engineer (C O Gleim, Hamburg), he won several prizes in international competitions for railway stations and port plans, including for Hamburg, Copenhagen and Kristiania (Oslo), where in 1897, he won first prize alongside his German colleague in a competition for the railway station design for Østbanen (the Eastern Line). The following year, he set up Ingeniør S. Eydes Ingeniørkontor (engineering office) in Kristiania (Oslo). The office won a number of competitions for railway station and port designs, including in Stockholm, where a branch office was set up. The competitions made Eyde famous in both Norway and Sweden. The company built ports and railway stations in cities including Gothenburg, Helsinki and Malmö, and until 1903, he served as a consultant for the railway administration in Norway. When he started his own career as an industrial organiser around this time, he was thus familiar with the establishment of infrastructure on a large scale. This must have been a contributing factor in the solutions he favoured, when, after having met Kristian Birkeland in February 1903, he devoted his time to the industrial use of Birkeland's method for the mass production of nitrate of lime. The problem of making calcium nitrate fertilizer by fixing nitrogen in the air was in fact solved as early as August the same year. Together, they continued to develop Birkeland's method on an industrial scale. In 1905, Sam Eyde set up the company Norsk Hydro to make use of the invention on an industrial scale. Eyde had raised Swedish financial capital (the Wallenberg brothers) in order to form the company. By marrying the Swedish aristocrat Anna Ulrika Mörner of Morlanda, he had gained access to Swedish financial circles. Cooperation with the Swedish entrepreneur Knut Tillberg, who was also a lawyer, state official and member of the Swedish Parliament, gave Eyde connections to

Swedish capital owners who were willing to make investments, and the first of these was the diplomat Fredrik Rappe. Later, Eyde made contact with brothers Knut and Marcus Wallenberg and their Stockholms Enskilda Bank, which really speeded up Eyde's projects.

Eyde was familiar with the American trial project at Niagara. In Notodden, where, as at Niagara, developed power was available, test production was started that showed promise. At the same time, there was potential to deliver considerably greater volumes of power by further developing the watercourse, with Rjukanfossen as the jewel in the crown. In a short space of time, all the pieces were in place for an industrial success story of great national and international importance. Sam Eyde was an important driving force in this process. Eyde had returned to Norway with huge ambitions to use the power in Norwegian watercourses. Among other things, he helped to form Elkem together with Swedish investors, Norsk Hydro with Swedish and French investors, and the power company A/S Tyssefaldene. The circle around Eyde was also crucial to the establishment of companies such as the British carbide company Sun Gas Company in Odda and to the arrival of the French-owned aluminium company DNN Eydehavn and Tyssedal.

Burial monument over Sam Eyde at Borre in Vestfold by the Oslo fjord, where his summer villa was built. Photo: Lisen Roll.

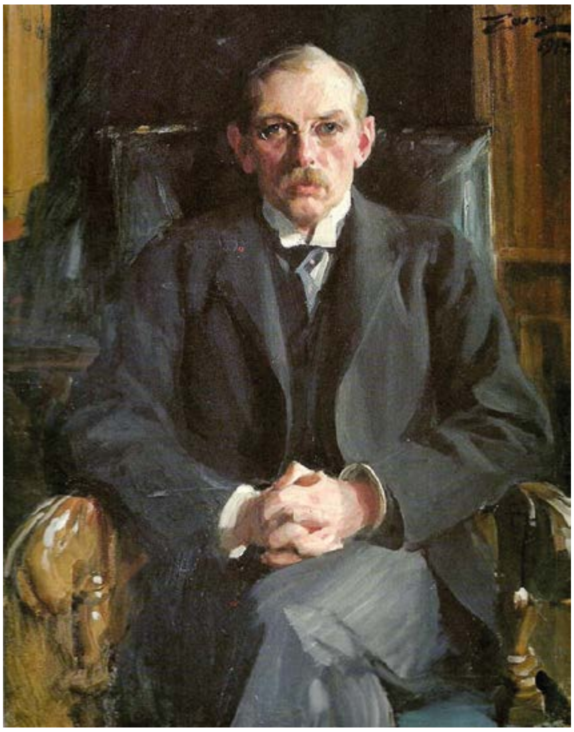
Kristian Birkeland (1867–1917), scientist and researcher

Kristian Birkeland was a scientist and an industrial researcher, a graduate of the University of Kristiania (Oslo), where he became professor in 1898 at the age of 30. He also studied in France, Switzerland and Germany. As an active participant in applied research, and always with several big projects ongoing at the same time, he made a substantial contribution to several disciplines – mathematics, theoretical and later applied physics. In Birkeland's day, classical physics developed into nuclear physics with the discovery of the nature of the cathode beam, X-rays and radioactivity. As a northern lights researcher, he developed theories on the transmission of energy

Kristian Bernhard Birkeland; physician, founder of theories of cosmic radiation, inventor of machines and industrial equipment, proposed for the Nobel Prize. Portrayed in his laboratory by Asta Nørregaard in 1900 and on a Norwegian banknote from today.

from the sun to the ionosphere via electric currents along the Earth's magnetic field, which formed the basis for modern space research. As an industrial researcher, he had 59 patents, 12 of which related to the electric arc furnace for fixing nitrogen from the air for the production of artificial fertilizer; also included was the Birkeland/Eyde furnace that is linked to the establishment of Norsk Hydro. The company Norsk Elektrokemiske Aktieselskab was set up immediately after the two gentlemen met each other for the first time, in 1903, at which time they were already discussing the possibility of developing an industrial method that was to succeed where Niagara had failed.

Marcus Wallenberg (1864–1943), Swedish financier



Marcus Wallenberg, painted by Anders Zorn.

Marcus Wallenberg was a lawyer. He started his banking career in the 1890s, and he and his older half-brother Knut became directors and main shareholders in one of Sweden's most important commercial banks; Stockholms Enskilda Bank. Marcus was responsible for the bank's industrial portfolio. The brothers used the bank as a tool for their personal investments, seeking out interesting projects that the bank subsequently financed. They often spent the profit on buying new holdings in the bank. The Wallenbergs represented a type of financial player that was non-existent in Norway at the time. In the beginning, Marcus worked on restructuring the Swedish engineering industry. In autumn 1903, he became involved in the nitrogen issue; a result of his interest in more modern industries after the brothers had taken over large ownership interests in the electric company ASEA, which thereby avoided going bankrupt. Among other things, ASEA supplied heavy-current equipment for the developing power industry, but it was affected by the international economic downturn in the sector. Wallenberg was hoping to procure sorely needed contracts for the company by getting involved in Norway. Marcus sent the newly appointed director of ASEA, Sigfried Edström, to Kristiania (Oslo) to learn more about Birkeland and Eyde's process for the large-scale industrial production of calcium nitrate. His interest grew when Edström returned home with a positive view of the electric arc process.

Marcus Wallenberg contributed to establishing a number of large companies; in Norway Orkla and A/S Tyssefaldene in addition to Norsk Hydro. Swedish authorities used him to conduct international negotiations.

Thorvald Astrup (1876–1940), architect

Thorvald Astrup was a student at Kristiania (Oslo) Technical College in 1891–1892, then at Norway's Royal Drafting School in 1892–1893, and then at Königlich Technische Hochschule in Berlin in 1896–1897. He then worked as an assistant for the architect Henrik Nissen and then for Henrik Bull. In 1900–1901, he worked as an assistant for the architect Carol in England.

In 1901, Thorvald Astrup set up his own architect's office in Kristiania (Oslo). His earliest works are characterised of what is known as the national style, from which Art Nouveau arises. Astrup was among the most skilled and most prolific architects in the first decades of the 20th century. After 1910, Astrup became a highly productive villa architect. He was hired as a **staff architect for Norsk Hydro** by Sam Eyde, who was looking for young, highly skilled employees in his entrepreneurial enterprise of establishing industry in Norway. Astrup was to design a number of imposing buildings for large-scale industry and power supply. His first big assignment was the **Tysso I** power plant (1906–1908) in Tyssedal together with Victor Normann. Then followed **Svælgfos II Power Plant** for Norsk Hydro (1909–1913), the **Admini (**administration) building in Rjukan (1908), in the classicising Art Nouveau style, **Såheim Power Plant** (1912–1915) together with Olaf B Nordhagen, **railway station buildings for the Rjukan Line**, several of the **factory buildings in Rjukan and Notodden** in the classical style, **Vemork Hydrogen Plant** (1928–1929) – Functionalism in glass and concrete. All the factory buildings he designed later were in the Functionalist style. Astrup's development as an architect can be illustrated by the fact that the buildings up until around 1920 were regionally inspired and adapted to their location, while Neoclassicism dominated in the 1920s and functionalism in the 1930s. The form and design were always tailored to the function of the building, with simple, clearly defined building proportions and balanced, decorative elements in and on clean surfaces, and striking entrances.

Several of Astrup's buildings for Norsk Hydro are located on the **Herøya** peninsula near Porsgrunn. By the Tinnelva river, he designed **Grønvollfoss power plant** (1931–1933), which did not belong to Hydro, but which is in the nominated area's buffer zone. From 1934, Thorvald Astrup worked with his son Henning Thorvaldssønn Astrup in an extremely productive general partnership. The firm was also the dominant supplier to Norsk Hydro in the 1940s and 1950s. Thorvald Astrup produced a variety of buildings for public and private clients in addition to Norsk Hydro, with the emphasis on private homes, industrial buildings and offices.

Olaf Brochmann Nordhagen (1883–1925), architect

Olaf Nordhagen was a student at Kristiania Technical College from 1898, and graduated as a civil engineer in 1902. In the period 1902–1905, he worked as an apprentice under the architect Bredo Greve (especially on drawings for the Norwegian Institute of Technology in Trondheim), at the same time as he attended classes at the Royal Drafting School under the architect Herman Major Schirmer. Nordhagen was a student at the Royal Danish Academy of Art in Copenhagen in 1905–1906, and also assisted the architect Martin Nyrop's office during work on Copenhagen City Hall. He went on several study trips to the UK, Germany, France, Sweden and Denmark.

In 1906, Nordhagen set up his own business in Kristiania (Oslo). He prepared a sensationally good draft of Bergen Public Library, which won the competition in 1906. The Art Nouveau-style library was completed in 1917.

Early on, Nordhagen developed the skill of handling extensive projects and was entrusted with the design of many **power plants.** He received the assignment for **Vemork Power Plant** from Sam Eyde at the age of 24. Later came more power plants, such as Årlifoss (Notodden, 1912–1915), Såheim (Rjukan, together with architect Thorvald Astrup – a highlight in Norwegian industrial architecture), Glomfjord (1918) and Follafoss (1922–1923).

Olaf Nordhagen's most important task as an architect started in 1910, when he set up business in Trondheim after winning the competition to lead the restoration of the Nidaros Cathedral. Nordhagen's ideas, based on independent interpretations of Gothic design rather than a faithful reconstruction, were highly controversial in their day, but his work was nonetheless chosen as the basis for the reconstruction.

As a church architect, Nordhagen designed a number of churches, and he also carried out individual large-scale assignments.

Helge Blix, architect

Helge Blix was hired as an architect at Notodden Calcium Nitrate Plant (Hydro) in 1909. He eventually became manager of Norsk Hydro's architectural department in Notodden. In 1916, he moved to Rjukan, as head of the architectural department there.

Henning Kloumann (1869–1941), architect

Henning Kloumann was a student at the Royal Drafting Academy in Kristiania (Oslo) before he became an assistant at architect Jacob Wilhelm Nordan's office. In the period 1883–1887, Kloumann worked at architect John Alder's office in the UK, where in 1886 he became site manager in charge of the construction of the Punshon Memorial Methodist Church in Bournemouth.

In the period 1888–1901, Kloumann worked on maintenance tasks for the City Surveyor of Kristiania (Oslo). At the same time, he carried out individual independent architectural assignments. In the period 1901–1904, Kloumann was employed at the school buildings office in Kristiania (Oslo), during which time he designed several new school buildings.

In the period 1904–1918, Kloumann was again responsible for municipal maintenance tasks, but now tended to be busier with private assignments. Perhaps best known are his assignments for engineer Sam Eyde: Villa at Thorleif Haugs vei 14 (1905) and **the Admini in Notodden** (1906, administration building for Norsk Hydro), a glorious villa in a classical and national romantic Art Nouveau style, with an imposing portico entrance. In Notodden, he also designed **Svælgfos Power Plant** (1907, in a fortress-like Romanesque revival style, rebuilt in 1937) and **Lienfos power plant** (1909–1911, Beaux Arts).

Architect Kloumann's most extensive project in the 1920s was probably Tåsen Haveby (garden town), which was erected in 1922–1923 in Oslo. In terms of style, the town is influenced by Norwegian 18th-century architecture, with its two-storey wooden houses with high, hipped roofs with dormers. From around 1920, Kloumann was head of Norsk Husbyggingskompani AS (Norwegian house-building company) in Hamar. From here, he supplied drawings for municipal housing and Kongsvinger's new primary school (1922–1924, Baroque revival).

In addition to this, Kloumann built mess halls and workmen's houses on Svalbard, and the radio facilities on Bjørnøya Island.

Sigurd Kloumann (1879–1953), engineer, site manager

Sigurd Kloumann graduated from Kristiania (Oslo) Technical College in 1899 as a civil engineer, after which he went on study trips to hydroelectric power plants and factory buildings in France, the UK, Germany, Switzerland, Italy and the USA. The very next year, he was hired by Glommens Træsliberi (pulp mill) for the development of Kykkelsrud power plant in Glomma, one of the first major hydroelectric power developments in Norway. Despite his young age, Kloumann's skills as an engineer were noticed, and his leadership qualities as the manager of big projects astounded Norway and Europe. In spring 1903, he was hired by Sam Eyde at Det norske Kvelstofkompani to survey Vammafossen with a view to developing it for a power plant. The way he carried out this difficult task earned him a reputation as a practical and efficient engineer. Together with two Swedish engineers, he planned the development of Vamma power plant. He also participated in the testing of the Birkeland/Eyde furnace at Ankerløkken and in the establishment of Norsk Hydro.

In 1904, Kloumann became site manager and head of the construction office for the development of **Norsk Hydro's first plant** in Notodden and **Sværlgfos Power Plant**, which was the biggest in Europe at the time. The development of the plants in Notodden and the regulation of Tinnsjø lake were completed in the period 1905–1907. Kloumann was also highly involved in the development of the Tysse facilities in the Sørfjord in Hardanger and in the planning of the development in Rjukan and the regulation work for Mårvatnene and **Møsvatn** lakes. He was also the obvious choice of site manager for Norway's biggest building project to date – **Vemork Power Plant**, **the production facilities in Rjukan** and **the transport routes from Rjukan to Notodden** – in the period 1907–1911. The dam at Svelgfoss creates a lake that is three kilometres in length at Tinnelva river, which is called Kloumannsjøen lake after the man who constructed it.

Through his contractor activities, Sigurd Kloumann was responsible for giving many Norwegian industrial communities a physical identity in the first half of the 20th century, when engineers and architects planned and built everything from distribution pools to industrial communities with their inherent class distinctions.

Sigurd Kloumann was one of Hydro's leading engineers. After a decade of realising Sam Eyde's industrial visions, Kloumann pulled out of Hydro in 1911 to start his own entrepreneurial career as a waterfall developer. He was pivotal to the establishment of A/S Saudefaldene in Ryfylke in 1913 and became managing director of the company. After entering into a contract for the sale of the electric power to Electric Furnace Products Co. in 1914, Kloumann was in charge of developing the first power plants in the period 1915–1920.

At the same time, Kloumann was busy with the development of Høyangfallene falls in Sogn og Fjordane. He believed it was high time that a big Norwegian aluminium works was established. As managing director of A/S Høyangfaldene, he was in charge of the development of the first power and production plants in Høyanger in 1916–1917. The aluminium factory came into operation in 1918. In 1928, a facility was built for making aluminium oxide on the basis of Professor Harald Pedersen's method for refining bauxite. Before the outbreak of World War II, 8 500 tonnes of aluminium was produced every year in Høyanger, and the number of employees was 650. During World War I, Kloumann had taken the initiative for the subsidiary A/S Nordisk Aluminiumsindustri with a production plant in Holmestrand, with a view to further refining aluminium into finished products for the domestic market. The factory in Holmestrand made plates, pots and pans and other kitchenware as well as all types of big containers and appliances of aluminium. Kloumann was director of the subsidiary A/S Dansk Aluminium Industri in Copenhagen, which further processed aluminium from Høyanger, and from 1933 for AB Svenska Aluminiumskompaniet. In 1925, he was made a member of the Norwegian Academy of Science and Letters. He was made Knight, First Class of the Royal Norwegian Order of St. Olav in 1911, and he was Commander of the Royal Order of Vasa. Kloumann's name is inscribed on a memorial monument in granite that was erected by the entrance to the Hydro Museum in Notodden in 2006.

Christian Frederik Jacob von Munthe af Morgenstierne (1880–1967), architect

Christian von Munthe af Morgenstierne was a trained bricklayer, and then studied architecture at the Royal Drafting School in Kristiania (Oslo) under Herman Major Schirmer in the period 1895–1898. After graduation, he went on a study trip in the Heidalen valley, led by Schirmer. He then studied at the Technical College in Charlottenburg, Berlin. In 1904, he took a state exam at the University of Illinois in Champagin, Illinois in the USA. Partly in parallel with his studies, Morgenstierne worked for five years as an apprentice at various architects' offices in the USA, mostly in Chicago. He then worked as an architects' assistant for three and a half years in Berlin, before returning to his home town of Kristiania (Oslo), where he set up the architects' office Morgenstierne & Eide in 1909, together with Arne Eide. The following year, he became a member of the municipal housing shortage committee. In 1916, together with Christian Gierløff, he published the article '*Proposal for solution to the country's housing shortage*'. He was hired by Hydro for the development in Rjukan, and designed several of the early industrial buildings there. Christian von Munthe af Morgenstierne was the Norwegian delegate at the housing congresses in Vienna in 1910 and the Hague in 1913. He was made Knight, First Class of the Royal Order of St. Olav in 1948.

Magnus Poulsson (1881–1958), architect

Magnus Poulsson was one of the most prominent architects in Norway in the first half of the 20th century. He was educated at the Royal Drafting School in Kristiania (Oslo) and the Royal Institute of Technology in Stockholm. In a highly personal way, he united traditional Norwegian building practice and modern designs, often characterised as masculine in style. Together with his friend Arnstein Arneberg, he became one of the most important creators of a new national architecture with strong Nordic roots, and they were responsible for some of the most important, imposing Norwegian buildings in this period, including Oslo City Hall (1931–1950). Poulsson also showed great interest in less pretentious buildings by designing workers' houses early in his career. In 1909 and 1911, he won prizes for designing dwellings for workers. In 1911, he drew workers' houses for Mesna Træsliperi (pulp mill) in Lillehammer, and 64 'Own Home' houses were erected in **Rjukan**. Magnus Poulsson won the architectural competition in 1913 (second prize, no first prize was awarded) and in the course of a few years, 64 of his house types were erected, variants of which were easy to devise.

Ove Bang (1895–1942), architect

Bang studied at the Norwegian Institute of Technology from 1913 and graduated in 1917. He began his career as an assistant to Magnus Poulsson in 1917. In 1913, Poulsson had won

Norsk Hydro's competition for the development of housing areas in the new industrial town of Rjukan, and in 1919, Bang moved there with Poulsson's office to take part in the development as an architect for Norsk Hydro at the sub-department **Rjukan Byanlæg**. In the period 1923–1930, he ran his own architect's practice in Rjukan. In 1930, he moved his practice to Oslo. Ove Bang was among the most productive, innovative Norwegian architects in the interwar period. In 1927, he submitted a draft for Frøystul power plant by Møsvatn lake in a modernist form and design. The ability to translate international models into a regional form and design became Ove Bang's enduring hallmark of quality.

3 JUSTIFICATION FOR INSCRIPTION

3.1.a Brief synthesis

The Rjukan – Notodden industrial heritage site consists of the central parts of the towns of Notodden and Rjukan in the inner part of Telemark county and the communication system that was constructed between them for industrial purposes. The sites include plants for hydroelectric power production, industrial areas and environments for the processing industry, and urban structures. The latter were built for the community of people who were to run/operate the plants for power supply and industry and the transport system. The area as a whole is defined by the artificial watercourse from the regulating reservoir on the Hardangervidda mountain plateau to Heddalsvatnet lake in Notodden and the transport route that follows and partly uses the watercourse. The area thus forms a linear structure with a total length of 90 kilometres, 125 kilometres including the buffer zone.

The cultural heritage that is proposed for inscription on the World Heritage List is made up of selected buildings and plants based on four different thematic components that were synchronically created by the same powers to form a unit that effectively functioned as a single entity. The unit represents a unique expression of new industrial developments during the Western world's *second industrial revolution.*

- **Hydroelectric power:** plants for hydroelectric power production with power plants, dams, water pipes, water tunnels and power lines
- **Industry:** industrial areas, production plants with buildings and industrial machinery
- **Transport:** transport system for transporting industrial products, raw materials and people
- **Company town:** Urban community with housing areas for workers and administrative staff at the above-mentioned enterprises, social institutions etc. that together form complete communities.

The industrial communities in Norway that have been selected as proposals for inscription on UNESCO's World Heritage List include unique and outstanding values related to each of these four components. However, it is as a whole that the area is deemed to be particularly unique in the international context. These Norwegian industrial communities are monuments to the second industrial revolution that took place in the Western world in the early 20th century, when, in the course of a few years, simultaneous and interacting breakthroughs took place in several countries in the field of technology and in other sectors of society. Advances and breakthroughs were achieved in different disciplines, in turns or simultaneously in different communities in many countries.

Rjukan – Notodden is an outstanding example of a marked shift in production conditions and financial and social conditions brought about by the second industrial revolution, not just in Norway but in general. The social changes that took place, primarily in Europe and North America, were fundamental. Social synergies arose from the technological innovations and concurrent economic, financial and political developments. The events were the result of increasing dynamics in the industrialised communities, and, together, they represent the breakthrough of modernity around the end of the 19th century. The decades around the year 1900 stand out for the plethora of important discoveries, inventions and events that occurred at this time. In just 20 years, from 1870 to 1890, ground-breaking developments took place in several areas. The internal combustion engine was invented, which made a huge impact on the 20th century. Inventions in the field of electrotechnology made it possible to put basic discoveries in physics into practical use. This formed the basis for the global expansion of mains electricity supply. Norway was a very early participant because its waterfall energy is ideal for conversion into electricity. Electricity was adopted for purposes that had previously been covered by other forms of energy, and purposes created by access to the electricity itself. Electrochemistry and electro-metallurgy were developed as qualitatively new industrial sectors. The waterfalls became Norway's 'white coal' in a modern industrialisation.

The physical results of the development of industry in the inner parts of Telemark in the early 20th century make up the nomination proposal. This proposal concerns the industrial development that took place on the initiative of engineer and entrepreneur **Sam Eyde** and under the auspices of the industrial companies that were set up to manufacture artificial fertilizer, first using Professor **Kristian Birkeland's** patented method in **electric Birkeland/Eyde furnaces** and later using a modified German method. The company **Norsk Hydro,** formed in 1905 with the backing of significant foreign capital, quickly became the most important of these companies. The product calcium nitrate, marketed as '**Norway saltpetre'**, became a major commodity on the global market. Production was highly energy-intensive and was based on the development of waterfalls in the eastern section of the Telemarksvassdraget watercourse, from the Hardangervidda plateau to Heddalsvatnet lake, with the **Rjukanfossen waterfall in the Vestfjorddalen valley** as the most important source of energy. The river Måna's fall past Rjukanfossen was exploited at **Vemork and Såheim power plants**, each of which was the biggest in the world at the time it opened (in 1911 and 1915). **Hydro's factories** were built adjacent to the power plants, because of the technological barriers that existed at the time, and for financial and political reasons. Around factories and power plants in the scarcely populated Vestfjorddalen valley, Hydro built **a new town called Rjukan**. It is a **company town** that reflects the social conditions of the early 20th century. It was a remote place. In order to link the factories to the international fertilizer market, a **transport system consisting of railway lines and railway ferries** was constructed to overcome the distance of approximately 80 kilometres to Notodden next to Heddalsvatnet lake. Notodden was situated at the northern end of a **canalised river system** that was connected to the North Sea through locks at Skotfoss and in Skien. This meant that 'Norway saltpetre' from the factory in Notodden, and eventually from Rjukan via the Rjukan Line for transfer at the Railway Quay in Notodden, could reach the global market via barge transport to Menstad by the Skienselva river.

In 1911, just a few years after the company was formed, Norsk Hydro exported its first batch of 'Norway saltpetre'. Norsk Hydro quickly became an important global producer of artificial fertilizer, and it represents the development in Europe that in the documents related to *the World Heritage sites of Humberstone and Santa Laura in Chile* is described as the reason for the fall of these mining communities. In order to achieve this position, Norsk Hydro had, using borrowed capital, invested an amount equivalent to the size of the Norwegian national budget at the time. In the course of a few years, the company built factories, railways and an entire town in Telemark in inland Norway. A series of power plants, which were among the biggest in the world, supplied the energy they needed.

The production process for 'Norway saltpetre', which was an important commodity on the global market for fertilizer products, also provided opportunities for the production of explosives that were attractive for the global arms industry. Ammonium nitrate from

Rjukan and Notodden was used in weapons by both sides in World War I, in which Norway was formally a neutral country, but because Hydro's biggest owner was French, the majority went to the Allied forces. During World War II, Hydro's production was controlled by the German occupying power. The issue was the strategically important properties of heavy water, a by-product of hydrogen electrolysis that Hydro used for ammonia synthesis. The substance had been discovered in the decade prior to the war, and Hydro was the world's biggest manufacturer. Towards the end of the war, Germany saw the production of nuclear weapons as the key factor that could decide the outcome of the war in its favour, which meant that it became vital for the Allies to prevent such a scenario. Allied forces and Norwegian saboteurs carried out operations that succeeded in this. Rjukan – Notodden represents circumstances that may have played a role in the outcome of both the world wars that took place in the first half of the 20th century, and the area is a significant testimony to the events of World War II in particular.

The objects included in the nomination proposal are presented in the following table:

ID no	**World Heritage attribute**	**Number of significant objects**	**Specification of the nature of the objects/ attributes**
	Hydroelecric power		
1	Tinfos power plants		
1.1–1.2		2	Buildings, dams, machinery
2	Hydro's power plants in the Tinnelva river		
2.1		1	Building
3	Vemork Power Plant		
3.1–3.5		5	Buildings, dam, tunnel system, machinery
4	Såheim Power Plant		
4.1–4.5		5	Buildings, tunnel system, machinery
5	Regulating dams		
5.1		1	Dam
6	Power transmission		
6.1–6.4		4	Buildings, equipment, power line

ID no	World Heritage attribute	Number of sig-nificant objects	Specification of the nature of the objects/ attributes
	Industry		
7	Hydro Industrial Park in Notodden		
7.1–7.15		15	Buildings
8	Hydro Industrial Park in Rjukan		
8.1–8.10		10	Buildings
9	Production equip-ment		
9.1–9.7		7	Industrial furnaces, customised process compo-nents, machinery
	Transport system		
10	The Tinnoset Line		
10.1–10.5		5	Railway track with equipment, buildings, quay
11	The Rjukan Line		
11.1–11.15		15	Railway track with equipment, buildings, quays, slipway, rolling stock, lighthouses, vessels
	Company town		
12	Notodden Hydro Town		
12.1–12.4		4	Buildings (private homes and administration), building environments
13	Rjukan Hydro Town		
13.1–13.23		23	Buildings (private homes, administration, social institutions), building environments, parks and town squares, bridges, cableway

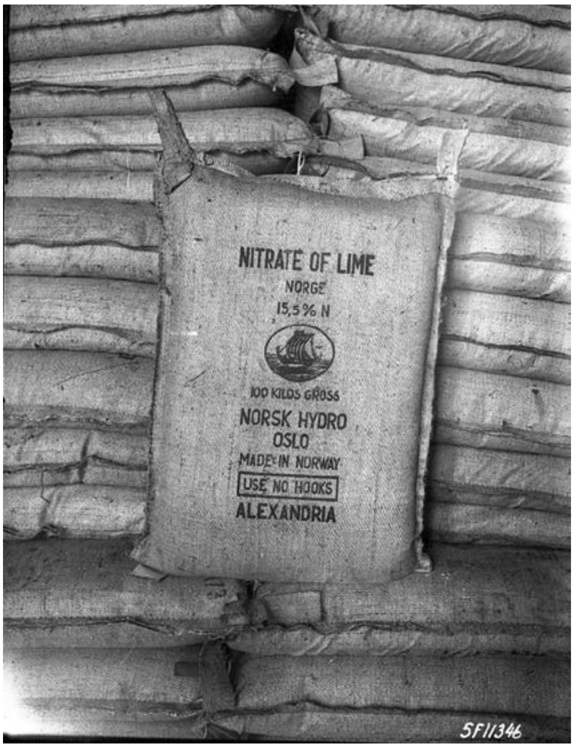
3.1.b Criteria under which the inscription is proposed, and justification for inscription

The Rjukan – Notodden industrial heritage site is nominated for inscription on UNESCO's World Heritage List under criteria (ii) and (iv), cf. Paragraph 77 of the Operational Guidelines for the Implementation of the World Heritage Convention. The area is nominated for its outstanding universal value by

- exhibiting an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design (criterion (ii))
- being an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history (criterion (iv)).

Justification for inscription under Criterion (ii)

Criterion (ii) – *'exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design'.*



Norway Saltpetre was shipped to the whole world. The question of safeguarding sufficient supplies of food from agriculture was a major issue in the world of early 20th Century, to which nitrate of lime produced by Norsk Hydro Company in Rjukan-Notodden contributed to a solution.

Rjukan – Notodden manifests science-based contributions and practical achievements in electrochemistry and electrotechnology. Advances in these disciplines took place simultaneously in several countries in Europe and North America around the turn of the previous century. The establishment of industry in Rjukan and Notodden was based on newly obtained knowledge and capacity in these countries and entails a breakthrough that moved knowledge fronts and capacities forward. More specifically, the development of this type of industry in Norway created a new product for the global market that achieved great global importance.

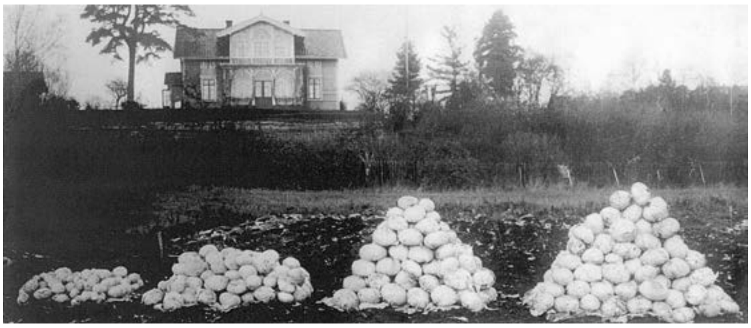
The industrial towns of Rjukan and Notodden were established as the result of an industrialisation process in which the use of hydroelectric power for energy production had become sufficiently developed. The scope of this industrialisation process, the growth of new industrial products and the range of technological inventions that were created within a limited period of time then led to rapid, sweeping social changes. What made these events, which have been called 'the second industrial revolution', possible was the exchange of results from science and research across national borders, of capital in an international arena for investments, and the sale of goods in a global market.

The nominated towns are the result of the changes that took place, but they have also contributed to these changes by being the scene of outstanding achievements that represent an important step forward for mankind in the areas of science and engineering. At the same time, the towns were production sites for a commodity, artificial fertilizer, which was highly important for the global agriculture industry. Around the time the nominated towns were built, i.e. the turn of the 20th century, the (industrialised) world's need for synthetic nitrogen fertilizer that could increase crop yields was a pressing issue. It was a question of obtaining sufficient food supplies for rapidly growing populations in the industrialised countries. The 'nitrogen issue' was high on the international agenda; in research communities, in diplomacy, in industry – and in financial circles. Using electric power to fix nitrogen from plain air seemed to be one possible solution. An industrial attempt at this by Niagara Falls proved unsuccessful. The Norwegian physicist ***Kristian Birkeland*** managed to solve the problem in collaboration with engineer and industrial entrepreneur ***Sam Eyde***. This resulted in patents, new companies and a large-scale industrial development backed by foreign capital.

Humberstone & Sta Laura Saltpetre Works (World Heritage List 2005) in Atacama Desert, Chile, provided fertilizer to global markets. Chile saltpetre was however considered to face an end due to the natural deposits being emptied. Photo: Nuria Sanz, © UNESCO

In political and economic history, the nominated area represents the final phase in the world's dependence on the import of natural sodium nitrate from Chile. Rjukan – Notodden can therefore be regarded in relation to the *Humberstone and Santa Laura saltpeter works,* which were inscribed on UNESCO's World Heritage List in 2005. At the end of the 19th century, the Western world estimated that the Chilean mines would be exhausted in a few years. At the same time, Western countries were competing for control over this remote resource and the sea transport routes. The UK, Germany and the USA required it for different purposes, but all the countries viewed a secure supply of nitrates as essential for continued industrial progress. The Briton Sir William Crooke expressed this view in an appeal in 1898 in which he warned of an upcoming resource crisis, and concluded that *'the fixation of nitrogen is vital to the progress of civilised humanity'.*

In 1905, Birkeland and Eyde demonstrated the electric arc process that is named after them, following which the production of calcium nitrate fertilizer was started and scaled up as the investors saw promising results. It was not until calcium nitrate was produced in Birkeland/Eyde furnaces by ***the company Norsk Hydro's*** factories in Notodden and Rjukan that artificial fertilizer from air became available to the global market. The commodity 'Norway saltpetre' made a significant contribution to increased crop yields.



Advertising for the use of artificial fertilizers. The Tennessee Valley, USA (Tennessee Valley Authority) Photo: Wikipedia.commons. Sam Eyde's own garden near Kristiania (Oslo), where the yield pr. 10 ares differs depending on the use of Norway saltpetre. As shown from left: no Norway saltpetre, next 80 kilos, 160 kilos and lastly 240 kilos, according to Mr. Eyde's experiments.

Birkeland/Eyde's electrochemical electric arc process required large amounts of electric energy. This could be achieved by developing Norwegian watercourses, which in the European context represented an attractive source of power with great potential. Rjukan – Notodden bears testimony to the exploitation of a natural resource in a way earlier communities had been unable to do. *Hydroelectric power plants* of unusual dimensions and industrial buildings that housed machinery for the various stages of the manufacturing process have been preserved, together with important components of the industrial equipment. Experiments and industrial testing took place in Notodden, where German companies and engineers were involved in several contexts, partly in collaboration and partly in competition with Hydro's Birkeland/Eyde furnaces. Here there are *factory buildings* that represent the essential stages in the process, which by their design and organisation make the production line decipherable, and which represent several phases in the factory's development until an alternative method for producing calcium nitrate had been tested and implemented. The German Haber-Bosch method that came later was more energy-efficient, and it became combined with the absorption stage in the Norwegian method. In Rjukan, there are factory buildings that were built for large-scale production targeting the global market, based on results from the test factory in Notodden that proved to be technically successful, and which also pleased the investors, who were mainly French and Swedish.

Norsk Hydro's industrial investment included the profitable capitalisation of a favourable economic rent (the increase in value of land that is due to technical advances). As Norway had not yet developed sufficiently strong financially, financing from European parties was needed. Key Norwegian participants had been educated abroad, and they used their contacts to raise foreign capital. The industrial project in Telemark took shape within a political framework that epitomised the nation, because it took place at the same time as the Norwegian nation state achieved its full independence in 1905. Internationally at the same time, there was a movement in favour of taxation or confiscation of the economic rent, called Georgism after the US economist Henry George. Hydro's industrial project triggered the development of national legislation that ensured that the utilisation of natural resources would benefit the country hosting the investments. The political conflict was part of the reason why the factories and houses were located in Rjukan, because, in addition to the power that would be wasted and the expense that would be involved in building power lines to transfer energy to places far away from the source of power, there was also a potential public licence fee that could be levied on transmission lines. The issues are graphically illustrated by the decision to locate the furnace hall and generator sets adjacent to each other in Såheim Power Plant. Rjukan – Notodden can be regarded as a testament to the implementation of legal instruments for social resource management as a universal solution, whereby successful nation building can be based on national control over own natural resources. Resource management through concession legislation is a transferable model. Experience from this era has also been the basis for regulation of the petroleum industry in Norway since the start around 1970.

Building a large-scale facility in Rjukan at the foot of Rjukanfossen waterfall, which was the ultimate source of power, meant that Hydro had to construct both a complete urban community in what had until then been a scarcely populated area, as well as a modern *transport system* from Rjukan to Notodden that served as a port of export for the products. The town of Rjukan represents the international *'company town'* or model town phenomenon. Its architecture and town plan were products of an international urban planning ideology and 19th-century models for urban organisation, which had taken the form of a positive, coordinating movement to create harmonic, rational and aesthetically pleasing urban environments. Making the remote Rjukan community an attractive place to live for working class families was essential. In Rjukan, ideas of social differentiation between management and workers, which is a feature of many company towns, were based on topographic conditions, where houses for senior managers, engineers and administrative staff had the advantage of being located higher up in the landscape and thus receiving more sun than the workers' houses on the valley floor. However, the workers' houses were of a relatively high standard, and the architectural style was not used as a social indicator to the same extent as in many other company towns. Sam Eyde, who was interested in architecture, used young Norwegian architects who had been educated abroad and who designed houses in a national style combined with contemporary trends such as Art Nouveau and Beaux Arts. Eyde intended the national element to underline the national importance and symbolic value of the industrial project as part of the construction of Norway as a progressive new nation after the country's independence from the union with Sweden in 1905.

The transport system that had to be built between Rjukan, with its power plants, factories and housing areas, and Notodden with its port by the Telemark Canal, was a major challenge because of the topography. There were hardly any roads in the area. The system was built as a costly installation with bold solutions. A railway ferry would cross Tinnsjøen lake instead of running the railway line along steep shorelines. In the valleys, the railway was constructed as a normal-gauge electrified railway using 10 kV and 16 ⅔ Hz. An international standard for this was an integral part of the system, and Hydro thereby became a pioneer by introducing the standard in Northern Europe before any national standard had been adopted in Norway. An essential element behind the choices was Sam Eyde's background as a engineer in Germany, where he had worked on major port designs and railways.

Justification for inscription under Criterion (iv)

Criterion (iv) *–'be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history'.*

The industrial revolution based on coal and iron created smoggy cities and bad living conditions. Here Essen in Ruhrgebiet, Germany, a country that took a leading position in the development of the second industrial revolution, based on electricity. Photo: Wikipedia. commons.

The second industrial revolution is a significant stage in human history. The era began in the Western world, where electric energy replaced coal as a source of energy in industry, creating new types of industries, products and towns. The Rjukan and Notodden area is a physical result and expression of this development, *as an industrial landscape consisting of power plants with dams, pipes and tunnels, factory areas, overland and lake transport systems and urban settlements,* created against a historical backdrop that was present for only a limited period of time. The whole ensemble of dams, tunnels and pipes to take water to the power plants, routes for power lines to the factories, the factory areas with buildings for the various stages in the production process, the factory towns with houses and social institutions, railway lines and a ferry service with navigational devices, was created against the background of a powerful natural environment. At the same time, it was based on a massive exploitation of water as a natural resource, in a way that had not been possible in earlier times.

Rjukan – Notodden is an early example of how new capacities led to the utilisation of resources and landscaping on unprecedented levels. The regulation of lakes and watercourses heralds a qualitative step in man's interaction with nature, where man's acquired technological capacity enabled nature to be manipulated by permanent interventions. The Rjukan – Notodden area represents a transformation of nature and society, where lakes were dammed up, rivers diverted through pipes, and where urban communities arose in areas that had previously been scarcely populated with marginal agriculture. The industrial project was carried out under a joint organisational framework, tied to the company Norsk Hydro, which was created for the purpose. It was created in a national context, but involved international financial and industrial players in a way that challenged the nation state. An increasing degree of organisation among the workers created new requirements for entire urban communities that were to be built from scratch. We see the transition to the more organised economy of the 20th century. Rjukan – Notodden is thereby the physical expression of a number of factors that are often regarded as the core of modernity.

As an industrial heritage site, the proposed World Heritage Site includes examples of types of buildings, architectural and technological ensembles and altered landscapes that characterise the second industrial revolution. The hydroelectric installations in the Måna river between Møsvatn and Tinnsjøen lakes represent a new type of power plant, with reservoirs in the mountains and the utilisation of high waterfalls, which is different to the river power plants in slow-moving rivers. Møsvatn was the first and biggest regulating reservoir in the high mountains. With a total fall of several hundred metres, Rjukanfossen in the Måna river was a giant that in the 19th century had been a symbol of Norway's wild, unspoilt scenery. The waterfall received visits from European tourists, including Jules Verne, who set the plot in 'The Lottery Ticket' ('Un billet de loterie') in the area. In 1903, it was possible to see it in a different light, through the eyes of industrial entrepreneur Sam Eyde, the Swedish Wallenberg capitalists and French bankers. The waterfall could be tamed.

Hydro's industries utilized the "white coal of Norway", hydroelectric energy, making the industrial towns of Notodden and Rjukan to appear as clean. Photo: Per Berntsen.

Rjukan company town, where Hydro fixed nitrogen from the air into fertilizers by the means of high voltage electricity from waterfalls located at the edge of a huge mountain plateau. Photo: Per Berntsen.

The hydroelectric power plants had to be pioneering plants of their era. The company Norsk Hydro, which Eyde, the Wallenbergs and Paribas formed, started with the Svælgfos plant in the Tinnelva river. Then came the Vemork and Såheim power plants in the Måna river. Each of the power plants was the biggest in Europe or the world at the time of their start-up. In 1907, only Ontario Power Company's plant at Niagara Falls was bigger than Svælgfos I. The plant is now an industrial and architectural cultural environment with ruins and remains of buildings, preserved buildings and technical installations. Vemork was the biggest power plant in the world in 1911. The building with turbines and generators, an overground penstock and a water tunnel from the intake dam to the distribution reservoir have been preserved, while today's power production is based on new machinery in a rock cavern behind the old plant. Såheim took over Vemork's position as the world's biggest in 1915. The power plant now produces energy using newer machinery. Two of the original generator units, the control panel and the penstock shaft are intact. The generator set, with the original machinery, is located in a separate cavern and is a pioneering facility. A number of power plants have since been built along the rivers of Måna and Tinnelva, which run into and out of Tinnsjøen lake. *The watercourse contains over a short stretch a remarkable succession of large, ground-breaking hydroelectric power plants from the pioneering phase of the early 20th century*.

Norsk Hydro, which was responsible for what was then a gigantic development of hydroelectric power plants, did so for industrial purposes. Large amounts of high-voltage energy were to be used to fix nitrogen from air, using Birkeland/Eyde's patented electric arc process in **large production plants**. After Norway gained full independence in 1905, the Norwegian state saw the need for national control of the natural resource represented by waterfall power, which Hydro, mainly owned by foreign parties, was in the process of developing. Long-distance transmission of electricity without losing a substantial amount of power was not possible until 1910–1920. In order to avoid state concession requirements on the transmission of power over distances that would have to be long if the factories were to be located by the export port, and which would cost an unknown amount to build, Hydro instead chose to build the factories near the power plants. In Notodden, a test factory had been built that was initially supplied with power from a small power plant at Tinnfossen before Svælgfos was completed. In Rjukan, an upscaled production facility was supplied by Vemork and Såheim. The factory area known as Notodden Hydro Park represents a pioneering and test facility from the very start of the electrochemical industry in Norway. The way the individual buildings are structured in relation to each other reflects the functional sequence of the production processes. The production lines and structures in the facility can be deciphered by the shapes and volumes denoted by the various stages in the electrochemical processes, from the period of the electric arc method (Birkeland/Eyde) and the ammonia process (Haber-Bosch) for the production of artificial fertilizer, and examples of important associated support functions. This is despite the fact that relatively little production equipment from the processes remains intact *in situ* in the buildings. *The Birkeland/Eyde furnaces* that have been preserved, one in Notodden and one in Rjukan, represent the early and mature development stages of this type of furnace and are unique technological objects. Rjukan Hydro Park includes buildings and objects that complement and complete Notodden, for example the fact that Notodden has a tower house building while Rjukan has one of the acid towers that used to be inside the tower houses. The furnace houses for electric arc furnaces and the tower houses for absorption towers are the most characteristic buildings in the production line for the Birkeland/Eyde process. Original production equipment from the subsequent ammonia synthesis process (Haber-Bosch) is found in Rjukan. The factory area represents historical values that are technologically and architecturally linked to the production lines in buildings, objects and surroundings. Their size, shape and content make Norsk Hydro's industrial parks cultural environments that document industrial development throughout the first half of the 20th century.

With the majority of the production of artificial fertilizer located in Rjukan, Hydro had to build a **transport system** from Notodden by Heddalsvatnet lake (16 masl) all the way up to Vemork Power Plant, and 80 kilometres further into the hilly landscape of Telemark. Two railway sections linked by ferries crossing Tinnsjøen lake were used to bring in equipment and parts for the construction of the big power plants, limestone for the factories, artificial fertilizer for export and later ammonia for Hydro's factories in other locations. The Rjukan Line, as this unique transport system was called, was also used for passenger transport and it was the people of Rjukan's link to the outside world. The railway sections were electrified as early as 1911. The line was closed down in 1991, but the whole system is intact, including tracks, ferry quays, slipways, lighthouses, rolling stock and vessels that are very rare. The two railway ferries that were in Hydro's service the longest can still be found on Tinnsjøen lake, one with a steam boiler ('D/F Ammonia'), while one lies on the bottom of the lake as a wreck and war memorial.

Norsk Hydro's wide-reaching, ambitious project in inland Telemark depended on a large workforce that could build and operate the various installations and factories: workers, engineers and various types of service personnel. On its own initiative, Hydro built not only houses for this workforce but also the social institutions that were necessary in order for Rjukan, as Norway's first planned **modern town**, to work as a complete community. Notodden includes housing areas for which young Norwegian architects designed attractive family houses and urban layouts, clearly influenced by contemporary international ideals. In Rjukan, Hydro's housing project was scaled up, as were the factories, and controlled by a separate department called Rjukan Byanlæg, set up by Sam Eyde in 1911. In two decades, a town with more than 10 000 inhabitants was created in a narrow, remote valley containing just a few small farms.

Rjukan is an outstanding example of a **company town** and the manner in which these were built during the second industrial revolution. The town is a testament to the modern lifestyle and social relations that are typical of this phase of the industrialisation in Western countries, which can be clearly deciphered in the standard and architectural style of the houses, and the structural features of the town plan. The topography was used to manifest a social division in which the social order mirrored the hierarchy of Hydro's staff positions. The creation of the company town was based on the need for a stable workforce of families in this remote location. The river Måna separated the factory area on the south side from the urban community on the north side, where the plots of land highest up in the valley had as much sunshine as the narrow valley could offer. The houses for the highest ranking positions were built here, for the senior manager, chief engineer, doctor, chief of police etc., and the typical workers' houses were built on the alluvial plain on the valley floor. However, all the houses in the town had a mains connection for water, a bathroom and a flush toilet as early as 1912, around 70 years before this was the case for Oslo. The quality of Rjukan's physical design and standard of living is an expression of the industrial enterprise's and the entrepreneur's ambitions in a political climate at the time of Norway's independence as a nation, of competition on the labour market, and of the participation of a working class that was establishing itself as a social force.

The basis for Rjukan as Hydro's company town was pragmatic and financial. At the same time, the town was intended as a model town, not built around an entrepreneur as a father-figure with moral, religious or philosophical intentions, but as a good place to live where working-class families would feel a sense of belonging to the industrial project and be less likely to go on strike.

Hydro hired skilled architects and town planners, like other big companies abroad during this industrial phase. The company created a number of buildings of architectural importance, where the industrial buildings in particular were meant to highlight Hydro as a powerful enterprise for distinguished visitors, while giving the workers a sense of participating in the building of a new, prosperous Norway. Rjukan – Notodden is a representative example that provides insight into the social and technical perceptions and values of the time. Good living conditions were combined with spacious urban environments where the offer of leisure activities was among the many financially motivated factors. The building of the *Krosso Aerial Cableway* in 1928 to bring the workers into the sunlight during autumn and winter marks the completion of Rjukan as a company town of outstanding quality and as a state-of-the-art example of the phenomenon.

The strategic importance of the Rjukan factories' products meant that Rjukan and its transport system became the centre of acts of war of far-reaching significance during **World War II**. In the nominated area and its buffer zone, there are important physical testimonies (as well as accounts and various documents) of the war as a significant stage in human development.

3.1.c Statement of Integrity

The nomination's four thematic components – international large-scale industrial production of artificial fertilizer based on hydroelectric power production, a transport system built to bring the industrial product out into the world, and the company town that was built to operate all this – together form a whole with a high degree of integrity. Within the boundaries of the nominated area, all the significant parts of this are intact to tell the story of Rjukan and Notodden as outstanding representatives of the second industrial revolution. The nominated area starts with Møsvatn Dam, includes Rjukan Hydro Town with power production, industry and the company town, follows the transport route down to Notodden where Hydro's housing areas and industrial area are included. The area is framed by the buffer zone of the landscape with the surrounding mountains, including Møsvatn lake as a water reservoir at the highest point. The nominated area is not threatened on any essential points and the objects are in an acceptable conservation and technical condition, as described in Chapter 4.

The components of power and industry

The components of power and industry in the nomination proposal include objects related to two production methods for artificial fertilizer: the electric arc method (Birkeland/Eyde) and the ammonia method (Haber-Bosch). Together, the two industrial towns Notodden and Rjukan have preserved objects that can illustrate the various stages of the two production methods, as conveyed by Hydro itself in a simplified manner, from the hydroelectric power-based production of electricity to artificial fertilizer as a finished product.

The buildings and the structures formed by the buildings are well preserved, and the two periods with their two methods are decipherable in these, despite the fact that the industrial plants are dynamic facilities that have gone on to develop further. With a few exceptions, the production equipment has been lost, but as for industry in general, it is a natural result of a development that has been necessary in order to be able to preserve the buildings to the extent that Rjukan and Notodden have done. Examples of important production equipment that was removed from the buildings have been preserved as individual objects in the nominated area. Selected objects in the form of buildings are in good condition and are largely in use for various purposes, including new industry, which does not compromise their robustness. Most of the objects are robust industrial buildings protected by law. They are therefore not exposed to the negative effects of development or decay.

The electric arc method (Birkeland/Eyde)

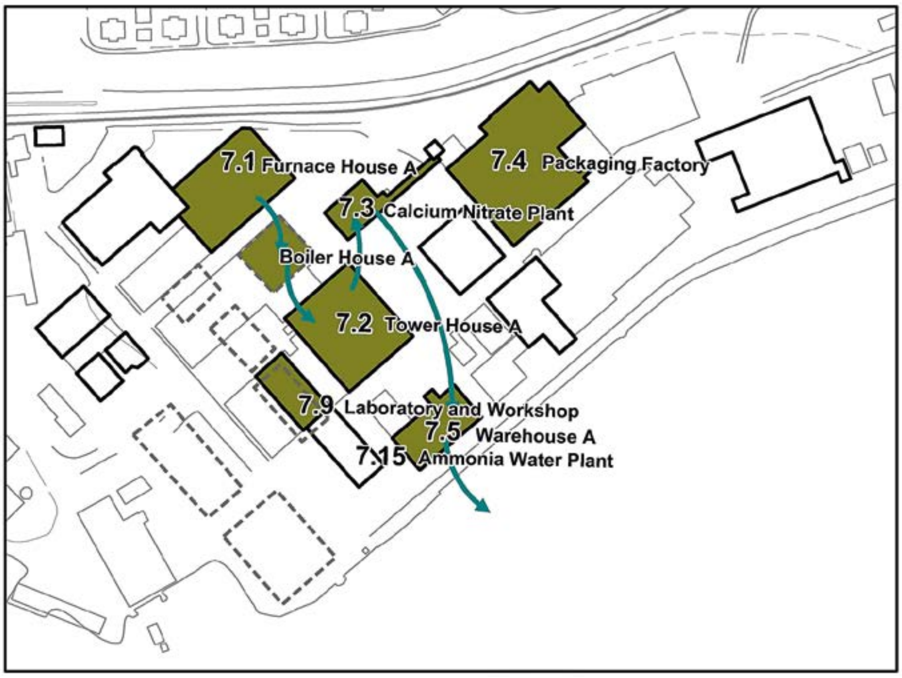
From the electric arc method, the nominated area contains an ample number of intact objects related to all ten of the production stages, from electric power from the world's biggest power plants to the packaging and shipping of artificial fertilizer (see table). Despite the fact that some objects are gone, all of the production stages are represented by well preserved and illustrative objects – both as individual objects and as a full set of production structure. The production line can be deciphered.

Birkeland/Eyde's electric arc method – list of preserved and lost objects

Production stage	ID no	Preserved objects	Demolished objects	Location
Power plant	1.1	Tinfos I with Myrens Dam		Notodden
	1.2	Tinfos II and the Holta Canal		Notodden
	3	Vemork Power Plant		Rjukan
	4	Såheim Power Plant		Rjukan
			Svælgfos I	Notodden
			Svælgfos II	Notodden
			Lienfos	Notodden
			Frøystul	Rjukan
Power transmission				
	2.1	Lightning arrester house and workshop		Notodden
	6.3	Transformer and distribution station		Rjukan
	6.1	Cable House		Notodden
			Distribution station in Furnace House I	Rjukan
			Power lines in Notodden and Rjukan	
Combustion of air for nitrogen oxide				
	7.1	Furnace House A		Notodden
	7.6	Furnace House C		Notodden
	8.1	Furnace House I		Rjukan
	4	Furnace House II (Såheim Power Plant)		Rjukan
			Furnace House B	Notodden
	9.2	Electric Arc Furnace, Notodden		Notodden
	9.3	Electric Arc Furnace, Rjukan		Rjukan
Cooling of gas				
	8.2	Boiler House		Rjukan
	4	Boiler House II (Såheim Power Plant)		Rjukan
	8.4/9.5	Pump House and AEG Pump		Rjukan
			Boiler house	Notodden
			Pump House	Notodden

Production stage	**ID no**	**Preserved objects**	**Demolished objects**	**Location**
Absorption of nitrogen in water for nitric acid				
	7.2	Tower House A		Notodden
	9.4	Acid Tower		Rjukan
	8.4/9.5	Pump House		Rjukan
	9.1	Ceramic pots		Notodden
			Tower House B	Notodden
			Tower House C	Notodden
			Tower House I	Rjukan
			Tower House II	Rjukan
Dissolution of limestone in nitric acid				
	7.3	Calcium Nitrate Plant		Notodden
			Boiler house	Notodden
			Lime Dissolution Plant I in Tower House I	Rjukan
			Lime Dissolution Plant II	Rjukan
	8.4/9.5	Pump House		Rjukan
Evaporation reduction				
	7.3	Calcium Nitrate Plant		Notodden
			Boiler house	Notodden
			Tower House I	Rjukan
			Tower House II	Rjukan
	8.4/9.5	Pump House		Rjukan
Cooling and solidification				
			Boiler house in the attic	Notodden
	7.3	Calcium Nitrate Plant		Notodden
			Solidification plant and packery	Rjukan
	8.4/9.5	Pump House		Rjukan
Screening			Boiler house	Notodden
	7.3	Calcium Nitrate Plant		Notodden

Production stage	ID no	Preserved objects	Demolished objects	Location
			Solidification plant and packery	Rjukan
Packaging				
			Barrel Factory	Notodden
	7.4	Packaging Factory		Notodden
	7.5	Warehouse A		Notodden
	8.3	Barrel Factory		Rjukan
			Solidification plant and packery	Rjukan



Adjacent buildings to the production lines under the electric arc process at Notodden, Rjukan I and Rjukan II. (See also Annex 1)

All parts of the **power production** are represented, from the regulating reservoir and tunnel system to penstocks and buildings. The power plants are intact and practically unchanged in their appearance, and the interiors are largely also well preserved. Såheim is still in operation. The same applies to Tinfos II, where old generator units still remain *in situ*. At Vemork, the production equipment remains *in situ* as museum objects. This is sufficient to be able to shed light on the power production, even though the first power plants Hydro built in Notodden are gone. Objects related to the transmission of power to the industrial plants using this method are largely gone, but a transformer and distribution station *(object 6.3)* is preserved in Rjukan with cells and equipment in use. These are sufficient to illustrate this production stage, especially when combined with the Cable House *(object 6.1)* in Notodden, the exterior of which is preserved, including the rack for receiving the overground power cables. The exterior of the lightning arrester house *(object 2.1)* is intact, and it bears testimony to pioneering attempts at the use and transmission of electric power.

The main stage of the electric arc method involving nitrogen fixing is sufficiently intact, with **factory buildings** and two **furnaces**. The furnace houses that housed the production are preserved in both Rjukan and Notodden with no significant changes, and two preserved electric arc furnaces show what the production equipment looked like. The furnaces have integrity as individual objects, but lack contextual integrity. The gas cooling process is demonstrated via the preserved Boiler House *(object 8.2)* in Rjukan. The corresponding building in Notodden has been demolished. The Pump House *(object 8.4)* with the original pump shows how water was used for cooling and other production stages. None of the tower houses for the absorption stage of the process remain in Rjukan, but the remaining Acid Tower and the well preserved Tower House A *(object 7.2)*, as well as ceramic pots in Notodden, mean that the stage is sufficiently illustrated by buildings and production equipment in the nominated area. In both places, the penstocks between the buildings for transporting gases and liquids are gone, but the production process can still be deciphered from the relative locations of the buildings.

The last four stages in the process before the packaging stage have the lowest integrity. However, the preserved Calcium Nitrate Plant *(object 7.3)* in Notodden was home to all these production stages, and represents them in the nomination. A number of technical installations in the exterior of the building, such as a limestone silo from 1919, have been demolished, however, and the façades have been partially altered, but the building is otherwise intact. Its place in the structure of Notodden Hydro Park also shows what functions it housed. The integrity of the packaging stage is very high, with a well preserved production plant in Notodden. Only some of the façades of the impregnation factory to the east have reduced integrity because they have been enclosed. With their structural location and design, the Packaging Factory *(object 7.4)* and Warehouse A *(object 7.5)* in Notodden represent the final stage in the electric arc method.

The by-product ammonium nitrate, which was used in the arms industry, is represented by the eastern part of the Calcium Nitrate Plant *(object 7.3)*, which for a few years was used for such production, and the Ammonia Water Plant *(object 7.15).* The main factory for this in Notodden has been demolished.

The ammonia method (Haber-Bosch)

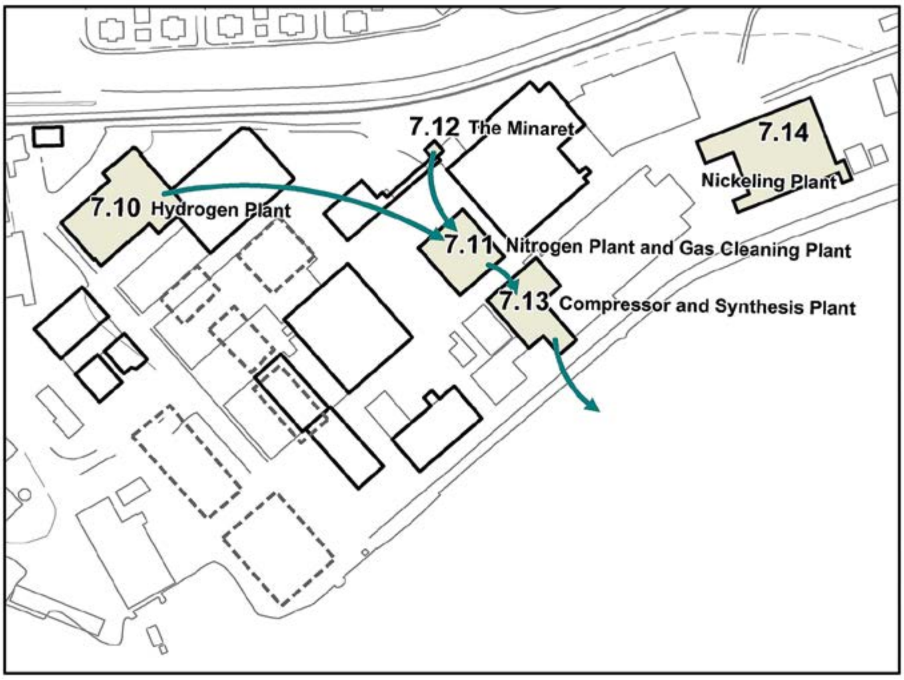
From the ammonia method, the nominated area includes intact objects related to all seven of the first and significant stages in the production method that differ from those of the electric arc method (see table). The objects are well preserved and illustrative, both as individual objects and as a complete production structure. The production line can be deciphered. The integrity of the final stages of the production of artificial fertilizer from ammonium gas is significantly reduced, as these stages took place in Rjukan, where most of the relevant buildings have been demolished. However, the final stages followed the same absorption principles as for the electric arc method.

The Haber-Bosch ammonia method – list of preserved and lost objects

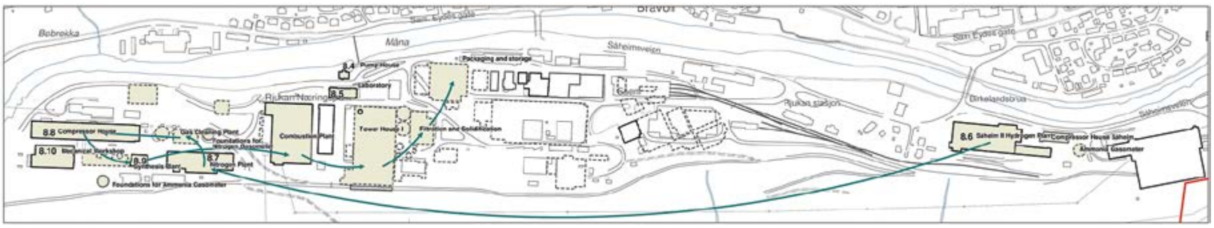
Production stage	ID no	Preserved object	Demolished object	Location
Power plant				
	3	Vemork Power Plant		Rjukan
	4	Såheim Power Plant		Rjukan
			Sværlgfos I	Notodden
			Sværlgfos II	Notodden
			Lienfos	Notodden
			Frøystul	Rjukan
Power transmission	6.1	Cable House		Notodden
	6.4	Power line 16/17		Rjukan
	6.3	Transformer and distribution station		Rjukan
	6.2	Control room in Furnace House I		Rjukan
			Power lines in Notodden and Rjukan	
Hydrogen plant				
	7.10/9.6	Hydrogen Plant		Notodden
	7.14	Nickeling Plant		Notodden
	8.6	Såheim II Hydrogen Plant		Rjukan
			Pump House	Notodden
			Vemork Hydrogen Plant	Rjukan
			Såheim I Hydrogen Plant	Rjukan
			Pipelines	Rjukan
Nitrogen plant				Notodden
	7.11	Nitrogen Plant and Gas Cleaning Plant		Notodden
	7.12	The Minaret		Notodden
	8.7	Nitrogen Plant		Rjukan

Production stage	ID no	Preserved object	Demolished object	Location
Gas cleaning plant				
	7.11	Nitrogen Plant and Gas Cleaning Plant		Notodden
			Gas Cleaning Plant Rjukan	Rjukan
			Nitrogen gasometer	Notodden
			Nitrogen gasometer (foundations preserved)	Rjukan
			Gas mixture gasometer	Notodden
			Gas mixture gasometer	Rjukan
Compressor plant				
	7.13	Compressor and Synthesis Plant		Notodden
	8.8	Compressor House		Rjukan
Synthesis plant				
	7.13	Compressor and Synthesis Plant		Notodden
	8.9	Synthesis Plant		Rjukan
	9.7	Synthesis Furnace, Rjukan		Rjukan
			6 tanks	Notodden
			Ammonia gasometer (foundations preserved)	Rjukan
Combustion plant				
	8.1	Furnace House I		Rjukan
Absorption plant				
	9.4	Acid Tower		Rjukan
	8.4/9.5	Pump House		Rjukan
			Tower House I	Rjukan
			Tower House II	Rjukan
Limestone dissolution			Lime Dissolution Plant I in Tower House I	Rjukan
			The new lime dissolution plant	Rjukan
Filtration and evaporation reduction			Tower House I	Rjukan
Solidification			Solidification plant and packery	Rjukan

Production stage	ID no	Preserved object	Demolished object	Location
			Solidification tower, Tower House I	Rjukan
Cooling and screening				
			Solidification plant and packery	Rjukan
Packaging				
	7.4	Packaging Factory		Notodden
			Solidification plant and packery	Rjukan



Adjacent buildings to the ammonia method at Notodden and Rjukan. (see also Annex 1)



Power production and power transmission during the period when the ammonia method was used are linked to equivalent objects as for the electric arc method, except in Notodden, where no relevant power plants are preserved. Vemork and Såheim in Rjukan represent the function sufficiently, however. The power transmission stage has been augmented with new objects such as an overground section in the form of power line 16/17 *(object 6.4)* and a Control Room *(object 6.2)* for the distribution station in Furnace House I where the power lines entered the building.

The factories in Rjukan and Notodden complement each other in the five main stages of ammonia production. In Notodden, all stages are intact, including the production line structure and well-preserved buildings for the hydrogen plant, nitrogen plant, gas cleaning plant and synthesis plant. Only the gasometers and the penstocks are gone. In Rjukan, the gas cleaning plant and two of the three hydrogen plants are gone. Evidence of two of the gasometers can be seen in the form of the remains of foundations. Såheim II Hydrogen Plant *(object 8.6)* in Rjukan is an intact building complex and represents this production stage together with the Hydrogen Plant *(object 7.10)* and the Nickeling Plant *(object 7.14)* in Notodden. All other stages of the ammonia production process are also sufficiently intact in Rjukan. The buildings are easy to decipher as a complete facility on a separate level in the terrain. However, the integrity of the Synthesis Plant *(object 8.9)* in Rjukan is significantly reduced, as only parts of the facility have been preserved, but it can be deciphered and sufficiently illustrates the structure of the plant. The production equipment is gone in both Notodden and Rjukan, but a Synthesis Furnace *(object 9.7)* from the synthesis plant in Rjukan has been preserved without contextual integrity, as well as three tanks that remain *in situ* in the Hydrogen Plant in Notodden.

In the first stages for utilising ammonia for artificial fertilizer production, Furnace House I *(object 8.1)*, which was used as a combustion plant, and the Acid Tower *(object 9.4)* from the absorption stage are intact. No objects in Rjukan have been preserved from the subsequent stages in the same way as for the electric arc process. All packaging production took place in Notodden, where the production complex is well preserved.

The transport system

The **transport system** as a component consists of all the elements necessary to illustrate the transport of the industrial products from Rjukan to Notodden. The individual parts of the system, such as tracks, station buildings, ferry quays, slipways, lighthouses, rolling stock and vessels are preserved and intact from the period of operation. The transport system has been more or less unused since 1991, which has affected its technical condition, as described in Chapter 4. The system is protected by law, however, and systematic work has been initiated with a view to the future maintenance and functional use of the system.

The Rjukan Line

The Rjukan Line has a high degree of integrity, including the overhead line equipment as an element that illustrates its early electrification. Only Såheim Engine Shed *(object 11.10)* and the Vemork railway track *(object 11.11)* have reduced integrity, but this does not affect the overall impression of the line. The engine shed function is also represented by the intact and still functional engine shed in Rjukan Railway Station. The integrity of the Vemork track is significantly reduced as a railway line, since most of the railway elements are gone, but the highly illustrative line in the mountainside is intact, and the railway elements are sporadically preserved in places. The tracks in the factory area have been removed. A large proportion of the Rjukan Line's rolling stock for the transport of industrial products *(object 11.12)* have been preserved as part of the line, and several well preserved, illustrative units have been protected by law. The integrity of the two preserved passenger coaches is reduced. The units are otherwise well preserved, but their condition is variable. Everything is owned by Norwegian Industrial Workers Museum.

The transport system's unique component with railway ferries across a lake is well preserved with ten lighthouses, two ferry quays and two types and generations of ferries that are virtually unchanged from when they were in operation for Hydro, plus the shipwreck of the 'D/F Hydro', which illustrates the war history element. All have a high degree of integrity. Several of the lighthouses lack the original gas apparatus, however, but this does not affect the overall impression. The ferry quays have undergone several alterations and individual parts have been replaced, but they have integrity in both design and function.

The Tinnoset Line

The Tinnoset Line has intact and complete tracks and built-up station areas. However, it does not have a complete set of overhead line equipment like the Rjukan Line. It has been lost due to theft and vandalism after the line closed down in 1991. The integrity of the Rjukan Quay *(object 10.3)*, which was the final transport stage until 1917, is reduced because only the foundations for the cranes and part of the railway tracks are intact. However, the preserved parts and traces of the track in the terrain can be deciphered sufficiently to illustrate their function.

Company towns

The **company town** component with the urban communities that were needed to operate the industry and transport are intact, easy to decipher and complete with all illustrative parts and structures represented in the nomination. No significant elements have been lost, and Hydro's design of the building environment and urban structure is visible and virtually unchanged in both Notodden and Rjukan. The town areas are in good technical condition. The most relevant threat to a few objects is lack of use and thereby a lack of maintenance, as described in Chapter 4.

Notodden

In Notodden Hydro Town, all the buildings in the housing areas that are part of the nomination are still present, and the structures appear with full integrity. With their location in the terraced landscape and the overall expression in relation to the factory area, the two urban areas and the Admini residence in Notodden still illustrate clear features of a single company's planning scheme for different types of employees. The Casino (*object 12.4*) for visiting engineers and administrative staff supplements the Admini's function. The outhouses in Grønnebyen (*object 12.1*) have been lost, but newer garages maintain the structure in the well preserved housing area for workers. The Villamoen area (*object 12.2*) remains intact with the buildings Hydro built there for its administrative staff. The villa style of the building environment is clear and intact. All buildings are well maintained and in use. Other parts of the town that Hydro built in Notodden are geographically separate from the rest, more difficult to decipher and have in part been drastically altered.

Rjukan

For Rjukan Hydro Town, the nomination proposal includes the entire urban structure, almost exactly the way it appeared when it was completed in around 1930. Town planning features and significant building types both remain intact, from Krosso in the west to Ingolfsland-Tveito in the east. The urban layout and development are well preserved and easy to decipher and remain virtually unchanged from the 1920s, with its housing areas, street network and town squares. The town still appears as a unified Hydro product with an intact and robust company town character. Some supplementary houses and a few replacements, have joined the existing structure. With a few minor exceptions, the building stock remains largely intact in the town, almost exactly the way it appeared in around 1930. In general, however, most of the original outhouse buildings are gone. Two brick houses of the same type as the eight preserved houses were destroyed in fires and demolished at Krosso, among other things to make room for a new road. In the old town centre, only the bakery has been demolished. Several changes have been made to the Private Bøen housing area, especially the western part, but this part of the town was the only one that was not built by Hydro and the changes are therefore less significant. In the large Tveito-Ingolfsland area, between five and ten buildings have been lost due to fire or demolition. The most significant object that no longer exists is the Øvre (Upper) Sing Sing housing quadrant, identical to the preserved Nedre (Lower) Sing Sing. The brick house in Tveito Allé 20 burnt down, but it has been rebuilt as a close reconstruction of the original. The others were small wooden houses.

Original buildings used for various social functions are well preserved and represented in the nomination, such as food production facilities, churches, hospitals, schools, stores, fire station, office buildings, assembly halls, residences for entertainment purposes, recreational facilities, bridges, parks and various types of houses for all classes of society. The close connection between homes and workplaces is intact and easy to decipher for several of the objects, such as schools and teachers' houses. In the Villaveien-Flekkebyen area, the terrain structure and landscape connection to the factory area is intact, as in Notodden. A large part of Hydro's various brick and timber houses are preserved in good condition in the nominated area, and a varied, representative selection is particularly emphasised as significant objects, distributed throughout the urban area.

The buffer zone

The landscape in the buffer zone that frames the four components is robust and intact. The most imminent threat is the risk that important sightlines may become overgrown.

3.1.d Statement of authenticity

Together, the four thematic components of the nomination form a whole of preserved values that in a credible and unified way shows the Northern European industrial heritage site of Rjukan – Notodden to be an outstanding representative of the second industrial revolution. The nominated area includes environments and individual objects with a varying degree of authenticity, but all the components include a sufficient number of objects with a high degree of authenticity. Rjukan and Notodden have sufficiently preserved their values relating to *form and design, use of materials, decipherability of function, setting and character, which corresponds to the Operational Guidelines in an adapitve manner*.

Hydroelectric power production

The hydroelectric power component has a high degree of authenticity relating to all values. The Vemork and Såheim power plants are both virtually unchanged, although the authenticity of Skarsfos Dam I with intake gate house as part of Vemork Power Plant is somewhat reduced due to the new dam. Vemork has been a dynamic facility that has seen several extensions during its operational phase. The more recent access ramp in front of the power station building affects the architectural impression somewhat, but not substantially. Hydro Energi has maintained the plants in accordance with conservation principles. The two power plants are the main bearers of the component's authenticity, together with Tinfos II and the Holta Canal in Notodden, which also has a high degree of authenticity. The power station buildings have well preserved interiors, including the original generator sets. The function of Tinfos I with Myrens Dam is not as easily decipherable and the form and design has become somewhat altered after it was taken out of use as a power plant and the penstock removed, but its setting, original use of materials and main character have been retained. The old Møsvatn Dam lacks authenticity in terms of its form and design, setting and character since it was replaced by a new dam. The function is not as decipherable but still sufficiently present. Hydro's power plants in the Tinnelva river have mostly been demolished, but Svælgfos lightning arrester house and workshop are virtually unchanged and have a high degree of authenticity. The objects relating to power transmission are also largely unchanged. The most significant change is that the section of line into the Cable House in Notodden no longer exists.

Industry

The industry component consists of buildings and objects of varying authenticity, but as a whole, the authenticity is high, considering the fact that the use and function of the plants have changed several times. Most of the buildings are still used for industry. The plants are in the process of obtaining protected status, and future measures will observe conservation principles.

Notodden

Notodden Hydro Park has gone through several changes, but it consists of fairly robust industrial buildings and has on the whole preserved the important values of the facility. Through their positions relative to each other, the buildings document the functional stages of the industrial process, despite the fact that more recent extensions and new buildings unrelated to the two artificial fertilizer methods have been added since the 1950s. The more recent buildings follow the three main north-south lines A, B and C in the facility and are otherwise situated on the outer edge and do not disturb the structure significantly. The form and design and use of materials have largely been preserved, but most of the buildings have had minor material alterations, such as some new doors and windows and new colours in places. Most of the buildings have been re-roofed, although the traditional type of roofing for such buildings has been used.

The buildings associated with the electric arc method in Notodden have a high degree of authenticity except for some less significant changes to the form and design. Furnace House A *(object 7.1)* has new windows and a new entrance on the north side, and the turret skylights on the ridge have been removed, but it otherwise appears authentic. Tower House A *(object 7.2)* is the facility's most authentic individual building, where only a new gate and a new chimney constitute substantial changes to the exterior. The authenticity of the Calcium Nitrate Plant *(object 7.3)* is moderate since its conversion into a welfare building in the 1950s, but the main outline and the architectural expression have been preserved. Furnace House C *(object 7.6)* and the other buildings that were built as a testing plant in 1909, as well as the Laboratory *(object 7.9)*, are well preserved with a high degree of authenticity. Furnace House C and the laboratory in particular have been partially enclosed, however. The Packaging Factory *(object 7.4)* is well preserved as a building complex, but the authenticity of the eastern part with the impregnation factory is reduced because it has been enclosed. The authenticity of Warehouse A *(object 7.5)* is low when it comes to the use of materials and the original form and design, which have been altered several times, but it remains intact when it comes to significant values such as decipherability of function and character. The character of the Ammonia Water Plant *(object 7.15)* is slightly changed because of some new windows and doors and a crane that has been removed from the gable towards the lake, but it otherwise appears authentic.

All the **buildings for ammonia production** from the 1920s are well preserved and authentic with minor alterations. However, the Compressor and Synthesis Plant *(object 7.13),* and the Nickeling Plant *(object 7.14)* have been partly enclosed by extensions, which means that the authenticity of several façades is reduced. A new outsize window has been fitted in the Nitrogen Plant and Gas Cleaning Plant *(object 7.11)*, which changes the form and design somewhat, but it is otherwise well preserved.

Rjukan

The same conditions as in Notodden apply to **Rjukan** Hydro Park, but there are fewer extensions and new buildings here, and large vacant areas where buildings have been demolished. The big tower houses that are no longer there mean that the authenticity of the facility is more moderate in terms of character. There is therefore room for appropriate new buildings within the structure, in order to develop the facility further and improve its character. By their positions relative to each other, however, the preserved buildings provide good, clear documentation of the functional stages of the industrial process. The three visual terrain levels that divided the facility into Rjukan I, II and III have been preserved. Some newer buildings have been added, but they either follow the main structure of the facility or have been placed on the outer edges and do not disturb the structure significantly.

The authenticity of **the buildings from the electric arc method in Rjukan** is good (with one exception). The exterior of Furnace House I *(object 8.1)* is virtually unchanged, while the Boiler House *(object 8.2)* has a partially altered façade, although this does not significantly affect the form and design and use of materials. The Laboratory *(object 8.5)* has been altered somewhat but not significantly. The roofing has been changed from slate to steel sheeting, and the chimneys and windows have been replaced – however, none of this significantly affects the form and design and use of materials. The function of the laboratory, with its strategic location close to the production line, can still be deciphered. The Pump House (*object 8.4*), which is located further down, is well preserved with a high degree of authenticity. The Barrel Factory *(object 8.3)* is the exception. Its authenticity is low due to significant changes to the façade, in addition to the fact that large parts of the original building were demolished in the 1940s due to war damage. Its form and design and, in part, the use of materials have been preserved, however. The function of the structure as the easternmost end of the production line can still be deciphered.

All the **buildings associated with the ammonia method in Rjukan** are well preserved (with one exception) and fairly unchanged, other than some new doors and gates. The façade of Mechanical Workshop (*object 8.10*) has been inappropriately altered with windows to the west, but this does not affect the building’s outline and character. The exception is the Synthesis Plant (*object 8.9*), the authenticity of which is low. Large parts of the building have been demolished. Small extensions were built on the remaining parts in the 1980s, and a prominent catalyser plant has been installed on the roof. The exterior rack for the synthesis furnaces has partially been demolished and has therefore lost its form and design. This means that the building's character has been significantly changed. The function and setting have been sufficiently preserved, however. In 2013, the catalyser will be removed, in order to improve the building's form and design and decipherability.

Transport system

Overall, the authenticity of the **transport system** is high. The whole transport section has been preserved, and its character and setting remain unchanged (with a few exceptions). The function is still decipherable both as a whole and for individual objects. Original elements relating to form and design and the use of materials are mostly well preserved, despite the transport system's dynamic character, where changes have been made according to Hydro's needs and improvements in railway technology.

The Tinnoset Line

The authenticity of the Tinnoset Line as a whole is moderate. The damaged and partly missing overhead line equipment means that the character and form and design of the electrified railway track has been altered. The character and setting have also been changed because the line has become overgrown in some places, but the track and route are intact. Plans are under way to improve these conditions. The station buildings are well preserved and have undergone few material changes. Hydro carried out some upgrades in the 1950s and 1960s, which can be seen in details on several of the buildings. Notodden old railway station building (*object 10.2)* has retained its character, but its form and design was slightly altered when the main entrance to the railway track was demolished after the station was closed down. The setting was changed somewhat with a new track and a new platform, but not substantially. The architecture is well preserved and the function can still be deciphered. The wagon weighing hut in Notodden railway station was repaired and restored in a satisfactory manner in 2012. The character and form and design of the Rjukan Quay (*object 10.3)* are significantly changed now that the cranes are no longer there. The function with foundations and railway tracks is sufficiently decipherable, however.

The Rjukan Line with the ferries

The authenticity of the Rjukan Line and the railway ferries is generally good. It has been a dynamic facility, displaying visible traces of Hydro's upgrades in the period from 1909 to 1966, but many of the original features have been preserved. This is demonstrated in particular by the well-preserved track and overhead line equipment *(object 11.1)*, where the various individual parts cover the entire time period, including original overhead line masts and beams from 1911. The Vemork railway track has low authenticity as a railway track, but its setting and important function as a route are well preserved.

The authenticity of the **buildings on the Rjukan Line** is variable but sufficient. In Rjukan Railway Station *(object 11.9)*, the engine shed is well preserved. The same can be said about Rjukan railway station building, which has kept its main outline from 1909 although the building has been affected by the modifications in 1963. The authenticity of the associated freight house is low, however, due to a number of alterations. The main outline and the function are nonetheless well preserved. The authenticity of Såheim engine shed *(object 11.10)* as a railway building is low, since it was converted into a hydrogen plant in the

1920s and subsequent changes were made to the façade, but it has kept its main features in terms of form and design and character on both the interior and exterior. Ingolfsland railway station building *(object 11.8)* has moderate authenticity with new roofs, minor changes to the façade and missing details, which in combination have changed the form and design somewhat. The character and the function are nonetheless well preserved. The buildings in Mæl Railway Station *(object 11.6)* and beside Tinnoset Ferry Quay *(object 11.2)* are all well preserved with few significant changes. However, the authenticity of the stationmaster's house in Mæl is reduced, with a number of changes that were made between its year of construction and the 1960s.

The railway ferry system is well preserved, and both ferry quays are authentic with individual components from several periods during Hydro's operational phase. Its original character is virtually unchanged. All lighthouses are highly authentic, but their settings are somewhat changed because they have become overgrown. The slipway with winch house is a dynamic object that is still being used, and is well preserved in its form and design, character, decipherability and use of materials. The two railway ferries from the operational phase are well preserved and authentic. Only minor changes have been made since they were completed in 1929 and 1956. The same applies to the rolling stock, except the passenger coaches, to which several changes have been made due to changed functions.

Company towns

The **company town** component consists of buildings and environments of a varying but high degree of authenticity. The urban communities as a whole are well preserved.

Notodden Hydro Town

The decipherability of Notodden Hydro Town is intact, including the division of terrain and with the connection to the factory visibly present. Few changes have been made to the housing areas after the repair and restoration of the Grønnebyen area *(object 12.1)* in the 1950s, which means that the form and design, use of materials and character are well preserved. Over time, the Villamoen area *(object 12.2)* has acquired a looser structure and greater variation in form and design and the use of materials in the buildings, but the area as a whole gives the impression of an authentic villa area for Hydro. Newer garages and outhouses, together with buildings erected by parties others than Hydro affect the structure's decipherability somewhat on the outer edges, but not significantly. The Casino with four buildings (*object 12.4*) presents an authentic whole in a setting that can be deciphered, but the villas have been altered in ways that reduce their authenticity in terms of character and use of materials. The main building is best preserved.

Rjukan Hydro Town

Rjukan Hydro Town has high authenticity as a company town. Individual buildings have been affected by inappropriate architectural alterations, however, which were carried out in the years after Hydro pulled out and the tenants took over as owners. The alterations included windows, doors, cladding, decor, extensions etc. This has not affected the area as a whole, for example in the Flekkebyen area, individual buildings have been altered while the area has kept its main outline and character in relation to Villaveien. Work is now under way on preparing guidance material for improvements and restoration.

The town plan and structure with town squares remain virtually unchanged from the 1920s, and a sufficient number of important individual buildings and building environments have been retained with a high degree of authenticity. Several of these buildings and building environments have or have had functions that can easily be deciphered in the town structure; everything from stores, schools, hospitals, offices and fire station, via the Rjukan House, which has recently been restored as an assembly hall, to workers' houses and villa areas. The buildings and building environments have largely retained their character and setting, and predominantly also the use of materials and form and design. For example, the Tyskerbyen and Rødbyen housing areas are well preserved building environments with houses and streets. Of the individual buildings emphasised in the nomination, only Såheim Private School *(object 13.11)* can be said to have some reduced authenticity due to alterations, but not to the extent that it affects its value as one of the representatives of Hydro's school buildings. The original architectural style is otherwise visible in well preserved standard houses such as the Sing Sing and Paradiset brick housing complexes, the timber houses in the New Town and the villas in Villaveien. Its character as a company town is well preserved and further increased by details like the fire hydrants that were actually designed in the town, fire escapes and other elements that can easily be found in the urban landscape.

3.1.e Protection and management

Due to the size of the World Heritage Site, and the division into components of varying natures and with complex ownerships, a complex system of legal instruments and management schemes is needed to protect the area's outstanding universal values. In principle, the legal system consists of two pieces of legislation: **the Cultural Heritage Act**, which is an overriding specialised act for cultural heritage sites, monuments and environments of national interest, and which is managed by the central government and county authorities, and **the Planning and Building Act**, which is the local authorities' instrument for managing land use and building activities, including building preservation and area protection, in accordance with political decisions. The buildings, plants, properties and objects in the World Heritage Site are owned by private commercial enterprises, administrative enterprises, foundations, public bodies and private individuals. The use and choice of legal protection will be subject to an assessment of what is expedient in each individual case, while amendments are made to the legislation with regard to ownership.

All four components of the World Heritage are affected by decisions pursuant to both acts. The OUV consists of 13 attributes broken down into the components of hydroelectric power, industry, transport system and company towns. Within each attribute, objects have been selected that, on the basis of their historical significance and high degree of integrity and authenticity, are regarded as particularly significant. In total, there are 97 significant objects, some of which consist of several objects. Obtaining protected status pursuant to the Cultural Heritage Act is appropriate for objects within all 13 attributes. A number of such decisions have already been made, and more are under preparation. In their land use planning, the municipalities emphasise the preparation of legally binding municipal sub-plans that cover the areas nominated for World Heritage status, especially for the industrial and housing areas. Zoning plans for properties and smaller areas can further specify the scope of the protection in dedicated provisions. For buildings, this may apply to the exterior and to outhouse areas.

The threats that are most serious in the long term are related to changes in land use and infrastructure resulting from general social development. These are issues that will be addressed by the parties in the World Heritage Site in their planning and case processing. For example, a change of ownership of the big properties may trigger development pressure and/or a change of functions. This will be subject to case processing and decisions by the bodies responsible in each case. The decision process includes the democratic procedure of public consultation.

The bodies that manage the two above-mentioned acts, the State (the Government represented by the Ministry of Climate and Environment), the county authorities and the municipalities, have signed a *declaration of intent* to use consideration for the World Heritage as the basis for exercising authority in the area and its buffer zone. A management plan has been drawn up that defines the parties' responsibilities and roles. It lists and describes measures and tasks for the protection, restoration/repair and dissemination of the area and its values. The parties will establish a World Heritage Council to coordinate, facilitate and quality assure the work under each party's authority.

Affected parties that manage large property portfolios, including private and public companies and enterprises as well as museums, need the properties to be systematically managed in accordance with their own management plans. The management plan for the World Heritage Site contains an overview of these plans. The World Heritage Council will be in contact with the affected parties, and will address issues relating to management and dissemination.

3.2 Comparative analysis

In the ICOMOS report 'Filling the Gaps – an Action Plan for the Future' (2005), the World Heritage List is analysed from three different angles: typologically based on categories, in a chronological-regional context, and thematically. All the three frameworks include classifications that are relevant for Rjukan – Notodden. The **typological framework** concerns the category *modern cultural heritage*, where industrial towns – i.e. from the late 19th century onwards – are included in the specification. The **chronological regional framework** specifies European cultural heritage relating to *the industrial revolution* in the broad sense, including testimonies of *advances in science and technology,* and modernist movements in art and architecture in the modern world. The **thematic framework** has a number of sub-categories under identified main topics. Among the sub-categories of the topic Creative Responses and Continuity are specified *industrial architecture* – including *factories and power plants*, as well as *transport structures*, *towns established in the 19th and 20th centuries* and *industrial landscapes*. Other topics specify systems for *water transport* and *railroads* with associated elements. Developing Technologies is a separate topic, under which subcategories are specified such as *dam constructions* for the utilisation of hydroelectric power (general), *electric power production* from various energy carriers, *building and construction technology*, *urban infrastructure* for the supply of water, power etc. As a nominated area consisting of four components, Rjukan – Notodden is characterised by the fact that it contains significant objects and groups of objects in all the above-mentioned categories. The ICOMOS analysis also concludes that virtually all these categories and topics are under-represented on the World Heritage List. In the report 'Industrial and Technical Heritage in the World Heritage List' (ICOMOS, 2009), all the inscribed sites that fall under this category are listed.

The nomination of Rjukan – Notodden focuses on modern, electro-based industry, 20th-century architecture and town planning, and landscaping for the purpose of exploiting a natural resource. A comparative analysis shall therefore look for relations to industrial communities that form a corresponding whole of many components, similarly to Rjukan and Notodden, i.e. hydroelectric power production, electricity-based processing industry, transport system and urban settlements of the company town type, and that bear testimony to the phase of the industrialisation that took place in the geo-cultural region of Europe and North America, referred to as the second industrial revolution.

Comparison with sites inscribed on the World Heritage List

The universal importance of the industrial revolution is represented when it comes to the first phase, which is roughly reflected by coal, iron and textiles. The *second industrial revolution*, however, which starts in the Western countries in the late 19th century and continues for some decades, is poorly represented. Hydroelectric power production and the electro-chemical processing industry are practically absent from the World Heritage List. The industrial areas on the list include several urban residential areas associated with factories, but they were established prior to the emergence of electricity as an available source of energy. Transport systems inscribed on the World Heritage List, and especially railways, of which there is only a modest number, tend to represent transport in itself, sometimes in interaction with the landscape. A search through the World Heritage List for industry, technology, new towns and modernity results in several inscriptions with which a comparison is necessary.

The following World Heritage sites in the UK represent the industrial revolution that started there in around 1700 and spread to other Western countries throughout the 18th and 19th centuries:

Ironbridge Gorge was inscribed in 1986 as a symbol of the industrial revolution. The area includes (traces of) iron and coal mines, furnaces, railways, houses etc. the way they were designed in the introductory phase of the industrialisation and which in some cases were invented there, such as the coke-iron production technique (1709). The place is named after the cast iron bridge from 1779, which is the first of its kind and an icon of the place. Ironbridge Gorge is made up of several components, but it obviously represents different values than Rjukan – Notodden.

Blaenavon Industrial Landscape (2000) also consists of several components that together cover a substantial area. Its most important elements include coal and ore mines, a primitive railway system and a community with social infrastructure. It represents the typical characteristics of the industrialisation that dominated the century prior to the second industrial revolution.

Derwent Valley Mills (2001) represented technological innovation relating to the textile industry, a branch of industry that was typical and dominant during the early industrial era. The factory in Derwent Valley was the start of the mass production of cotton that was made possible by new technology developed here, relating to water-powered spinning mills. The factory became a model for industrial architecture adapted around the new technology. Workers' houses are spread over a large area, which together with the spinning mills forms an industrial landscape. Before Derwent Valley was industrialised, it was (like Rjukan and Notodden) a rural community that in 1776 was taken over by settlements designed and built by the factory's owners (Arkwright). Derwent Valley Mills is inscribed on the World Heritage List with its housing areas, directors' homes, public buildings such as a police station, church, hotel, schools, waterworks, transport system and surrounding landscape. It is easy to conclude that the site represents a different industrial cultural heritage than Rjukan – Notodden.

New Lanark and **Saltaire** are also industrial communities connected to the textile industry. Both were inscribed in 2001 at the same time as Derwent Valley Mills. As nominations, the sites complement each other as outstanding examples of the characteristics of the industrial revolution. While Derwent Valley Mills (and to some extent the Blaenavon Industrial Landscape) focuses on technology, it is primarily the new type of complete industrial community with workers' houses and public buildings established around the factories that is important in Saltaire and New Lanark. In these cases, the focus is on the results of a paternalistic industrialist's idealistic motive of providing better living conditions for the workers. The ground-breaking industrialisation had been followed by a brutal exploitation of workers and the emergence of a new class society.

New Lanark was established in the early 19th century with a textile factory and workers' houses in an underdeveloped rural area. The site was chosen because of its access to water, which was necessary for the spinning mill. The philanthropist and Utopian idealist Robert Owen designed New Lanark as a small industrial model town, where spacious and well-designed workers' houses and a school are testament to Owen's humanism. New Lanark is often regarded as the predecessor to Howard's garden city concept and thereby as the model for a number of industrial towns/company towns worldwide. The company's influence is clear in the design and social infrastructure of the village that attended to both spiritual and physical needs. In Saltaire, it was Titus Salt who later in the 19th century built workers' houses and public buildings in a harmonious style to a high architectural standard, organised within a structured town plan. The town was established because of the location's access to soft water for wool production. The model town gives an impression of Victorian philanthropic humanism. The architecture and town plans are outstanding examples of new planning ideals, a hierarchically structured garden city with more than 800 houses along wide streets, a big dining hall, baths and laundries, a retirement home, hospital, school, church and park. Saltaire has also influenced the garden city movement.

Compared with Rjukan – Notodden, New Lanark and Saltaire represent a different, earlier type of industry and resource utilisation, which belongs to the first industrial revolution, and an integrated transport system is not part of the inscribed sites. As urban communities of the *company town* type, however, they have common characteristics. However, company towns as part of a shared industrial cultural heritage must be diversified, according to both the regional cultural context and to the different phases of the industrialisation process. Louis Bergeron (TICCIH, 2001) has made a contribution in this connection. Among other things, he points to a division that takes place after the breakthrough of the garden city movement. Rjukan and Notodden are examples of what he defines as the later generation of company towns, where a high standard of living and the quality of materials and design are no longer based on any kind of Utopian idealism, but financially and pragmatically founded on the need to secure a stable, loyal workforce in a market where there is competition for labour. In the case of Rjukan – Notodden, this is further emphasised by the need to make a new community in a remote location an attractive place for families to live. In the 20th century, the growing organisation and political participation of the working class became a new influential factor. As model towns, Rjukan and Notodden also have an extra dimension in that they were intended as symbols of the recent independence of Norway as a nation state and a new, progressive future for the country.

Crespi d'Adda in Italy, inscribed in 1995, has common characteristics with Rjukan and Notodden as a company town. The sites partly overlap in time, with Crespi d'Adda as the oldest, which can also be seen in the fact that Crespi d'Adda is connected to the textile industry, while Rjukan and Notodden are connected to branches of industry that did not exist until the turn of the 20th century. As a company town, Crespi d'Adda is an outstanding example of an urban community built by enlightened industrialists to meet the workers' material needs. The site is an outstanding example of the generations of company towns built in Europe prior to the 20th century, and typical of the way they were established in the UK, Belgium, France and Germany, close to a source of raw materials or energy. Louis Bergeron points out that Crespi d'Adda must be considered in a Southern European cultural framework. A Catholic mindset, Southern European city culture and the influence of Alessandro Rossi gave father and son Crespi an ideological context that differed from the models in Northern and Western Europe. The result was a town with an urban, elaborate concept that is an original, characteristic expression of the distinctively Italian context.

The factories in Crespi d'Adda were based on energy from coal. A hydroelectric power plant was nevertheless built there and is part of the World Heritage Site. The power station did not serve industrial purposes, but supplied electricity to the workers' homes, public baths and other services. All in all, it is clear that Rjukan – Notodden stands out from Crespi d'Adda in several respects.

Germany also has sites on the World Heritage List that represent the industrial revolution, and which bear testimony to later phases and a different organisation of industrial activities.

Völklingen Iron Works (inscribed in 1994) is unique as an intact example of a large industrial complex for iron production in the Western world. The works, which are from the late 19th century, were initially based on coal-fired furnaces and a dedicated coking plant was later added to the facility, before it became the first ironworks in the world to start using gas in the enormous furnaces. The works demonstrate modernisations throughout the 20th century, with new and sometimes ground-breaking technological installations until around 1930, when it came to a standstill until it was closed down. There is a certain parallel to Rjukan – Notodden, but this is not as strong as the factors that distinguish the sites as representations of industrial values.

Like Völklingen, **Zollverein Coal Mine Industrial Complex in Essen** (inscribed in 2001) is an industrial complex covering a large area. It consists of a complete infrastructure related to coal mining, with a focus in World Heritage terms on modern 20th-century industrial architecture. The site is a material testament to progress and decline in an essential branch of industry over the course of 150 years. Zollverein was closed down in 1986, and following protests against its demolition, a protection order was issued for the purpose of preserving the industrial buildings, railway line, housing and consumer and welfare facilities. The industry halls were restored and renovated with a view to providing premises for artists, creative enterprises and cultural purposes as well as museums and dissemination initiatives. Part of the area is reserved for recreational activities (layout plan developed by the architect Rem Kolhaas).

In contrast to the mining industry, Rjukan – Notodden is an example of an industrial branch that emerged in the 20th century based on electrochemical processes. Like Zollverein, Rjukan and Notodden include examples of significant industrial architecture, although on a smaller scale in terms of significant architectural history. However, Rjukan – Notodden has a much broader focus and includes important architectural buildings, among which hydroelectric power plants.

Humberstone & Santa Laura Saltpeter Works (inscribed in 2005) in Chile consist of a cluster of closed down saltpetre mines that from 1880 supplied large parts of the world with the fertilizer product Chile saltpetre from the world's biggest natural deposits of sodium nitrate. This fertilizer made it possible to cultivate new agricultural land and increase crop yields in North and South America and Europe. The expected depletion of the resource contributed strongly to the efforts initiated by science, industry and financial circles in the USA and Europe to develop synthetic calcium nitrate fertilizer, of which Rjukan – Notodden is an outstanding example. The production in the mines neither required nor led to technological innovations, belonging to the industrial era prior to the second industrial revolution, but it is nevertheless historically linked to the transition into the era that was to come. The location of the mines in the empty Atacama Desert meant that company towns had to be built for workers who were recruited from Chile, Peru and Bolivia. Capital from the USA and Europe contributed. Today, Humberstone & Santa Laura are examples of industrial investment and entrepreneurship in a marginal area that flourished for a limited period under given historical conditions, and of a community of the company town type, in which social organisation and justice were hard won in a cultural environment that developed among workers that had moved there from many different countries. Decay and damage from earthquakes to the vulnerable building structures have resulted in a condition that is so poor that the site is on the List of World Heritage in Danger.

There are several parallels between Humberstone & Santa Laura and Rjukan – Notodden as historical phenomena. In particular, calcium nitrate fertilizer as a product links the sites together. The sites complement each other by representing successive stages in a development that is closely linked to modernisation in several regions of the world. Although they represent different values, the sites' significance will be mutually increased if they are both inscribed on the World Heritage List.

Conclusion

The World Heritage List contains sites that express values that correspond to or border on the values expressed by Rjukan – Notodden's attributes. The overall picture is that these inscribed sites are outstanding examples of typological elements included in the proposed nomination of Rjukan – Notodden, while they also typically represent development phases and/or contexts that clearly differ from Rjukan and Notodden. The combination of values expressed by Rjukan – Notodden does not seem to be represented on the World Heritage List.

Comparison with other industrial sites in Norway

Compared with other Western European countries, Norway was industrialised slowly and at a late stage. The first industrial revolution mainly resulted in cellulose and paper factories located by the many river systems with waterfalls that were manageable enough to be used to operate the machinery. With the second industrial revolution, however, Norway became an important arena for the establishment of new, electro-based industries. A number of new industrial communities were established, typically along the fjords of Western Norway with their short, steep valleys from the high mountains down to ice-free harbours. When man discovered how to use the energy resource of the waterfalls, energy-intensive industries were established, for which raw materials were shipped from abroad, such as coke, chalk and metals, to be converted through electro-based processes.

Odda industrial town with the Smelteverk to the right. There has been three, and still are two, industrial complexes located around the inner end of Sørfjorden, all harnessing the nearby waterfalls. Photo: Turid Årsheim, Riksantikvaren.

Odda and Tyssedal by the Sørfjord in the Hardanger region are examples of such industrial communities, and *they are submitted on Norway's tentative list* for nomination to the World Heritage List. The idea was to include Odda – Tyssedal as part of a serial nomination with Rjukan – Notodden based on hydroelectric power and the processing industry for artificial fertilizer. In this perspective, the towns share values relating to the utilisation of river systems with high and powerful waterfalls fed from catchment areas on the Hardangervidda mountain plateau; the river Måna with Rjukanfossen and the river Tysso with the Tyssestrengene and Skjeggedalsfossen. Another thing they have in common is the fact that the industrial product that was manufactured through the use of electric power had properties as an artificial fertilizer. A serial inscription of the towns would mean that all three of the methods for the production of artificial fertilizer would be represented. A future serial nomination with Odda and Tyssedal would have to await local decisions and clarifications concerning the scope of protection and the use of structures and properties for new functions. The decision process and its results will be of vital importance for the values of the site with regard to its integrity and authenticity. A lack of support in the local community precludes a nomination of Odda and Tyssedal for the time being.

The nomination of Rjukan – Notodden has a completely independent basis. This can be seen in light of certain fundamental differences in the sites' backgrounds. For example, the development of the waterfalls follows different patterns. Although Sam Eyde was involved in both areas, his involvement was purely speculative in Hardanger, in the sense that the power plant was not intended to be part of a self-initiated industrialisation. The power would be used by carbide and cyanamide factories that British capitalists would build in Odda, seven kilometres away from the power plant in Tyssedal. It was foreign companies that set up the industrial facilities and equipment that they brought along from their home countries, and they located the facilities near Norwegian waterfalls that would provide cheap power through development. The technological innovation behind calcium cyanamide as a product cannot be ascribed to Norwegian developments, as is the case with Rjukan – Notodden (UNESCO's criterion (ii)). Carbide as an end product belongs to a transitional phase between earlier industry and the second industrial revolution. Carbide is formed at high temperatures in a reaction between coke and limestone. It was first made in coal-fired furnaces and mainly used for lighting before electricity and incandescent lamps were available for the purpose, for applications such as mine galleries, street lighting etc., using carbide's reaction with water to create acetylene gas. At the start of the 20th century, electrotechnical advances provided access to stable supplies of high-voltage electricity and triggered the invention of new processes to utilise this energy. The development started in the USA with electric furnaces for carbide and aluminium. In the course of a few years, calcium carbide became an element in the production of calcium cyanamide, a substance that was used in one of the processes for manufacturing artificial fertilizer. The cyanamide process was developed and patented in 1903 by the Germans Adolph Frank and Nikodem Caro, at the same time as Birkeland/Eyde's electric arc process. Both processes were technological innovations in response to a pressing need in the Western world. In other words, two alternative processes existed at the same time, and Norway was an attractive country in which to establish businesses once hydroelectric power became available. Full-scale cyanamide factories were first set up in Italy and Germany (1905), and from 1908 at the smelting plant in Odda. As it spread to many smelting plants around the world, the cyanamide variant became a major commodity. Nitrogen was extracted using both the electric arc process (Birkeland/Eyde) and the Frank-Caro process in electric furnaces as two parallel ways of making artificial fertilizer, until the ammonia process (Haber-Bosch) took over as the third and most efficient method about 20 years later.

Like Rjukan – Notodden, the Odda – Tyssedal area is part of the industrial breakthrough in Norway. However, developments here were not organised in the form of a master project under the control of a single entity, as in the case of Rjukan – Notodden. The party responsible for developing the power was a company whose only purpose was the resale of power. The carbide plant and the cyanamide factory were initially two different companies. A British company (Sun Gas Co) was behind the carbide plant (1906). Coke was imported from England and limestone from domestic quarries to the ice-free port in Odda. Rjukan and Notodden did not need any imported raw materials. The British-owned North Western Cyanamide Company built the cyanamide factory, which had the biggest production capacity of what were known as the eight first-generation cyanamide factories in the world (1909). The global depression in the 1920s led to the bankruptcy of both companies. In 1924, operations were resumed by a merged company, Odda Smelteverk, one of the founders of which was the Tyssefaldene power company.

In the industrial-history context, Odda Smelteverk represents important values. A number of buildings and industrial machinery from the post-1924 era have been preserved at both the carbide plant and the cyanamide factory. This does not include the earliest furnace types, however. The lime kilns at the plant have been demolished. The newest of the three carbide furnaces remains. It is a three-phase electric reduction furnace from 1979–1982 that is said to have been the biggest of its kind, and building the furnace represents technological pioneering work. However, this took place far later than the period in focus in the nomination. Of special interest are 325 Frank-Caro furnaces that represent the furnace technology the way it had developed in the 1930s. These furnaces are not energy-in-

Odda Smelteverk with the carbide Oven 3 to the right, the only remaining furnace from the Cyanamid factory. The Dicyanamid part of the works in the center. Photo: Harald Hognerud.

tensive in the same way as the lime kilns earlier in the production line. However, it is rare in the international context to find electrochemical production equipment of such age in intact condition and *in situ* in a large industrial hall.

Technological innovation of international importance took place at Odda Smelteverk as well, but not as a basic premise for the establishment, as it was in Rjukan and Notodden. In 1928, smelting-plant employee and chemist Erling Johnson patented the Odda process for the production of artificial fertilizer based on the dissolution of rock phosphorous in nitric acid. A dedicated test facility was constructed at the smelting plant, and a number of new inventions related to the process were developed until 1930. The process was not used in the production at Odda Smelteverk, however. Norsk Hydro entered into negotiations to license the process and requested that the licence right be transferred abroad, which the Odda management could not accept. At the same time, systematic work took place in Hydro's laboratory in Rjukan to circumvent Johnson's patents. In 1931, Hydro applied for a patent on a similar process that involved adding ammonia nitrate. At first, Hydro's patent application was granted, but the decision was reversed in 1935 following a complaint from Odda Smelteverk, and Hydro was denied a patent. Hydro nonetheless started producing compound fertilizer without a licence at the factories on Herøya in 1936–1938. In 1945, Hydro was faced with a summons for patent infringement by Odda Smelteverk and Erling Johnson. The parties reached a settlement and entered into a collaboration agreement that enabled the parties to use each other's patents and experience with compound fertilizer. Hydro's compound fertilizer factory then started using the unmodified Odda process. In 1955, Erling Johnson received Norsk Hydro's special award for his work on the Odda process. The Odda process was licensed

Some of the buildings and constructions at Odda Smelteverk are in question for listing as cultural heritage and clarification for reuse, among them the Smithy (left), the cableway and the Oven 3. Photo: Harald Hognerud.

The more than 300 ovens of the Frank-Caro type in the Cyanamide factory are a unique feature at the Odda Smelteverk. Photo: Trond Taugbøl.

to companies in several countries and is currently used by Yara in Norway, among other companies. In order to be qualified under criterion (ii), it is essential to determine whether the smelting plant contains physical evidence of the Odda process that is of sufficient integrity and authenticity.

Tysso I power plant (1906-1918) in Tyssedal is a magnificent example of an early high pressure hydroelectric construction scheme. Photo: Lubowidski (left), Trond Taugbøl (right).

The Tysso I power plant in Tyssedal is an important hydroelectric power plant that includes Ringedalsdammen dam, the rock tunnel to the distribution reservoir at Lilletopp approximately 400 metres above the power station, and the penstock down the steep mountainside. It is slightly more recent than Hydro's power plants in Telemark, but was nonetheless a technologically pioneering plant, since it was the first high-pressure plant in Northern Europe. While two hydroelectric power plants utilised the total fall of Rjukanfossen, a single plant operated in Tyssedal, where one high, steep fall could compensate for a lesser water flow. The power plant was therefore given its remarkable location by the fjord, which made the transport of generators and equipment simpler than in Telemark, where a special railway track had to be built. The Tysso I power plant was designed by the architects Victor Nordan and Thorvald Astrup; the latter was also hired by Hydro in Rjukan. It is in a more classical Italian style than the power plants in Rjukan. Aesthetically, Tysso I is a successful plant, but as an expression of industrial architecture, it is not as powerful as the Hydro plants in Telemark. The power plant's appeal is as much due to its location in spectacular surroundings, which highlights the audacity of the facility.

The granite dam Ringedalsdammen raising lake Ringedalsvatn up to 464 m.a.s.l. is part of the Tysso I power plant scheme. Photo: Birger Lindstad.

The granite dam for the Ringedalsvatnet reservoir still serves its purpose. At 521 metres in length and with a height of 33 metres, it is large for a Norwegian mountain facility from the early phase (built in 1910–1918). Regulating dams in Rjukan and Notodden are only partially intact (the Møsvatn Dam). In the Rjukan and Notodden area, a granite dam of the corresponding type is represented by the well-designed intake dam by Skardfoss for Vemork Power Plant. Like the old

Møsvatn Dam, it has been replaced by a newer dam further downstream and is therefore no longer in use.

An aluminium smelter had been built by the fjord in Tyssedal in 1916. This led to the erection of workers' houses inspired by the garden city movement. The number and structure are not sufficient to form a company town. In their style and quality, however, several buildings are of significant value. Odda also has workers' houses and public buildings of importance. It cannot be characterised as a company town, as the design and development cannot be linked to a single dominant company or individual. Nor do the buildings make up a coherent environment that bears witness to architectural and town planning ideals from the establishment phase, the way they do in Rjukan in particular.

Tyssedal is a tiny industrial village itself, with electro metallurgic work, school, and workers homes in a garden city layout, adjacent to the hydroelectric power plant. Photo: Trond Taugbøl.

Odda – Tyssedal can potentially complement Rjukan – Notodden as testimonies of the development of industry in Norway in the 20th century, under criterion (iv). In part, Odda – Tyssedal contains a parallel combination of values. However, Rjukan – Notodden is a more outstanding example of completely unique characteristics of the breakthrough of the second industrial revolution. Because of the link to self-developed technology and organisational and financial collaboration across national boundaries, the Rjukan – Notodden area is more specific in that it can also be considered in relation to criterion (ii). At the same time, Rjukan and Notodden comprise objects and topics that provide more breadth, in that infrastructure for transport and the company towns are also conspicuously integrated in the site as a complete project.

Herøya near Porsgrunn was Hydro's biggest plant. The peninsula at the mouth of the Telemarksvassdraget watercourse was acquired as early as in 1912. When Hydro, in the late 1920s, decided to close down its electric arc furnaces of the Birkeland-Eyde type and switch to the ammonia method, new ammonia plants were built in Notodden and Rjukan based on the Haber-Bosch method. Ammonia became the basis for the production of the nitric acid that the company needed to dissolve limestone for the production of calcium nitrate. At the same time, Hydro decided to build a completely new production plant for calcium nitrate at Herøya. The location was very favourable with options for both sea and overland transport. The extensive construction work in Telemark was completed in 1929, which also was the year the plants at Herøya were put into operation. Herøya had the world's biggest calcium nitrate factory, and the plants quickly became Hydro's biggest and most important production site.

The Herøya factories (Eidanger Salpeterfabrikker) were not fitted out to include ammonia production. The ammonia Eidanger needed was produced in Notodden and Rjukan, and transported to Herøya by railway and barge. From 1934, all the ammonia that was produced at Notodden was sent to Herøya, and from 1949, Herøya also received ammonia from Hydro's factory in Glomfjord in Northern Norway. Transport by tankers was carried out by Hydro's own shipping company.

The first stage of the process at Herøya was the combustion plant in the nitric acid factory, where the ammonia was mixed with air and burnt at around 800 degrees Celsius in the presence of a platinum catalyst. This caused instant formation of nitrous gas (NOx), which was percolated with water in tall absorption towers to form nitric acid (HNO_3), used in turn to dissolve the limestone. At the same time as the factories at Herøya started production in 1929, Hydro established new limestone mines at Kjørholt near Brevik. The stone was transported from the mines to the factory's dissolution plant, where it was dissolved in the nitric acid from the nitric acid factory. The solution was then cleaned, refined, evaporated and prilled to form the finished product.

Hydro built a factory based on the ammonia synthesis process (Haber-Bosch) at Herøya. The area soon developed to the biggest industrial site in Norway. Today Yara continues Hydro's production of artificial fertilizer here. Photo: Norsk Hydro.

The top of one absorption tower is placed as a memory of the altogether 71 that were in place at Herøya between 1929 and 1982. Their height was 30 meters, weighing 26.000 tons and containing 13.000 granite blocks. Photo: Trond Taugbøl.

Herøya was chosen as the location for the calcium nitrate factory based on a good fresh water supply, good harbour conditions, good opportunities for arranging electricity transmission and establishing railway lines, and its proximity to Hydro's own limestone quarry. In a massive landscaping project, the peninsula was flattened and filled to form a coherent industrial area of 1.8 km^2 with 3 000 employees. After repeatedly expanding the capacity and product range under the name Porsgrunn Fabrikker, production reached a peak in 1960, when Hydro had 6 500 employees at Herøya.

The production facilities were bombed during World War II. In 1940, the German occupyers had decided to build aluminium and magnesium plants at Herøya. In 1943, when the facilities were about 70% completed, the whole site was bombed by American planes. The aluminium and magnesium plants were destroyed. Fertilizer production was quickly rebuilt and resumed, while the magnesium plant was not rebuilt until after the war. The aluminium plant was then not reestablished, and some of the buildings were instead rebuilt in 1951 for the production of PVC.

In recent years, Hydro has gradually reduced its activities, which have been replaced by a wide range of new enterprises, especially in energy-intensive industries. The largest individual enterprise is still the fertilizer manufacturer Yara. As Norway's biggest industrial facility, Herøya represents the industrial phase that followed the pioneering plants in Rjukan – Notodden.

Only fragments remain of the railway to Herøya. Parts of the production line for artificial fertilizer have been preserved in the form of buildings. Transmitting power from the power stations in Notodden and Rjukan was too expensive in the early phase. The power and heat plant that used coal to produce electricity has been preserved. Herøya therefore represents other values than the power production in Rjukan-Notodden. The combustion plant for ammonia has been preserved and is still in operation. The building is in the same architectural style as the New Facilities in Rjukan, but it is partially enclosed by other buildings. Some old furnaces of the same type as the oldest ones are still in use. The absorption plant with outside towers has been demolished, but the site has been preserved as a partially open space. Only the building for evaporation reduction remains of the calcium nitrate factory. The first dissolution plant has been demolished. In excess of one million tonnes were shipped from the more than one kilometre-long quay each year. The warehouse for intermediate storage of the calcium nitrate before shipping remains, but it has been extended and altered. It was originally 225 metres long, with a floor space of 24 000 m^2 and room for 150 000 tonnes of calcium nitrate. The laboratory and office building remain, but they have been severely altered. The top of an acid tower and the remains of a cableway for transporting lime have been moved and placed as sculptures in the area. Granite blocks from the acid towers have been reused along the waterfront.

In 1940, Hydro also erected an Admini building and a director's residence at Herøya. Hydro was mainly a facilitator and not the developer of the housing around Herøya, which dates from the period after Rjukan – Notodden. Because of the proximity to the town of Porsgrunn, Hydro only had plans for limited housing development in this area, which is quite different from Rjukan in that respect. The need for housing grew, however, and Hydro bought up much of the land near the factories in order to provide housing for the workers. The architect Sverre Pedersen was engaged, and in 1929, he created the plan according to which the Herøya housing area was built. Around 300 houses were built between 1929 and 1937, by which year the population had increased to 2 500. A dedicated municipal school was in place in 1932. After the bombing during the war, the employees were offered favourable loans to build their own homes in the area. Many houses were erected based on house type drawings from Hydro. Today, the area is dominated by post-war houses. The area represents a different period and other values than those that are reflected in the housing areas in Rjukan and Notodden. Herøya has certain features in common with Rjukan in that calcium nitrate was produced using the ammonia method, but it cannot demonstrate the same values and the same breadth as Rjukan-Notodden.

Several industrial communities were established in the first decades of the 20^{th} century along Norwegian fjords where waterfall energy could be exploited. They are connected to either the electrochemical or electro-metallurgic smelting industries. The distinction between the two types of electro-based industry should be maintained, as Rjukan – Notodden's values are explicitly related to electrochemical innovations and the production of artificial fertilizer. However, places that developed around the establishment of the electro-metallurgic industry can also comprise parallel values with regard to elements such as hydroelectric power production and town communities.

Glomfjord under the Svartisen glacier in Nordland county has a power plant that was started at a private initiative in 1912. In 1918, the State bought the plant's first building phase, with an output of 60 MW. Two generator units and an overground pipeline were completed in 1920. A third generator unit and second pipe were completed in 1922. The three final generator units and a third turbine pipe were put into operation in 1949 and 1950, increasing the plant's output to 120 MW. Together with subsequent additional regulations, this increased the average annual production to approximately 860 GWh. The plant by the fjord exploits the 461-metre fall from Nedre Navervatn lake, which receives water from Storglomvatnet lake in a transfer tunnel. Glomfjord power plant supplied power at a 25 Hz frequency, compared with the normal 50 Hz, because it best suited Norsk Hydro's factory. One of the generator units was converted into 50 Hz and put into operation from May 1994. The 25 Hz production was discontinued on 25 November 1993 when Svartisen power plant with its intake from Storglomvatnet lake started up. The average production capacity at Glomfjord power plant was thereby reduced from 860 to 85 GWh. Only one of the original power plant's six generator units is now used; a Pelton turbine with a horizontal axle that generates 20 MW. Glomfjord power plant is state owned by Statkraft.

The power was originally used for a zinc plant, but it had to discontinue operations as early as 1921 due to falling prices on the global market. British and German interests came in and started up aluminium production in Haugvik at Glomfjord in 1927, based on imported aluminium oxide. The aluminium plant was taken over by the Alliance Aluminium Compagnie trust in 1932. During the occupation, the Germans began an expansion of the plant to try to increase the production of aluminium for the German arms industry. In September 1942, Allied saboteurs blew up the turbine pipes and two of the generator units. After the war (1947), the State made an agreement with Norsk Hydro that Hydro would take over all the power, except the quantity that was to be supplied to the State as a compulsory quota of power. Based on this agreement, Norsk Hydro set up ammonia production in Haugvik in Glomfjord. Production reached over 60 000 tonnes of liquid ammonia a year. Part of this was used on site for the production of compound fertilizer and calcium nitrate. The rest was sent to the Eidanger calcium nitrate plant at Herøya in the company's tankers. The hydrogen plant in Glomfjord produced approximately 16 500 tonnes of hydrogen per hour. The hydrogen electrolysers were of the same type as at Såheim II in Rjukan. Capable of converting approximately 81 000 kW from alternating current into direct current, the rectifier plant was one of the biggest in Scandinavia. The compound fertilizer plant that was started up in autumn 1955 had a capacity of more than 140 000 tonnes of product per year.

In the larger perspective, Glomfjord was established through intermittent phases of development through much the 20th century. With the exception of transport, Glomfjord is made up of the same components as Rjukan – Notodden. These components are spread out both geographically and timewise, however, and are thus less representative of the early 20th century's industrial breakthrough. The elements that made up the industrial component were of a more fleeting nature involving different parties and represents a later phase than Rjukan – Notodden.

Høyanger in Sogn is an industrial community based on the establishment of an aluminium smelter in 1917. It is based on the investments in the electro-metallurgic industry that followed the second industrial revolution, and that in Norway's case was based on the use of hydroelectric energy for an energy-intensive processing or melting down of ore from sources overseas (for example from iron or bauxite mines), which was then shipped to the global market as a semi-finished product. The idea was originally to start steel production, which was changed to aluminium because of World War I. This background is sufficient to conclude that the place represents values related to universality that are different than Rjukan – Notodden. There are nonetheless significant architectural values in Høyanger, and historical connections to Rjukan and Notodden can be argued. Engineer Sigurd Kloumann, who had been one of Sam Eyde's close colleagues during the development of Hydro's calcium nitrate plants in Telemark, became an industrial entrepreneur after breaking ties with Eyde. He got involved in Høyanger and used the architects Morgenstierne and Eide, who also received assignments from Hydro in Rjukan. The architects prepared a zoning plan for a spacious garden town consisting of 'Own Homes' houses. The location of public buildings was decided jointly with the local authorities. Wooden houses in the Neo-classicist style with a certain regional colouring dominate the place, although gradually some brick houses were added. The Sing-Sing quadrant was a direct parallel to the block of flats with the same name in Rjukan. With its systematic, plan-based development, Høyanger was perceived as a Norwegian 'ideal town' in the early 1940s. Since then, significant parts of the distinctive workers' town have been demolished.

The town of **Sauda** in Rogaland county became the site of a manganese alloy plant, established in 1915 and in production from 1923. The plant belonged to the US company Electric Furnace Products Company, later Union Carbide Corporation. The plant was supplied with electric power from a company it owned itself, AS Saudefaldene, which developed the Saudavassdraget watercourse as part of the process of establishing the smelting plant. Sigurd Kloumann, who started out in Sam Eyde's company Hydro and got involved in Høyanger, managed the power company. Sauda comprises recognised significant values in power production and urban communities. Compared with Rjukan – Notodden, however, it falls into the same category as Odda and Høyanger, and it cannot be seen as a more outstanding example than Rjukan – Notodden of industrial cultural heritage linked to the second industrial revolution.

Other urban industrial communities that were established near hydroelectric power plants and energy-intensive smelting plants in Norway are either considerably smaller and/or came some decades after Rjukan and Notodden. This is why Ålvik, Svelgen, Sunndalsøra and Årdal are not being considered for a nomination. The sites' combination of values corresponding to those of Rjukan – Notodden is expressed by attributes of lower authenticity and integrity as representations of the early 20th century.

The port of **Kirkenes,** to which iron ore from mines in the inland was transported by railway, was established in 1906, but the nature of the activities and the absence of the hydroelectric power component mean that it represents a different category than Rjukan – Notodden.

Conclusion

Rjukan and Notodden's completeness and significance as pioneers in the international context are unsurpassed by any of the other industrial communities in Norway.

Comparison with industrial communities in other countries

United Kingdom

The UK's tentative list does not contain nominations for any additional examples of the industrial revolution in the sense of sites that demonstrate a combination of the essential values of the phenomenon. The Forth Bridge in Scotland is an outstanding example of iron structures made possible by engineering feats and new steel production processes towards the end of the 19th century. The Forth Bridge is an individual structure from that period.

Kinlochleven in the Scottish Highlands is a place with clear parallels to Rjukan – Notodden. Here, hydroelectric power development took place at the same time as Hydro was developing Svelgfoss. Sam Eyde turned to his British contacts to learn more about this project by attending the 7th international Congress of Applied Chemistry in London in 1909. The power development was related to the establishment of an aluminium plant, which was something Eyde also considered for the development of Rjukanfossen. A large gravity dam was built in 1907 in rough mountain terrain approximately 6 kilometres from and 300 metres higher up than the factory. Engineers Patrick and Charles Meik built a six-kilometre-long aqueduct and penstock as an element of the power plant. The solution is regarded as the last significant example of the British tradition of 'navigational engineering', which for many years had formed the basis for designing canals and railway lines. Compared with Rjukan – Notodden, the use of tunnels there can be noted as a more genuine expression of 20th-century engineering.

Kinlochleven has got some components that calls for a comparison with Rjukan-Notodden, but only the hydroelectric power plant with penstock from the Blackwater Dam and also the former company town still exist. There is an empty space where the industrial buildings used to be. Photo: Wikipedia.commons.

Kinlochleven lies at the end of a navigable fjord arm, in a relatively remote location where two local communities (Kinlochmore and Kinlochbeg) were turned into a company town with housing for the plant's 700 employees. The village of Kinlochleven became a pioneer by being the first in Scotland to provide mains electricity to all its houses. Bauxite was shipped in from mines in Ireland. Production at Kinlochleven Aluminium Smelter closed down in 2000 when the furnaces had become outdated and its size was no longer competitive. The factory buildings were then demolished. The production was transferred to North British Aluminium Company's **Lochaber** smelter at Fort William, approximately 20 kilometres further north. This plant had been constructed in 1929 and connected to Lochaber hydroelectric power plant, and it is still in use. The company's first facility was established in 1895 by Loch Ness in the Caledonian Canal, where the **Fall of Foyers** was used to supply electric power to an aluminium smelter. It was closed down in 1967, and the power station is now part of a system using a pumped storage power plant that efficiently uses the energy in a water reservoir.

In Kinlochleven, the power plant and penstock can be regarded as testimonies of the early British electro-metallurgic industry. The village is now a tourist destination mainly used for outdoor pursuits. (Ice climbing are among the attractions, the same as in Rjukan.) Kinlochleven may be regarded as the most representative British example of electro-metallurgic industrial development at the start of the 20th century. A more detailed study of the site with regard to integrity and authenticity will be necessary if a serial expansion of Rjukan – Notodden is to be considered. The site's values nonetheless seem to be more relevant in a context where other Norwegian industrial communities of an equivalent type are considered.

Germany

Germany's tentative list contains proposals that share characteristics with Rjukan – Notodden in certain thematic aspects.

Speicherstadt in Hamburg is an example of how new planning ideals were used as a basis when older baroque housing was replaced by a complete, new residential area in accordance with new principles between 1883 and 1928. However, the example cannot be related to new towns connected to resource development in remote areas. Nonetheless, company towns that were built in the early 20th century were modelled on workers' houses built by German industrialists and corporations from the late 19th and early 20th century. In the Ruhrgebiet district in Germany, urban communities emerged alongside large industrial enterprises, especially in the coal mining and iron industries.

There are several German examples of *arbeitersiedlungen* or company districts based on the garden city concept. In Eastern Germany, **Gartenstadt Hellerau** (garden city) is now a part of Dresden. The housing area was established in 1909 around Karl Schmidt's carpentry factory. Hellerau is regarded as the first German garden city designed according to Howard's garden city concept, with terraced houses and curved streets that follow the line of the terrain. The area was designed and planned by Richard Riederschmid. The public buildings and the associated villa area were designed by the architects Tessenow and Muthesius. The idea was to create a socially homogeneous settlement where different social classes could live together in green surroundings at affordable prices, in contrast to the workers' districts that were emerging in other parts of the city. The area consists of 345 buildings of 34 different house types, which were the first standard houses in Germany with variations in stairs, windows and doors. With this typification of elements, the houses could be manufactured at a reasonable price without losing the artistic design. The whole area is listed as a conservation area in Saxony.

Gartenstadt Welheim was built in the period 1914–1923 near the mine that was established, and it is one of the largest garden city districts in the Ruhr area. Welheim is famous for its architecture and town plan with generous green spaces. The area is perceived as uniform and homogeneous, but it consists of 40 different house types and around 1 240 two-storey houses. The houses are loosely organised along tree-lined avenues and green spaces. Grand façades disguise the fact that the flats were usually no bigger than 35 m^2.

What the German examples have in common is that they are company towns or *arbeitersiedlungen* designed and paid for by industrial enterprises. In Hellerau, the houses were even owned by the company. They were built in underdeveloped places with access to a desirable natural resource. By creating good living conditions and a good quality of life for the workers, the housing communities were intended to strengthen their ties to the factory. Green spaces, gardens, common areas and a social infrastructure resulted in a stable, efficient workforce. Architects were hired to design the communities with qualities in both design and materials, and standards like water and electricity were introduced. The German examples provide an important background for Rjukan and Notodden, not least because Sam Eyde with his educational background, work experience and connections in Germany brought German examples and experience to Telemark when he established Rjukan and Notodden. However, the examples are not part of a complete planned project with several components based on new industrial processes.

On the industrial side, the enormous factories, such as those of BASF, with all the industrial equipment for the chemical production of nitrogen fertilizer, no longer exist. At the BASF facility in Oppau, established in 1913, the Haber-Bosch method was tested for the first time. This production facility was completely destroyed during an explosion in 1921. The incident was the biggest disaster in German industrial history. The factories of the industrial conglomerate IG Farben, of which BASF was a part, became vital to Nazi Germany's economy. Nitrogen compounds for explosives, gas, synthetic rubber etc. were strategically important products for the German armed forces. BASF's factories at its headquarters in Ludwigshafen and at Oppau were primary targets during World War II. The destruction was so complete that production ceased towards the end of 1944. Consequently, there are no known facilities in Germany that represent Otto Schönherr's electric arc process or the Haber-Bosch process for ammonia synthesis with original equipment.

Of the hydroelectric power plants in Germany that can be compared with Rjukan – Notodden, **Altes Kraftwerk Rheinfelden** would have been first in line. It was a river power plant in the Rhine where the river forms the border with Switzerland, and it is therefore located in both countries. As a river power plant in a wide river with a low fall, it is clearly different to the hydroelectric power plants in Telemark. The power plant was nonetheless important as a technological pioneering plant in electrotechnology, and it represented the transition from the small power plants that marked the start of the age of electricity to the big stations. A standard frequency of 50 Hz was made the norm here. The plant was built in 1895–1898, which means that the start of an electricity supply for general consumption in Europe can be traced back to here. A transmission grid, in which Rheinfelden was central, was established in the early 20th century, and it was the first to have transmission lines to several countries.

Rheinfelden Altes Kraftwerk in the river Upper Rhine. The power plant as it used to be until 2010 (left), under demolition, March 2011 (right). Photo: Wikipedia Commons.

Altes Kraftwerk Rheinfelden has now been replaced by a new river power plant. The old power station building, the steel walkway and the gatekeeper's house were demolished in 2011, despite the status of the facility as an important historical and building-technological monument in the state of Baden-Württemberg. The old station had to give way to the new. This was necessary in order to be able to establish a fish ladder past the power plant, to compensate for the encroachment on nature. Supported by Icomos and TICCIH, activists in both countries campaigned to get Altes Kraftwerk Rheinfelden on the tentative list for nomination to the UNESCO list. Protests against the demolition did not succeed. In July 2012, the exhibition pavilion ***Kraftwerk 1898*** was opened near the site of the former power plant. It displays generator unit no 10 alongside a number of showcases and three viewing platforms along the banks of the river Rhine.

Together with the power plant in **Lauffen**, Rheinfelden was a direct follow-up of the Berliner Elektricitäts-Werke (1884), as a spearhead in the electrification of Germany. Lauffen was where electric power was transmitted successfully over a long distance for the first time, in 1891, from a generator set connected to a cement factory beside the river Neckar over a distance of 175 kilometres to Frankfurt. Using three-phase alternating current and 15 kV high voltage, the energy loss was 25%. The power plant in Lauffen was demolished in the 1930s.

Sweden

There are no 20th-century towns formed around the establishment of electro-based industry in Sweden. This statement is based on **Kiruna** falling into a different category than Rjukan – Notodden, which is easy to conclude because Kiruna is a town connected solely to mining. There are nonetheless certain interesting parallels worth mentioning. These are related to the concurrent establishment of urban communities in remote and scarcely-populated areas, with the railway as a port connection. Iron ore mining in one of the world's biggest ore bodies started in the late 19th century, when a new technique for making steel from the phosphorous-rich ore made it of commercial interest to start mining the deposits, which had been known since 1660. Large-scale production started up, with the Swedish state as one of the parties involved. The operations take place in a complex of mines with associated towns and sites, including railway lines to ports at Bothnian Bay (Luleå) and in Norway, where Narvik was established as an ice-free port. The complex of sites consisting of Kiruna, Malmberget, Svappavaara etc. represent values that have more in common with the industrial landscape of Nord-Pas de Calais Mining Basin in France and industrial landscapes in Belgium.

There are some important hydroelectric power plants in Sweden. Swedish watercourses have waterfalls with modest drops compared with Norwegian rivers and lakes. Swedish watercourses can be seen as more typical in the European context, while Norwegian watercourses are atypical, even in relation to the Alps and similar mountain ranges that lack a high-lying peneplain with large natural water reservoirs. Nor were Swedish waterfalls the subject of speculative purchases, as was the case in Norway, where Swedish capitalist owners took part in the game until the nation state gained control through concession legislation. Norwegian watercourses could be owned and sold by private individuals, unlike in Sweden and the European continent, where the watercourses were usually public property. In Sweden, it was the Swedish state that developed the hydroelectric power. The company ASEA, in which Eyde's partner Wallenberg had holdings, produced electrotechnical equipment.

Olidan at Trollhättan in the Göta river was the Swedish state's first hydroelectric power project and the first big hydroelectric power project in Sweden. The plant started up in 1906, and the eight generator units started operating between 1910 and 1914. An expansion with a further five generator units was completed in 1921, after Vänern lake could be regulated. The head is 32 metres. The architect for the magnificent power plant in hewn Swedish granite was Erik Josephson.

Porjus power plant, with a big dam and a head of 56 metres in Stora Luleälv river, was built in the period 1910–1915 as the result of an ambitious government policy to stimulate industrial investment. One important object was the electrification of the railway from the mining town of Kiruna to the shipping port of Narvik in Norway. The plant was made bigger than required, in the hope that it would contribute to the industrialisation of the Norrbotten area. In the 1970s, a new power plant was built, which is now the third largest in Sweden. The old power station building is a museum about the history of Swedish power stations. The power plant contains a generator set that represents almost the whole of the 20th century. The transformer station, designed by Erik Josephson, has been declared a monument to 20th century industrialisation. The development of these Swedish hydroelectric power plants took place in a different context than in Rjukan – Notodden, with an active state as the driving force but without being integrated in a concurrent industrial project.

France

France's tentative list does not contain any proposals that represent combinations of values corresponding to Rjukan – Notodden. The **Le Chemin de fer de Cerdagne** railway touches on certain thematic aspects. The line was built in 1903–1911, i.e. at the same time as the Rjukan Line. Like the Rjukan Line, it is a pioneer in its country as an electrified railway line, and it was powered by electricity from a hydroelectric power plant in the Pyrenees. However, the line is a narrow gauge railway, and its role as a technically advanced project is equally related to viaducts of reinforced concrete in a mountain landscape. As a transport structure, it is not connected to an industrial enterprise.

In **Soulom** in the Hautes-Pyrénées department, Hydro undertook to build a factory based on an agreement with the French war ministry. The factory was equipped with Birkeland/Eyde furnaces and started operating sometime in 1916. Production was aimed at supplying the French explosives industry with ammonium nitrate and nitric acid. A corresponding switch to production essential to the war effort took place at the plants in Telemark. The factory started with energy leased from a hydroelectric power plant that the French state-owned railways had built by the river Gave de Luz in the area. When it proved impossible to utilise the whole capacity of the plant's six one-phase generator units for the intended purpose of railway operations, excess power could be used to supply the planned nitrate plant. The power plant that Hydro built under the management of Norwegian engineers was not completed until after the war. When the war ended, the Allied governments acknowledged Hydro for services rendered by a neutral company, although the majority of its owners were French. The power plant and factory were sold as early as 1925, and the Birkeland/Eyde furnaces were transferred to Norway. The furnace house and tower house for the absorption towers have been demolished. The status of the power plant is unclear. Soulum existed as a village before Hydro's establishment. The population changed little between 1911 and 1926; it was 457 in 1911, 464 in 1921 and 541 in 1926. Soulom is not considered to be a company town.

France has several examples of company towns, mainly belonging to earlier phases of the industrialisation and associated with paternalistic industrialists. Of them, **Salins-les-Bains & Royal Saltworks of Arc-et-Senans** (Claude Nicolas Ledoux), inscribed on the World Heritage List (1982, 2009), is an example of an 18th-century ideal town where the ideas of the Age of Enlightenment were reflected in the architecture. The site comprises a complex of semi-circular shapes, which led to a rational, hierarchic organisation of the work. As Louis Bergeron pointed out, there is a typological distinction between such early company towns and the generation to which Rjukan and Notodden belong. Bergeron's other remarks on French company towns point out that the houses tend to be of mediocre quality, and he places this feature in a context of cultural background and tradition.

Italy

Italy's tentative list contains a proposal of **Ivrea** as a 20th-century industrial town. This town was built in the period between 1930 and 1960, however, and is associated with Adriano Olivetti's socio-cultural industrial project. The intention is a serial nomination of sites that show examples of design that differ from previous national and international experiments, represented by Crespi d'Adda as the inspiration, or sites that had developed as part of larger conurbations. The Ivrea proposal focuses on architecture and town planning, regulation of urban growth in controlled forms with division into functional zones and environmental quality as the basis for social processes. Both the period and the industrial and technological context differ from Rjukan – Notodden.

There is a range of early hydroelectric power plants in the Adda watercourse close to Crespi d'Adda. Among them is Taccani that opened in 1906. Like the other hydroelectric power plants in this tributary to river Po, it was constructed to supply the nearby city of Milano, and never was an integrated part of an industrial project.
Photo: Skyscrapercity.com (left), luna.e-cremona.it (right).

Near Milan in Italy, in tributaries to the river Po, there are power plants from the early 20th century that represent significant architectural and technical values. The oldest is a small plant from 1895 at Paderno d'Adda that produced direct current according to Edison's system. The plant is situated by the river Adda approximately 13 kilometres upstream of Crespi d'Adda. The river power plant **Ludovico il Moro** opened in 1904 with five turbines, designed by the architect Moretti. A new plant with a greater capacity was built in 1994. The old building has been preserved and it contains some original equipment, such as two Francis turbines and a control panel. In 2003, the rest of the turbines were replaced by new ones. The station has a 15-kilometre-long transfer canal with intake system along the Ticino river, by Vigevano near Pavia. The **Taccani** power plant opened in 1906 with 10 generator units and a total output of 10 000 kW. It is also a river power plant on the Adda river, at Trezzo near Milan, designed by the architect Moretti. The power plant has been modernised. In 1914, Edison's company was behind the **Esterle** power plant, and in 1920 the **Semenza** power plant by Calusca d'Adda with a dam two kilometres from Trezzo. Architecturally and in size and type, these river power plants have more in common with the Tinfos company's Tinfos II power plant from 1912 in Notodden than Hydro's big plants in Rjukan. It is very interesting to look at Tinfos II in light of the North-Italian power stations. The rivers in the Italian Alps, with their greater heads, were developed from 1908 onwards. The **Malnisio** power plant in Friuli Venezia Giulia at the foot of the mountains dates back to that year.

Switzerland and Austria

The two countries' tentative lists do not contain proposals for sites that represent combinations of values corresponding to Rjukan – Notodden. The river systems in the Alpine mountain region make it natural to search for hydroelectric power plants from the breakthrough period in the first decades of the 20th century, and any associated processing industries in places where sources of power suitable for development were the location factor. This phenomenon belongs to the second industrial revolution in the early 20th century and is one of the characteristics of the period. Older power plants are not relevant as they would be too small and built for other purposes than heavy industry, for example electricity for lighting. Switzerland has a share in Rheinfelden, an early high-voltage installation previously described under Germany.

The Alps have many rivers with steep courses. The flow rate of the rivers typically varies with the seasons, being at their lowest in spring. They do not have natural water reservoirs in the form of lakes. If rivers are to be used for power development, regulating reservoirs must be constructed by damming up the valleys with high dams. Most of the watercourses in the Alps have undergone such interventions, so that very few are in a natural state (less than 10%). In the 1890s, the watercourses started to be developed for energy-intensive industry, aluminium smelting and electrochemistry. The industrialisation in Switzerland had started earlier, based on the country's handicraft traditions, cf. the watchmaker towns of **La Chaux-de-Fonds/Le Locle** in the Jura Mountains, which were inscribed on the World Heritage List in 2009 as examples of early 19th-century town planning. There are certain parallels between these towns and Rjukan and Notodden in that they are associated with mono-industrial activities. Like Rjukan, they were used as examples in economic analysis (Karl Marx in Das Kapital), but at that time it was because of the capitalist organisation of their production facilities during an earlier industrial phase.

Towns or company towns like Rjukan and Notodden do not seem to have been built for the electro-based processing industry, nor were transport systems built to reach remote sites because the Alpine valleys were usually inhabited.

Transport in mountainous areas nonetheless entails challenges that have features in common with Norway. For example, both Switzerland and Austria have examples of outstanding engineering feats of railway construction that are inscribed on the World Heritage List; namely the **Rhaetian Railway** in the Albula/Bernina landscapes, inscribed in 2008 transnationally with Italy, and the **Semmering Railway** in Austria, inscribed in

2000. The Rhaetian Railway opened in 1904. As a World Heritage Site, focus is on the line's tunnels, viaducts and bridges, with architecture and engineering feats in a harmonious relationship with the landscape. The traffic was largely aimed at tourism. The Semmering Railway was built between 1848 and 1854 and it represents the same type of values, but relating to older technological and architectural solutions to the challenges. Electrification of the railway lines in the Alpine countries accelerated after World War I. The Swiss Federal Railways (SBB) built several hydroelectric power plants, by the Gotthard Railway in Ritom (1920) and **Amsteg** (1922). Here, a branch line was used during the facility's construction. A new underground power plant was opened at Amsteg in 1998 in when the new Gotthard Base Tunnel was built. The majestic old plant is now not in use, but some equipment has been preserved inside.

Technically speaking, hydroelectric power plants that utilise medium to high drops, i.e. between 40 and 500 metres, in smaller rivers, will have turbines of the Francis type. This turbine type was invented in 1849. For extreme drops that provide a high pressure even at small amounts of water, Pelton turbines, invented in 1879, will be suitable. Large rivers with a modest head often use Bulb turbines for the biggest water flows and lowest head, and Kaplan turbines in river power plants with heads varying from 10 to 60 metres. The latter turbine type was invented as late as 1922, and came after the problems associated with energy losses caused by the transmission of power over large distances had been resolved. Consequently, plants using the first of those turbine types will be comparable with Rjukan – Notodden.

Together with AEG in Germany and ASEA in Sweden, the Swiss machine manufacturer Oerlikon built and supplied equipment to European pioneering plants. Switzerland and Austria also led the way in developments later in the 20th century, by building hydroelectric power plants with extreme heads. In Austria, such plants were constructed between 1950 and 1961 at **Kaprun** and **Reisseck**, the latter consisting of a series of power plants and systems of pipes and tunnels exploiting heads of up to 1 772 metres. The tallest in the world is currently **Bieudron** in Switzerland, where three Pelton turbines with an output of 423 MW each exploit a head of 1 883 metres. Production started in 1998. Norway also took part in this development. For example, the Norwegian-built 350 MW Pelton turbines were the biggest in the world in 1980, when the Sima plant with a head of 885 metres opened.

The Czech Republic

The Czech Republic's tentative list includes the **industrial complexes at Ostrava**. The complexes are unique in the international context in that a single area contains all the important elements of heavy industry the way it developed to a fully mature level in the first phase of the industrial revolution. The area includes coal mines, coking plants and furnaces, which provide a complete representation of the technology that was used in anthracite-based production of iron. At the same time, the industrial heritage is an integral part of the centre of a larger urban structure that in the course of the 19th and 20th centuries developed out of an older stagnated town and its surrounding villages. The combination of efficient infrastructure consisting of, among other things, railway lines, also formed the basis for the development of metallurgic and chemical industries and electric power plants. From the late 19th century, the town's development was followed by progressive urban concepts and welfare programmes, directly linked to the industrial development. Some facilities contain buildings from the turn of the 20th century. Some have original electric machinery from the pioneering period until the 1990s. Due to their size, the industrial plants dominate the city visually and have become its symbol. Ostrava is significant from a historical, technological and architectural perspective as one of the most important sites in Europe for coal mines and heavy industry. It thereby represents values different to those that Rjukan – Notodden can contribute to the picture of European industrial history.

Canada

Canada's tentative list does not contain any proposals that represent combinations of values corresponding to Rjukan – Notodden. Nor does a search through the list of National Historic Sites administered by Parks Canada result in findings of such sites, but some sites have common thematic characteristics with Rjukan – Notodden. Several objects can be linked to the industrial revolution, most typically a number of canal systems from the 19th century, of which the Rideau Canal was inscribed on the World Heritage List in 2007. In Sault Sainte Marie, the first electrically powered locks opened between 1888 and 1894. The passage of railway lines through the Rocky Mountains from the 1880s to 1915 is represented; they were however not electrified. At Forges du Saint-Maurice in Quebec lie the ruins of Canada's first iron industry, which started in the late 17th century, where the first Canadian industrial town developed in the 18th and 19th century. The products were shipped to France.

Canada has an important role in hydroelectric power production and electro-metallurgic industry from a global perspective. **Niagara Falls**, which Canada share with the USA, were the starting point for the electro-based processing industry that was established in both countries in the early 20th century in this area. The waterway between Lake Ontario and Lake Erie was developed from the 1820s through the Welland Canal on the Canadian side. The canal and the pertaining water supply system were also constructed for the purpose of operating mills with direct power. Twelve Mile Creek and the dammed Lake Gibson are part of this. The first hydroelectric power plant on the Canadian side was a small station from around 1892 for the Niagara Parks River Railway, which transported tourists around the area on electric trams. When the tram line was replaced by the Niagara Parkway for car traffic in 1932, the plant was closed down.

As early as the 1880s, the **DeCew Falls** in the Welland river, which were considerable smaller than Niagara, became the subject of studies with a view to power development and transfer to the town of Hamilton, 56 kilometres away, prior to any form of standardised electricity supply. The power plant, which was developed in 1898, then supplied alternating current with a frequency of 66 ⅔ Hz. When the plant was taken over by Ontario Hydro in 1930, it was converted into 60 Hz. DeCew I is the oldest plant in operation at Niagara today. Unlike Hydro's plants in Rjukan and Notodden, the development was not associated with a specific industrial purpose. During the war in 1939–1945, Canada initiated measures to contribute to the production of war material on the Allied side, which included rapid development of hydroelectric power. In 1943, the bigger DeCew Falls 2 plant came into operation, in collaboration with the plants at Niagara.

Rankine Power was built in the period 1901–1905 by US company Canadian Niagara Power Company, as a river power plant approximately 400 metres above Horseshoe Falls. When it opened, the plant had two generator units. In 1924, all 24 were in place, with a total output of 76 MW (100 000 Hp). It supplied three-phase power at a frequency of 25 Hz to a number of small customers on both sides of the border, but in more recent times, its main client has been the steel industry in Hamilton. The 25 Hz system was taken over from the Adams Plant, which the American owners had built earlier. Operations were discontinued in 2009, and the supply of 25 Hz power thereby ended. The plant was built with solutions that in engineering terms were advanced for their time. Most importantly, the plant became a prototype for Nikolau Tesla's three-phase alternating current system. The water intake was designed to handle massive ice formation. Architectural features include cut natural stone and arched windows in the façades, like the slightly younger Vemork Power Plant in Rjukan. In both cases, the grand architecture helps to underline the status of electricity as a beneficial power. A transformer building associated with the station also remains intact. It is situated at some distance to prevent the overhead lines from encroaching on the park by the waterfalls.

Construction of the massive **Ontario Power Generating Station** under Horseshoe Falls in the Niagara River started in 1902 and was completed in 1905. The power station was the biggest in the world when it opened, and continued to be until Vemork was completed in 1911. The station produced alternating power at 25 Hz pursuant to what had then become a North American norm (see description under the Adams Station in the USA). Water was taken from upstream of Niagara Falls with the intake house just south of the Toronto plant, and then fed approximately 1.9 kilometres in two large underground steel pipes down to the station situated just below the waterfall, where it was distributed in pipes to the generator set. The interface section was connected via tanks that were designed to reduce pressure differences that could arise in the supply. Overflow pipes from the open tanks fed water back into the river. The power plant has been taken out of operation. Today, the building and one of the surge tanks remain. Architecturally, the plant bears a certain resemblance to Såheim in Rjukan with its solid structure. The plants in Rjukan pushed advances in tunnel system development further forward.

The **Toronto Power Generating Station** was completed in 1906 as the first Canadian owned plant at Niagara Falls, just after and upstream of Rankine Power. The station was built to supply electricity for the big city of Toronto approximately 140 kilometres away. It produced 75 MW two-phase alternating current at a frequency of 25 Hz. The problem associated with transferring power over long distances was solved by transforming it up to 60 kV (cf. description under the Adams Station in the USA). Water was supplied through a penstock from a retention dam extending 224 metres into the Niagara River. The outlet was through a tunnel leading to below and behind Horseshoe Falls. The station with 11 turbines was taken out of production in 1973. The building is intact.

Some kilometres downstream of Ontario Power lies the **Sir Adam Beck** hydroelectric power plant, consisting of two large power stations, the oldest of which has been in production since 1922, with 10 generator units. The original name was Queenstown Chippawa, and the station was fed water through a 14-kilometre-long headrace canal of this name from the Welland Canal. After the first development phase, the authorities declared that water rights and new power plants were to be publicly owned. Adam Beck was a politician working for the development of hydroelectric power plants in Ontario, represented by the state-owned Ontario Hydro Company, the first publicly owned power company in the world. The system of Canadian hydroelectric power plants on the Niagara River is in the process of being restructured. Sir Adam Beck 2 with 16 generator units was built in 1954 and fed from two tunnels each nine kilometres in length. The reservoir and pump station were added later. The station is being upgraded and a new 10-kilometre-long tunnel directly from the Niagara River to the power plant complex will make it the central facility in a system that utilises the total energy of the river more efficiently.

The line of large power plant buildings for the closed Canadian stations is comparable with Rjukan – Notodden as representatives of important hydroelectric power plants. Unlike Rjukan and Notodden, they are not integrated as part of an industrial context or connected to company towns.

In Quebec, an electro-metallurgical industry based on hydroelectric power was established at an early stage. **Shawinigan Falls** by the St. Maurice River attracted the attention of investors. Shawinigan bears testimony to the breakthrough of the second industrial revolution, in an ensemble that displays remarkable common characteristics with Rjukan – Notodden. The 44-metre-high waterfalls are situated inland, approximately 30 km from the St. Lawrence River, where the watercourse that drains large parts of Quebec's wilderness drops from the plateau formed by the Canadian Shield. Around 1860, hotels were built near the waterfall to accommodate tourists from the big cities and the USA, wooden buildings that have been lost in fires. The area was otherwise scarcely populated before it was developed for industry, and logging was the dominant livelihood. Timber floating took place on the St. Maurice River from 1850 to 1995, and a timber flume that no longer exists went past the waterfalls at Shawinigan with their 'Devil's Hole'. In 1897, the waterfall and adjacent land were bought by Shawinigan Water & Power Co (SWP), a company set up by US entrepreneurs with US and Canadian capital. The work of damming up the river, digging a canal and building the gate house and the Shawinigan I power station

Shawinigan in Quebec, where the generator floor and water outlets remain from the Shawinigan I power plant, besides the power house building of Northern Aluminum Co (left) that is now part of a theme park on electricity. Photo: Trond Taugbøl.

In Shawinigan the ruin of Alcan 16 power plant that was demolished in 1946 shows concrete structures for leading the water to and through the turbines, as part of the theme park. Photo: Trond Taugbøl.

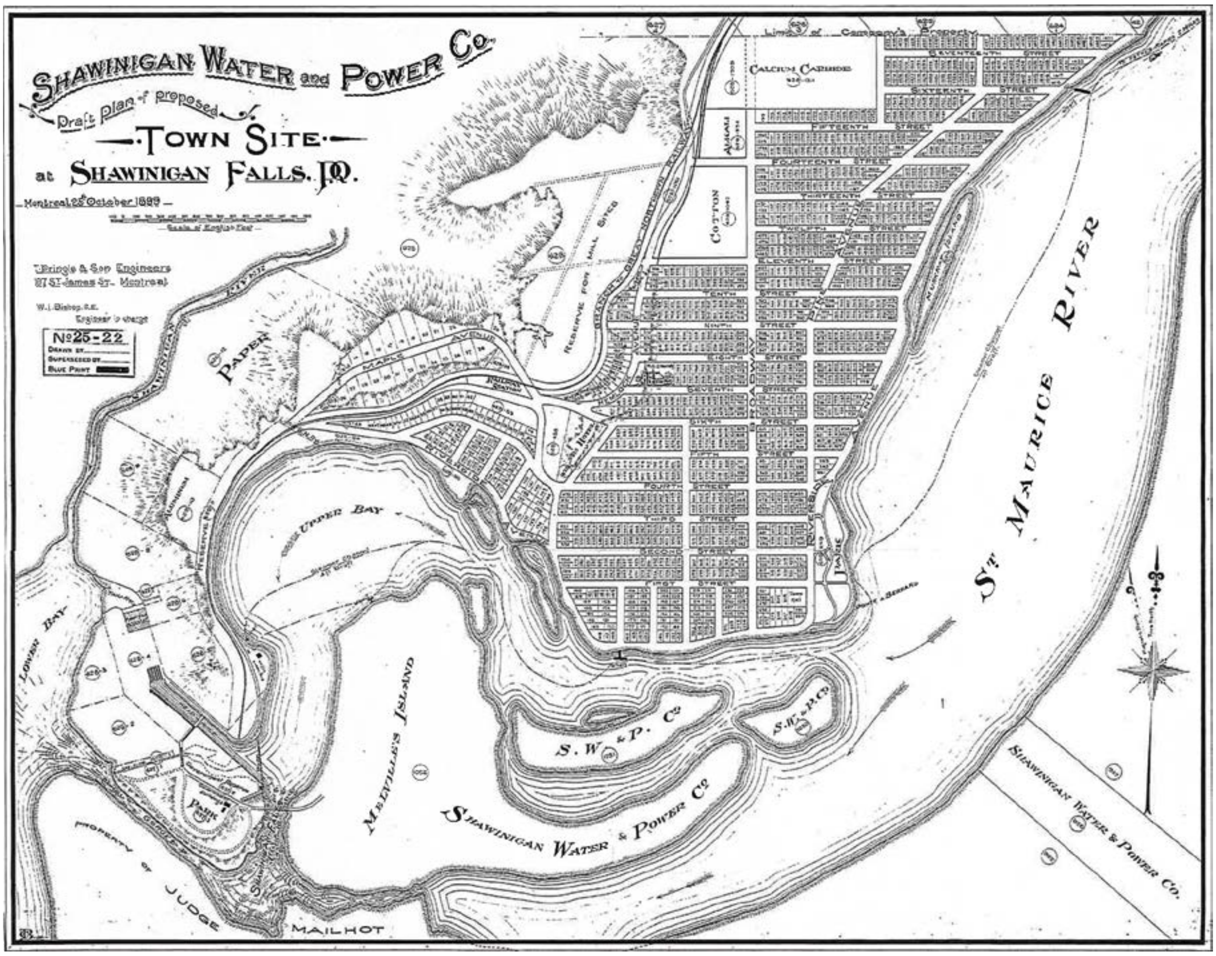
started in 1899 under the leadership of US engineers with experience from the hydroelectric power development at Niagara. The station opened in 1901 with two turbines, and another four were added during the next eight years. For some years from 1903, the station supplied electricity to Montreal 137 km away (alternating power with a voltage of 55 kV). It was closed down and demolished in 1946. All that remains today is the foundation wall with the openings for discharging the spent water. Where the generator floor used to be is a tarmacked car park. Next to the power station stands the contemporaneous power station that was built by and for Northern Aluminum Co (NAC). It was also closed down in 1946, when Alcan, which had owned it since 1916, started up a new aluminium plant north of the city. That plant will be closed down in 2013. The buildings that made up NAC's aluminium plant – the first in Canada – have been preserved just upstream of the waterfall. They have the status of a National Historic Monument. Together with the power station building, they are part of the exhibition and theme park *'La cité de l'énergie'*. None of the buildings contain industrial machinery that was previously used there. The aluminium plant buildings house an exhibition on fire prevention, and the power station building houses an exhibition on hydroelectric power and the processing industry. The power station displays the water intake from the penstock, and the transition from the original brick and natural stone to concrete can be observed as a building technical feature from the extension of the plant in 1906.

'La cité de l'énergie' was started in 1997 as a non-profit organisation. It disseminates information about technology and history together with the publicly owned power company Hydro Quebec, which, following the nationalisation of the private company Shawinigan Water & Power in 1963, now owns two of the current power stations: Shawinigan II and III. Shawinigan II was built in 1910–1911 to meet the growing need for electric power. When it opened, the station had two 11 kW-generators with horizontal shafts, which at the time were deemed to be the biggest in America. In 1913 and 1914, first one and then two more generator units were added, which involved extending the power station towards the south. From 1922 to 1929, the building was further extended, this time to make room for three new units with vertical shafts. All these units are still producing today. With an output of 200 MW, this is one of very few power stations operating with generator units with both horizontal and vertical shafts. It is open to the public through visits to 'La cité de l'énergie'.

Other energy-intensive production in the surrounding area included cellulose and silicon carbide (carborundum), a synthetic abrasive that has been mass-produced since it was discovered in 1890. Belgo Canadian Pulp & Paper Co was formed with Belgian capital and was in business between 1904 and 2008. Like the aluminium plant, the carbide factory from 1908 was the first of its kind in Canada. Textile industry was also established in the area. Very little remain of these facilities today. The various enterprises were severely affected by the depression in the 1930s. After a period of prosperity during and following the war in 1940–1945, they entered a new period of decline and there is now little industry left the area. At Grand-Mère, a twin town that was established in the 1920s some kilometres further up the St. Maurice River, stands the only paper mill that is still in operation. There is also a waterfall here with a power station.

There are two railway lines to/from Shawinigan, owned by two different railway companies. The first railway that was built in the area predates the industrial establishment and did not reach Shawinigan until 1907. The railways served the local industries, but were not constructed as a necessary, integral part of the industrial operations. Downstream of Shawinigan, the St. Maurice River was navigable by ship, and the machinery for the power development was transported by river.

Planning for the housing area began in 1899, by the engineering company T Pringle & Son in Montreal, and the company town gained town status in 1902. The town plan was a classical 19^{th}-century grid plan, with streets numbered from 1 to 11 and intersected by avenues, including Broadway, with reference to the founders' hometown of New York. The street grid could not be followed to the letter, as it was not adapted to the local topography. Today, few or no houses remain from the original town development around 1900, when SWP Co made plots within the grid layout available to the workers. They were given one year to erect a two-storey house, or the company would reclaim the plot. Some two-storey brick buildings from the latter half of the 1920s line the streets. The social distinctions between the workers, who were French-speaking, and the engineers and directors, who were English-speaking, is decipherable in the villas along the Maple Road/Rue des Erables, situated on a hill west of down-town Shawinigan. In connection with the major restructuring that took place in the 1940s, when the aluminium plant was moved to a new location and the oldest power stations were demolished and replaced by the new Shawinigan III, times were good and the city built a big new town hall of a design reminiscent of New York.



A company town was raised on land that was owned by Shawinigan Water and Power Company, with streets in a classic grid and plots where the families had to build their homes. Shawinigan is not an obvious example of the breakthrough of modern society within fields of city planning and welfare to the same degree as Rjukan-Notodden. The town has never reached the figured extent.

Although the distance between the different components is small, they are not readily seen or understood to be part of a functional whole as they are in Rjukan – Notodden. In 'La cité de l'énergie, a pylon has been re-erected that formed part of the aerial cable span across the St. Lawrence River. The 115-metre tall mast has a viewing platform at the top that provides views of the area. The different components were not established by one big company as part of an integrated development like they were in Rjukan – Notodden.

In conclusion, Shawinigan, in a concentrated area, bears witness to significant activities within heavy industry, and to the utilisation of hydroelectric power from an early stage. The Rjukan and Notodden area is nonetheless a more striking example of the interests and events that worked together to create the second industrial revolution in the Western world, by the way it was organised and financed in one overall project. The topography in Rjukan – Notodden gives the components a more compact and readily decipherable setting. The company town component in Rjukan – Notodden is particularly more representative of the urban and industrial innovations of the 20th century.

Further north in Quebec lies the town of **Arvida**, which was established by the company Alcoa in 1927 for aluminium production. This company town was planned as a model town. Electricity was supplied by several big power stations in the Saguenay River, the first of which was Isle Maligne from 1925. The site represents a later phase of the 20th-century industrialisation than Rjukan – Notodden.

In **Shalalth** in British Columbia, the Bridge River was developed for hydroelectric power production in the 1920s. Shalalth was then built as a model town associated with the power plant, which was completed in 1962. There was no electro-based heavy industry here. Situated by the Pacific Great Eastern Railway, the village became a centre of communication during the gold rush in the area. Having prospered in the hectic periods, the place has now dwindled into quietude.

A general feature of company towns that applies to North America in particular is that they become ghost towns when the industrial activity that created them ceases. This is most typical of mining communities, which tend to be isolated because of large distances and wilderness areas. Building dedicated urban communities has been necessary for companies that wish to engage in resource development in underdeveloped areas, while distances and natural conditions have often prevented settlement and development.

The USA

The USA's tentative list does not contain any proposals that represent combinations of values corresponding to Rjukan – Notodden. The country has places of major significance to Rjukan –Notodden as examples of the breakthrough of industry based on hydroelectric power. Reference is made in particular to the description of the pioneering plants at Niagara in Chapter 2.b page 254-255.

The **Adams Station** power plant at **Niagara** was the world's first big hydroelectric power plant. Utilising the enormous power of Niagara Falls for industrial purposes had been the subject of several speculative projects throughout the 19th century. They revolved around various ways of converting the energy mechanically, for example by using canals and shafts for controlled distribution of the water, and by using axles, belts, cables etc., or an hydraulic tunnel to create water pressure or compressed air. Before electricity was perceived as a realistic opportunity (after 1890), Niagara Falls was primarily a tourist attraction, like Rjukanfossen. Both waterfalls were illuminated for the purposes of tourism with power from small, local power stations. The Adams Station was built before the full potential of electric power had been discovered, and it was intended primarily to meet the needs of the local chemical industry and industrial engine power. When the turbines were installed, it had not been decided whether to use them for the production of electric power or for pneumatic power (compressed air). For that reason, and because alternating current had not yet become the applicable standard, a frequency of 25 Hz was chosen. The turbines were designed to operate at 250 rotations per minute, which was more suitable for pneumatic compressors than electric generators. When electricity production became a viable option, generators were chosen that could make use of the slow-moving turbines that had already been installed. The generators were then given 12 poles that produced power at 25 Hz. The fact that it made electric lamps flicker was considered a minor problem, as lighting and general power distribution were still seen as secondary needs.

To the left: Adams Power Plant with Powerhouse 3 in the foreground, the only preserved part of the plant. To the right: Powerhouse 3 of Adams Power Plant as it appears today, serving no use. Photos: Library of Congress.

The changeover from Edison's direct current to alternating current in North America started in the town of Buffalo in 1892, one year after Germany. Long-distance transmission became a reality in 1895 when George Westinghouse gave Nikolau Tesla the task of installing the first power station at Niagara Falls. At the same time, Niagara Falls Power Company was formed, under the expectation that industrial complexes would be developed in the area, which included the town of Buffalo. From 1896, the power plant produced more than 15 000 hp, but not all the power generated by the plant could be used in the area, as most machinery had a maximum capacity of approximately 100 hp. The company planned to use 200 000 hp, but this technological leap required greater financial resources than were available. With the help of transformers and overhead lines for two-phase 11 kV voltage, Buffalo was connected to the first commercial network of transported electricity in 1896. This meant that new industry could be set up in the area. The Americans built the Rankine power plant on the Canadian side to exploit more of the river's forces. By then, technological defects in switchgear and lightning arresters at the Adams Station had been eliminated. These improvements are probably the reason for the lightning arrester house at Svælgfos I *(object 2.1).*

At the power plant in 1902, Charles S Bradley and D Ross Lovejoy and the company Atmospheric Products Co started an industrial trial of electric arc furnaces to fix nitrogen from the air. The furnaces they constructed were supplied with direct current from the Adams Station, which was able to supply considerable amounts of power at a reasonable price. The technology was not mature enough, and the trials were abandoned in 1904. The battle in the USA between Thomas Edison and his company, which promoted direct current, and Nikolau Tesla and George Westinghouse, who were advocates of alternating current, was then finally decided in favour of alternating current. This was essential if power was to be distributed over long distances, because alternating current enabled voltage in the transfer system to be raised and lowered using transformers, which reduced the power losses that occurs during transfer. Alternating current can be transformed into high voltage, which results in less power loss, and then back again for distribution to end users after being transported. Tesla and Westinghouse were behind the Adams Station. The station was named after the businessman who was president of the Niagara Falls Power Company. The power plant was closed down in 1961, and the water was redirected to the Robert Moses station.

The Adams Station consisted of several machinery houses, of which only machinery house no 3 remains, known as the Adams Powerhouse, which is listed as a National Landmark for its historical significance as the place where the electrification of the world began.

Tesla's three-phase alternating current system was chosen as the international standard at an experts' meeting held in London. This led to greater efficiency and safety in the distribution of electric power, and a huge expansion of the power distribution. The USA chose a different path than Europe, when it opted for two-phase alternating current at 25 Hz frequency, as described above. The European norm was three-phase current at 50 Hz frequency. Westinghouse endorsed the 60 Hz system, which eventually became an alternative North-American standard.

On the American side, Niagara Falls is now exploited by the **Robert Moses Niagara** power station, which was built in 1961. An earlier station, Schoellkopf, broke down in 1956. The station, with 13 generator units, lies directly across from the Sir Adam Beck power plant on the Canadian side.

The American industrial company Alcoa, the Aluminum Company of America, set up an aluminium factory in the Tennessee Valley. Planning and acquisition of properties and rights started in 1910, and the smelter was in operation during World War I. Power was provided by developing the Little Tennessee River. The company was responsible for establishing **Alcoa, Tennessee** as a classic company town. The name was first used for the construction camp where the river power plant was built at Calderwood and moved to an area near the town of North Maryville, which the company had purchased, 35 kilometres from the power plant. Here, the smelter and a model town consisting of 150 houses were built from 1914 onward, based on plans developed by the company's engineers. The model town was designed with four parts, a division that ensured the segregation of Afro-American families in a separate part of town. Activities expanded with the demand for aluminium during World War I. In 1920, approximately 3 350 people lived in the town's 700 houses. The town was wholly dependent on the company and its varying success under economic fluctuations. During the Great Depression, the workers organised strikes, one of which resulted in two workers being killed and the intervention of the National Guard. During World War II, production increased by 600 %, another plant was added and the labour force grew to approximately 12 000. After the war, the town became less and less dependent on its parent company. The town was desegregated, and in the early 1950s, the company started to sell the houses to its employees. By the end of the decade, it had withdrawn from ownership of the town's houses and public buildings.

Between 1933 and 1942, Alcoa built a large hydroelectric power plant in the Columbia River by **Grand Coulee** Dam. The power station powered Alcoa Aluminum Works in Bellingham on the Pacific Coast, 270 kilometres away. The power plant is the biggest in the USA, and the dam is one of the biggest concrete structures in the world. In the Colorado River, the

Hoover Dam, originally called **Boulder** Dam, was constructed between 1931 and 1935 as a crisis measure during the Great Depression. The plant was designed to control floods, provide irrigation water and produce electric power for general power supply in Nevada, Arizona and California. Boulder City was built nearby for the workers on the plant.

Tennessee Coal, Iron and Railroad Company, which had started out with mines and railways in Tennessee, moved its activities to Alabama in the late 19th century and became the owner of several satellite towns around Birmingham. Of these, **Ensley** was founded in 1886 as a new industrial town near a coal deposit at some distance to the rapidly growing city of Birmingham. Ensley's street network and infrastructure were designed with a separate sewage and surface water system. The ironworks' activities ceased for a period in the 1890s due to an economic downturn, but operations resumed after 1898, and the company developed an open-hearth process of making steel. New workers' houses were built, and eventually also schools, churches and other public buildings. When the U.S. Steel Corporation became the owner of the company in 1907, it started planning a new, larger ironworks at **Fairfield,** eight kilometres west of Birmingham. Fairfield company town was founded in 1910 as a model town, planned by the company for the workers at the ironworks. The town was originally called Corey, after one of the directors of the U.S. Steel Corporation. The town hospital was a pioneer in industrial medicine. Today, the original model towns have merged with the city of Birmingham.

Japan

Japan's tentative list includes **Kyushu and Yamaguchi** as examples of the first modern industry outside the Western world. Japan had pursued an isolationist policy vis-à-vis the outside world until the country was forced by Western powers in 1854 to be more open. By importing technology, Japan then made rapid steps towards industrialisation. The nominated site comprises examples that manifest this development. It includes a group of four factories in an organically interconnected relationship. The site comprises coal mines and heavy industry such as shipyards, ironworks and steelworks, a railway connection to port facilities, as well as light industry such as a porcelain factory and brick works. It thereby also demonstrates a combination of traditional Japanese industry and Western technology, created by a combination of public and private capital. Kyushu and Yamaguchi is an outstanding example of modern industrial activities in the broad sense, but it represents values that are clearly different to those of Rjukan – Notodden. As a World Heritage Site, Kyushu and Yamaguchi exemplifies an approach to modern industry, where the core is a constellation that forms a thematic cluster of particularly important industrial heritage. Rjukan – Notodden consists of production plants and buildings that are related to various industrial activities, but that are functionally integrated in a single superior enterprise.

Mexico

The industrial complex of the textile factory **La Constancia Mexicana** and its residential area are inscribed on the country's tentative list. It is connected to a family-owned textile factory that was established in 1835, when new types of automatic machinery and a new architectural style were introduced to Latin-American industry, but the site also comprises significant developments from around the turn of the century, including factory and warehouse buildings and public buildings. In 1972, ownership of the factory was transferred to the workers. There are no direct parallels to Rjukan – Notodden.

South Africa

Pilgrim's Rest Reduction Works Industrial Heritage Site is inscribed on the country's tentative list. The site and village are connected to the first gold rush in Africa in the 1870s. In 1910–1911, the Belvedere hydroelectric power plant was constructed and a 30-kilometre-long power line built to supply the town of Pilgrim's Rest and the surrounding mines with electricity. The power plant was closed down in 1972.

Conclusion to comparative analysis

The investigations do not seem to result in findings of any sites that are more significant examples than Rjukan – Notodden of *the breakthrough of the second industrial revolution*, represented by a correspondingly unique combination of typical, intact values from this specific period. Rjukan – Notodden is a constellation of essential characteristics of the second industrial revolution, which, unlike other sites where corresponding values are found, also incorporates scientific and organisational aspects of this civilisational era. Rjukan – Notodden also includes a transport system that represented state-of-the-art technology in its field.

Inscription on the World Heritage List of sites that with their full breadth are capable of reflecting *the importance of electricity* specifically as a universal factor will, however, have to be seen in context with the hydroelectric power plants, transformer stations etc. in several of the countries mentioned in this analysis, of which preserved facilities in Canada seem to be of particular importance. In this context, it will be necessary to include individual facilities in Norway in a transnational series, if this should become relevant, including Hydro's power plants in Rjukan and Tysso in Hardanger with pertaining dams, tunnels and penstocks, and machinery equipment. With regard to the industrial aspect relating to ground-breaking electrochemical industry, a more detailed analysis is needed in several countries, including countries that are not discussed here and that may potentially have such examples on their territory. Russia will be among these, although the country has no industrial heritage sites of this type on its tentative list.

3.3 Proposed statement of outstanding universal value (OUV)

a) Brief Synthesis

The industrial towns of Rjukan and Notodden in Telemark county in Norway are outstanding examples of a ground-breaking industrial development and a testament to the social transformation that took place in the Western world at the beginning of the 20th century. This was a time when scientific and technological progress interlocked with economic and political factors and created what is known as 'the second industrial revolution'.

With its dramatic scenery and numerous waterfalls, Norway was an ideal location in which to establish the new type of energy-intensive industry. The industry project represents the transition from coal to hydroelectric power for industrial use, and thereby a gateway to the second industrial revolution in Northern Europe. At a time when the ways of transmitting power over great distances were limited, manufacturing facilities and local communities were set up where the power was. Building what was then the world's largest power stations in a remote valley under Northern Europe's biggest mountain plateau was an achievement in itself. The new industrial towns were built for the production of previously unknown products using newly developed methods, targeting an international market. That this development was achieved is due to domestic scientific achievements and an active entrepreneurship in close cooperation with foreign financial investors. Technologically and organisationally, the Rjukan and Notodden area is seen as a hub for developments that took place simultaneously and in interaction with several countries.

The two industrial towns were created as a direct response to the Western world's great demand for artificial fertilizer for agriculture. The aim was to supply the international community with a product that at the time was considered a necessity for the future of civilisation.

The transport system that had to be built to connect the factories and industrial town to the outside world and the global market is a further expression of the pioneering aspect of the industrial project in inland Norway. The system of two railway sections connected by train ferries across a lake is in itself unique. The electrified railway contributed to the breakthrough of an international standard for electric rail operations.

The whole ensemble of power stations, factories, transport systems and company towns was created by visionary, ambitious people, whose plans were achieved through hard work and the efforts of an extensive labour force under the organisational framework of a single company: *Norsk Hydro-Elektrisk Kvælstofaktieselskab (Norsk Hydro)*. Rjukan – Notodden is thereby an outstanding manifestation of how innovation, capital and man's creative power shaped a fundamental new reality in the early 20th century.

b) Justification for Criteria

Criterion (ii)

The industrial towns of Rjukan and Notodden were established as the result of an international industrialisation process in which the use of hydroelectric power for energy production had been sufficiently developed. Internationally, the growth of new industrial products and the range of technological inventions that were created within a limited period of time led to sweeping social changes. What made these events possible was the exchange of results from science and research across national borders, of capital in an international arena for investments, and the sale of goods in a global market.

Rjukan – Notodden is the result of the changes that took place, but the towns themselves have also contributed to these changes. The production of artificial fertilizer using the electric arc method was the invention of the Norwegian physicist Kristian Birkeland. Later, the Haber-Bosch method was used and further developed in Rjukan. Rjukan – Notodden was the scene of outstanding achievements that represent an important step forward for mankind in the areas of science and engineering.

Criterion (iv)

The era of the second industrial revolution started first in the Western world, where electric energy replaced coal as a source of energy in industry, creating new types of industries, products and places. Rjukan – Notodden is one physical result and expression of this development. The World Heritage includes four thematic components with associated World Heritage attributes for hydroelectric power, industry, transport and company towns. The whole ensemble of dams, tunnels and pipes to take water to the power stations, pipe trenches to the factories, the industrial areas and industrial equipment, the factory towns with houses and social institutions, railway lines and ferry service with navigational devices, was created against the background of a powerful natural environment. Together, they form an outstanding example of technological innovations and industrial landscapes created under historical conditions that were present during early 20th Century, and that characterises this limited period of time.

c) Statement of Integrity

Within the proposed limitation of the World Heritage Site, all important parts of the complex industry project will be preserved. As a whole, they document the story of Rjukan and Notodden as outstanding representatives of the second industrial revolution. The nomination area will be framed by a proposed buffer zone that ensures that the whole landscape around the nominated power stations, production plants, urban communities and transport facilities is protected. There are no factors that can pose a material threat to the World Heritage values in Rjukan and Notodden.

d) Statement of Authenticity

The World Heritage Site comprises environments and individual objects with a varying degree of authenticity. All the thematic components comprise a sufficient number of environments/objects with a high degree of authenticity, so that the area as a whole contains outstanding examples in the fields of technology, urban planning and architecture.

e) Requirements for protection and management

The World Heritage Site is sufficiently protected under the Norwegian Cultural Heritage Act for the most important individual objects, and the Norwegian Planning and Building Act for bigger, more complex areas. A management plan has been prepared for the World Heritage Site. All management levels have signed a declaration of intent for protection of the World Heritage values. A World Heritage Council with representatives of all management levels will coordinate the management and contribute to positive development and sustainable use of the World Heritage status.

4 STATE OF CONSERVATION AND FACTORS AFFECTING THE AREA

In Norway, a number of public bodies are responsible for collecting information about and inspecting the condition and level of threat in different areas of society. These bodies shall ensure that the condition and level of threat are in accordance with the statutes, regulations and adopted goals they are set to manage. These are discussed in more detail in Chapter 5c.

These bodies and public and private owners have supplied the material on which the assessments of condition and threats made in this document are based, and they will provide similar material in future. The Directorate for Cultural Heritage and Telemark County Authority have compiled and quantified the material together with Tinn and Notodden municipalities. At the local, regional and national level, there is awareness that the industrial towns of Notodden and Rjukan have unique cultural values and that they are the axis around which the story of the water that was transformed into electric power and used for industrial development on a global scale spins.

4a. Present state of conservation

The nominated area has thirteen attributes that together have outstanding universal value (OUV). Each of these industrial history attributes are related to one of the four thematic components: hydroelectric power, industry, transport system and company towns. Six attributes are related to hydroelectric power, three to industry, two to the transport system and two to company towns. The current condition of the attributes is deemed to be good overall. Ten attributes are considered to have a normal level of maintenance, while three are in need of moderate or extensive improvements. Of the 97 significant objects to which the attributes are associated, 23 % require moderate or major improvements.

Method

Norwegian Standard (NS) 3423 *'Condition survey of protected buildings and buildings with historical value'* has been used as the basis. This standard was taken into use in connection with registration of the condition of protected buildings in an extensive national project in 2007–2009, and it has since been used as the standard for monitoring and updating the condition of this type of objects. The standard has been followed by NS 16096:2012: 'Conservation of cultural property – Condition survey and report of built cultural heritage', which upheld the same condition classification system.

The standard stipulates the main elements to be included in a condition survey and sets out rules for how to register, assess, describe and document the condition of protected and historic buildings. The standard entails a general condition registration, consisting of visual observations, if necessary combined with simple measurements. The assignment of a condition class is based on an overall assessment and weighting of all relevant symptoms, i.e. indicators of an object's condition in relation to a given reference level. The reference level is based on technical condition and on the main heritage conservation principles for maintenance and preservation of objects that are protected and/or worthy of preservation. Each object must be assessed on its merits based on the heritage values that are emphasised. The main emphasis in the condition survey is on the technical condition, however. The aim of the survey is to identify the condition of the objects and to specify the need for necessary measures, which will form the basis for more detailed planning, further investigations and implementation. The description below will include work that is being planned, work in progress and work that has recently been completed.

The three following condition classes (CC 1–3) are used:

Condition class (CC) 1: In good condition. Minor symptoms. Ordinary maintenance needed – i.e. a condition requiring ordinary planned maintenance. By maintenance is meant measures necessary to sustain the building at a defined quality level in technical and heritage terms, and thus to use it for a given period. Examples: in good condition, paint is worn, moss on roof tiles and a few broken tiles.

Condition class (CC) 2: Moderately strong symptoms. Moderate improvements needed. Example: localised damage caused by minor wet rot infestation in panel boards, localised damage to building component requiring improvement and partial replacement.

Condition class (CC) 3: Major symptoms. Major improvements needed. Encompass breakdowns and complete functional failures. Examples: leaking roof with consequential damage, collapsed foundation walls, major damage caused by moisture, missing overhead line equipment.

The above standard is to be used in monitoring and as a basis for reporting. This is the currently established practice in connection with the administration's follow-up of protected buildings and facilities.

Description of condition

An overall survey of the attributes has been carried out following a discretionary weighting of the condition of components and objects. The condition of individual significant objects has also been assessed. The assessments were carried out in 2012. The results of the assessments break down as follows:

Condition class	Number of attributes	Number of significant objects
1	10	73
2	1	17
3	2	7

Component / ID no	Attribute	Condition
Hydroelectric power		
1	Tinfos power plants	CC 1
2	Hydro's power plants in the Tinnelva river	CC 1
3	Vemork Power Plant	CC 1
4	Såheim Power Plant	CC 1
5	Regulating dams	CC 1
6	Power transmission	CC 1

Component / ID no	Attribute	Condition
Industry		
7	Hydro Industrial Park in Notodden	CC 1
8	Hydro Industrial Park in Rjukan	CC 1
9	Production equipment	CC 3
Transport system		
10	The Tinnoset Line	CC 3
11	The Rjukan Line	CC 2
Company towns		
12	Notodden Hydro Town	CC 1
13	Rjukan Hydro Town	CC 1

Hydroelectric power

The attributes of the hydroelectric power component are generally in good condition. The level of maintenance is ordinary (CC 1). However, several of the significant objects are still in use for power production and are thus subject to a stringent management regime.

1. Tinfos power plants

Tinfos power plants as an attribute are considered to be in condition class 1 with ordinary maintenance needs. The various components of the attribute are in use, and the owner has ensured regular, good maintenance. Only minor, limited measures are needed. Maintenance and repairs/restoration are carried out in accordance with heritage conservation principles in collaboration between the owner and Telemark County Authority, assisted by the Norwegian Water Resources and Energy Directorate (NVE).

ID	Object	Condition	Measure
1.1	Tinfos I with Myrens Dam	CC 1	
1.2	Tinfos II and the Holta Canal	CC 1	2010: Work carried out on walls and flashings. The canal has been sealed/lined with stone/ concrete and repaired.

1.1 Tinfos I with Myrens Dam

Tinfos I with Myrens Dam is in good condition (CC 1). The assessment is based on the fact that it has not been used as a power plant since 1955. The power plant is of rendered brick on granite foundations with bare-brick ornamentation. The roofing is new. As a building, it has not been altered much, not even in connection with the transition from power plant to workshop in 1955. The building has a few cracks and the walls have some blemishes. There is some local moisture damage in one of the corners due to a malfunctioning downpipe. The penstock from Myrens Dam can be deciphered at both ends. There is some rust and vegetation problems, especially close to the power station building. As a dry intake dam, Myrens Dam is in good condition. It is used as an area for spare time activities. There are some problems with vegetation and surface cracking, however.

1.2 Tinfos II and the Holta Canal

Tinfos II and the Holta Canal are in good condition (CC 1). The facility is still in use as a power plant and is therefore maintained in accordance with applicable laws and regulations. The power plant is built of rendered brick with ornamentation in brick, granite and copper. The penstock consists of three riveted and one cast-iron pipe. Very few changes have been made to the building itself and its interior. The 2009 condition survey pointed to damage to the brickwork, joints and copper roofing in several places. That damage was repaired in 2010. Major maintenance work was carried out on the Holta Canal during the same year. Minor external damage to the concrete foundations is being monitored by the owner.

2. Hydro's power plants in the Tinnelva river

Of Hydro's power plants in the Tinnelva river, only one building still stands. The rest have been demolished and preserved as partly overgrown remnants of walls. The condition of the industrial heritage ruins has not been assessed, but clearing of vegetation could make them more visible. This attribute has therefore been assessed on the basis of its single significant object.

2.1 Svælgfos lightning arrester house

Svælgfos lightning arrester house and workshop are in good condition (CC 1). The building is constructed of concrete faced with natural stone and has a clay-tiled roof. The walls have some scratches and minor damage, and there is some rust on the iron glazing bars of the windows. As a whole, the building appears to be solid and in good condition, despite the fact that it is empty and not in use.

3. Vemork Power Plant

Vemork Power Plant as a whole is in good condition (CC 1), even though it no longer serves as a power plant. The facility is well maintained by the owner and user. Only one of five sections requires more than ordinary maintenance.

ID no	Object	Condition	Measure
3.1	Power station building	CC 1	
3.2	Penstock	CC 1	Vegetation clearance done in 2013
3.3	Penstock valve house	CC 1	Roof repaired 2012
3.4	Skarsfos Dam I with intake gate house	CC 2	
3.5	Tunnel system with six waste rock dumps	CC 1	

3.1 Power station building

Today, the power station building is home to a museum and is in good condition (CC 1). The building is of concrete faced with natural stone. The roofs have been repaired over the last couple of decades. Only one roof surface at the back has not been repaired yet, but it is still functional. The walls are in good condition, though there is some local vegetation. The windows have iron glazing bars and there is a growing rust problem in some places. The tower of the reserve power station building has been degraded to condition class CC 3 as a result of inadequate maintenance. The absence of gutters and downpipes has given rise to moisture damage and effervescence.

3.2 Penstock

The penstock is in good condition (CC 1). The owner is required to inspect the penstock annually and report on its condition to NVE. The penstock consists of robust, riveted iron pipes. They are surface-coated, but rust has developed in some parts. The pipes are particularly exposed to moisture and vegetation where they interface with concrete, but the exposed sections are still in good condition. The penstock is under threat of being overgrown, though vegetation clearance is carried out intermittently. Vegetation clearance was last done in 2013. The light poles and the steps up to the cable car have suffered local rot damage.

3.3 Penstock valve house

The penstock valve house is in good condition (CC 1), even though it has been out of use and left almost untouched since 1971. The building is constructed of concrete faced with natural stone. A solid concrete shell was added during World War II. The concrete has only suffered minor local effervescence and peeling in a few places. The condition of the reinforcement bars is unknown. There is some incipient rust in the iron glazing bars of the windows. Previous leakages were sealed when a new roof was laid in 2011 in collaboration with the heritage conservation authorities. There is no moisture or visible damage in the interior of the building. The eleven valves are in excellent condition.

3.4 Skarsfos Dam I with intake gate house

The Skarsfos Dam I and intake gate house are in need of moderate repairs (CC 2). Today, the full height of the natural stone wall that formed the dam is submerged upstream of the new dam. It has no leakage points and is in good condition. The intake gate house is in need of repairs, however. It is constructed of concrete faced with natural stone. It is being overgrown by vegetation and has malfunctioning gutters and downpipes, so that the walls have suffered moisture damage and effervescence. The walls are peeling. There is moss growth and cracking in the foundations.

3.5 Tunnel system with six rock dumps

The tunnel system and rock dumps are in good condition (CC 1). The waste rock has been left untouched and visible since it was dumped. The tunnel system is used in power production and is therefore subject to continuous monitoring and covered by a repair schedule.

4. Såheim Power Plant

The attribute Såheim Power Plant is in good condition (CC 1). The main part of the plant is still used for power production and it is therefore subject to applicable related rules on monitoring and condition. The owner has its own maintenance schedules in place. Major repair works were carried out in 2011 and 2012. Maintenance and repair/restoration work are carried out in accordance with heritage conservation principles in collaboration between the owner and Telemark County Authority.

ID	Object	Condition class	Measures
4.1	Power station building	CC 1	Repaired 2011–2012
4.2	Underground turbine generator hall	CC 1	Phased out and closed in 2011 – climate measure
4.3	Penstock	CC 1	Phased out 2011
4.4	Workshop	CC 1	
4.5	Tunnel system with seven waste rock dumps	CC 1	

4.1 Power station building

The power station building is in good condition (CC 1). The building has several functions, but it also houses a power plant. It is well maintained by the company that owns it, Hydro Energi. The building is constructed of concrete faced with natural stone. Condition registration of the power station building was carried out in 2008 as part of a nationwide project. It was assessed as being in CC 2 at the time. Damage was found to have been caused by water ingress from the roof and from interior downpipes in walls of the generator hall, and the windows had deteriorated. The damage was repaired by the owner in the course of 2011 and 2012 in collaboration with heritage conservation authorities, as applies to buildings protected under the Cultural Heritage Act. The windows with iron glazing bars were repaired and restored at the same time. Internal concrete expansion in the walls of the building is causing problems, but this is being monitored and kept under control by the owner. There are plans to repair the walls along the sides of the building in the course of 2013 and 2014.

Såheim power station building was under restoration in 2012. Photo: Eystein M. Andersen.

4.2 Underground turbine generator hall

The underground turbine generator hall is in good condition (CC 1). It was in use and underwent regular maintenance until the turn of the year 2010/2011. It has subsequently been closed down and shut in with all the equipment intact inside the cavern. The atmosphere is kept stable by means of dehumidification and heating. The paint is peeling on concrete surfaces, which show every sign of having been inadequately maintained during the final decades of the plant's operation. The rock portal for entry to the cave is partially overgrown.

4.3 Underground penstock

The penstock is in good condition (CC 1). The penstock comprises nine robust, riveted iron pipes. They were phased out in 1993 and 2011. They are located in a damp environment inside the rock, but are partially protected against direct exposure to moisture in that they are under cover.

4.4 Workshop building

The workshop is in good condition (CC 1). The building is constructed of concrete faced with natural stone. Like object 4.1, it is well maintained and in use.

4.5 Tunnel system with seven waste rock dumps

The tunnel system and rock dumps are in good condition (CC 1). The waste rock has been left untouched and visible since it was dumped. The tunnel system is used in power production and is therefore subject to continuous monitoring and covered by a repair schedule.

5. Regulating dams

The attribute regulating dams is in good condition (CC 1). The assessment is based on the single significant object to which the attribute is associated. The dam structure is subject to safety regulation and monitoring by the Norwegian Water Resources and Energy Directorate.

5.1 Old Møsvatn Dam

Old Møsvatn Dam is in good condition (CC 1). It is constructed of concrete faced with natural stone and was originally 25 metres high. In 2004, it was replaced by a new dam further downstream and demolished down to 15 metres. It was preserved as a retention dam for use in connection with technical inspections and as a cultural heritage monument. Old discharge gates of concrete and steel have also been preserved. The old dam is submerged in water. It appears to be robust. Nothing has been done to it since 2004.

6. Power transmission

The attribute power transmission is in good condition (CC 1). The various parts are well maintained, even though they have not retained their original function. The power transmission function of the various parts is still readily decipherable

ID	Object	Condition class	Measures
6.1	Cable House	CC 1	
6.2	Control room in Furnace House I (building no 242)	CC 1	
6.3	Transformer and distribution station (building no 273)	CC 1	
6.4	Power line 16/17	CC 1	Regular clearing of vegetation and inspection every five years.

6.1 Cable House

The Cable House is in good condition (CC 1). The interior was converted to office premises in the 1980s, and exterior maintenance has been carried out since then, including re-roofing. The building is constructed of rendered concrete. The surface has suffered some minor cracking and local moisture damage. There is some incipient rust on the iron glazing bars of the windows. The rack for receiving cables and the insulators are in good condition after being phased out, and there is no need for any major measures.

6.2 Control room in Furnace House I

The control room in Furnace House I (building no 242) is in good condition (CC 1). The control room is still in use as part of the distribution station and is therefore maintained in good condition. The room is not exposed to wear or heavy use. It has remained virtually unchanged since the year it was built.

6.3 Transformer and distribution station

The transformer and distribution station (building no 273) is in good condition (CC 1). It is a three-storey concrete building that appears to be robust and well preserved and maintained. The roof structure is of concrete with roof trusses and steel girders. The roof is covered in felt. The iron glazing bars of the windows have suffered minor corrosion damage. The exterior of the building was renovated in 2007. The ground floor of the building is still in use as a transformer and distribution station and must therefore meet the applicable requirements for such operations. The rest of the building is used for cold storage. The exterior remains unchanged, with the exception of a storage shed that has been added to the southern end wall.

6.4 Power line 16/17

Power line 16/17 is in good condition (CC 1). The line consists of a 1 418-metre long overground section with nine riveted steel pylons on concrete foundations, six conductors and one earth wire, porcelain insulators and a rack for receiving cables. The object was used for power transmission until the end of 2011, and was thus subject to regular maintenance and monitoring in accordance with the Norwegian Water Resources and Energy Directorate's rules and regulations until then. In autumn 2012, a separate inspection was carried out and a condition report was prepared, which included recommendations. The inspection showed the line to be in good condition overall, with only minor damage and little corrosion considering its age. Wear and tear on suspension bolts and brackets have not yet been inspected as this is difficult to do from ground level. One stay foundation needs to be repaired and some of the pylons' steel sections need corrosion protection. Another superficial inspection is scheduled to take place in five years' time and an thorough inspection in ten years from now, and vegetation clearance will be carried out regularly.

Industry

Two of the three attributes under the industrial component are in CC 1 and have ordinary maintenance needs. The production equipment attribute will remain in CC 3 for as long as the equipment is left outdoors, but simple measures will suffice to safeguard such equipment. Maintenance and repairs/restoration are carried out in accordance with heritage conservation principles in collaboration between the owner and Telemark County Authority.

7. Hydro Industrial Park in Notodden

The attribute Hydro Industrial Park in Notodden is on the whole in good condition (CC 1). Nine of fifteen objects are in CC 1, four are in need of moderate repairs and one is in need of major repairs. Repairs are being planned.

ID	Object	Condition class	Measures
7.1	Furnace House A (building no 60)	CC 2	
7.2	Tower House A (building no 70)	CC 2	Roof repaired 2012
7.3	Calcium Nitrate Plant (building no 105)	CC 1	
7.4	Packaging Factory (building no 140)	CC 1	
7.5	Warehouse A (building no 95)	CC 3	Repairs planned in 2014
7.6	Testing Plant and Furnace House C (building no 20)	CC 1	
7.7	Testing Plant and Electrical Workshop (building no 25)	CC 1	
7.8	Testing Plant and Blacksmith (building no 30)	CC 1	
7.9	Laboratory and Workshop (building no 80)	CC 2	
7.10	Hydrogen Plant (building no 55)	CC 1	
7.11	Nitrogen Plant and Gas Cleaning Plant (building no 115)	CC 1	
7.12	The Minaret (building no 135)	CC 1	
7.13	Compressor and Synthesis Plant (building no 130)	CC 2	
7.14	Nickeling Plant (building no 160)	CC 1	
7.15	Ammonia Water (ammonium hydroxide) Plant (building no 90)	CC 2	

7.1 Furnace House A (Building no 60)

Furnace House A is in need of moderate repairs and is thus in CC 2. The building is constructed of brick and has many blemishes, loose and damaged bricks and poor joints. There is some major damage locally and a risk that the moisture problems will increase. Heightening of the surrounding terrain and poor drainage have give rise to moisture and fungus problems in the cellar. The windows on the northern facade have been replaced by new windows with iron glazing bars. The original wood-framed windows on the southern facade are in need of maintenance. The roofing felt is of more recent date.

7.2 Tower House A (Building no 70)

Tower House A under restauration in 2012. Photo: Eystein M. Andersen.

Tower House A is in need of moderate repairs and is thus in CC 2. The building was constructed with very thin walls of reinforced concrete, which now have several holes and cracks, particularly in the upper part. The downpipes are poor in some places and rendered concrete sections are peeling. The windows are damaged by corrosion and some of them are coming loose. Doors and gates are in need of maintenance. All leakages have been stopped with the installation of new roofing felt and roof flashings in 2012. The structure should be examined more closely.

7.3 Calcium Nitrate Plant (Building no 105)

The Calcium Nitrate Plant is in good condition (CC 1). The building is constructed of rendered brick and concrete. It appears to be robust and in good condition. The plastering is subject to some minor peeling. The iron glazing bars of the windows are exposed to corrosion and some of the window panes are missing. The roof has been redone with felt, sheet metal roofing and new flashings.

7.4 Packaging Factory (Building no 140)

The Packaging Factory is in good condition (CC 1). The building complex is in good condition, but there are some moisture and corrosion problems relating to the windows. The impregnation factory is partially empty, and its surfaces suffer from inadequate maintenance. The former sack factory was upgraded technically to accommodate new users in 2012.

7.5 Warehouse A (Building no 95)

Warehouse A is in need of major repairs and is thus in CC 3. The building is constructed of rendered concrete with old sheet metal roofing of the lock-joint type. The roof structure with adjoined pitched roofs is exposed to water damage. The building is experiencing problems with leakages from the roof, and it needs re-roofing and new roof flashings. Due to movements in the ground, parts of the building are sinking, while the roof structure with its steel girders is left in place and comes loose from the underlying building. This gives rise to cracking, and loadbearing elements are in danger of coming loose. The walls on the southern façade have been retro-fitted with insulating boards. These boards are damaged and moist. The concrete is cracking and peeling. Downpipes and gutters are damaged and in need of replacement or repair. The owner is planning to repair the building in 2014.

7.6 Furnace House C (Building no 20)

Furnace House C is in good condition (CC 1). The building is constructed of brick and rendered concrete. It has new sheet metal roofing. There are some minor blemishes in the bricks and joints. The windows are exposed to corrosion and have poor fixings. Some moisture enters the building via the windows. The gutters are in need of maintenance.

7.7 Testing Plant and Electrical Workshop (Building no 25)

The Testing Plant and Electrical Workshop are in good condition (CC 1). The building is constructed of brick and rendered concrete. There are some minor blemishes in the brick and joints, and the plaster is peeling in places. The windows are in need of maintenance. The roof has newly been re-laid with metal sheets. The interior of the building has been refurbished several times and the building has been retro-fitted with insulation.

7.8 Testing Plant and Blacksmith (Building no 30)

The Testing Plant and Blacksmith are in good condition (CC 1). The building has brick veneer walls and a new sheet metal roof. There are some blemishes in the bricks and joints. There is local rot damage where the wall meets the ceiling and in the ground beam. The windows with iron glazing bars have recently been repaired.

7.9 Laboratory and Workshop (Building no 80)

The Laboratory and Workshop are in need of moderate repairs and are thus in CC 2. The building is constructed of reinforced steel-framed concrete, with a sheet metal roof and windows with iron glazing bars. It has suffered from moisture and leakage problems, the plaster is moist and peeling, and the windows and sheet metal roofing are damaged by corrosion. The acute leakages have been stopped, but the building has not otherwise been repaired.

7.10 Hydrogen Plant (Building no 55)

The Hydrogen Plant is in good condition (CC 1). The building is constructed of unrendered reinforced concrete and has tall windows with iron glazing bars. There is some cracking and peeling in the concrete, particularly under the eaves, and the windows are damaged by corrosion. Under the eaves, the reinforcement bars are visible in several places. The interior downpipes are in need of inspection.

7.11 Nitrogen Plant and Gas Cleaning Plant (Building no 115)

The Nitrogen Plant and Gas Cleaning Plant are in good condition (CC 1). The building is constructed of rendered concrete as two adjoined halls with pitched sheet metal roofs. It has tall windows with iron glazing bars. There are minor blemishes and some peeling in the concrete and some corrosion of the windows and sheet metal roofing. Previous leakages have been repaired.

7.12 The Minaret (Building no 135)

The Minaret is in good condition (CC 1). The tower is constructed of concrete, and the lower part has rendered surfaces. There is some minor peeling in the concrete. The sheet metal is damaged at the foot of the tower and needs to be replaced. The lower part of the door in the foot of the tower has some rot damage and the door as a whole is in need of maintenance.

7.13 Compressor and Synthesis Plant (Building no 130)

The Compressor and Synthesis Plant are in need of moderate repairs and are thus in CC 2. The building complex is constructed of rendered concrete as three adjoined halls with pitched sheet metal roofs. It has visible moisture damage and peeling walls, and the sheet metal roofing and roof flashings are worn. Parts of the building have suffered from leakages. The windows are damaged by corrosion. The tower has broken windows, a leaking roof, peeling concrete and is very exposed to moisture.

7.14 Nickeling Plant (Building no 160)

The Nickeling Plant is in good condition (CC 1). The building is constructed of rendered concrete and shows signs of peeling. The windows are exposed to corrosion. The gutters are worn and filled with vegetation.

7.15 Ammonia Water Plant (Building no 90)

The building is in need of moderate repairs and is thus in CC 2. It is constructed of reinforced concrete with partially rendered surfaces. It has eternit roofing tiles. The walls have extensive and visible blemishes with peeling all the way into the reinforcement bars in some places. There is crack propagation in the walls in several places. Some of the windows are in poor condition with heavy corrosion and some broken panes. Some of the flashings are damaged, and poorly functioning gutters and downpipes are causing damage to the walls. There is vegetation in the gutters.

8. Hydro Industrial Park in Rjukan

The attribute Hydro Industrial Park in Rjukan is on the whole in good condition (CC 1). Nine of ten objects are in CC 1 with ordinary maintenance needs. One object is in need of moderate repairs.

ID	Object	Condition class	Measures
8.1	Furnace House I (building no 242)	CC 1	
8.2	Boiler House (building no 246)	CC 1	
8.3	Barrel Factory (building no 282)	CC 1	
8.4	Pump House (building no 249)	CC 1	
8.5	Laboratory (building no 248)	CC 1	
8.6	Såheim II Hydrogen Plant	CC 2	
8.7	Nitrogen Plant (building no 226)	CC 1	
8.8	Compressor House (building no 228)	CC 1	
8.9	Synthesis Plant (building no 229)	CC 1	
8.10	Mechanical workshop (building no 230)	CC 1	Repairs to exterior walkway planned in 2014

8.1 Furnace House I (Building no 242)

Furnace House I is in good condition (CC 1). The building is constructed of brick with an interior steel frame and consists of five adjoined halls. The roof structure with adjoined roofs is exposed to leakages, but leakages most frequently occur through the ridge turrets. This is being monitored. There are some minor blemishes in the bricks and joints. The windows have suffered some corrosion. New flashings were installed in 2012.

8.2 Boiler House (Building no 246)

The Boiler House is in good condition (CC 1). The building is constructed of rendered brick with an interior steel structure. There are some minor blemishes and damaged parts in the bricks and joints. The windows show signs of corrosion, and some of the upper windows are broken.

8.3 Barrel Factory (Building no 282)

The Barrel Factory is in good condition (CC 1). The building is constructed of brick and concrete with an interior steel structure. Apart from some minor blemishes and damaged bricks and joints, the building appears to be robust and in good condition.

8.4 Pump House (Building no 249)

The Pump House is in good condition (CC 1). The building is constructed of rendered brick. The plaster displays some minor blemishes and there is some local corrosion to the windows. The western gate has some local rot damage and is in need of maintenance.

8.5 Laboratory (Building no 248)

The Laboratory is in good condition (CC 1). The building is constructed of rendered concrete. New windows were installed in 2003. There is some moisture and effervescence in the cellar, but otherwise the building appears to be robust with ordinary maintenance needs.

8.6 Såheim II Hydrogen Plant

The Såheim II Hydrogen Plant is in CC 2 and in need of moderate repairs. The building complex consists of three parts, constructed in reinforced concrete. The newest part at the western end suffers from moisture problems associated with interior downpipes from a flat roof and missing flashings as well as a number of broken window panes. There is some peeling and scratches in the walls. The building bears visual signs of being unused. The remaining and older parts towards the east (office building/ former compressor house and engine shed) have ordinary maintenance needs.

8.7 Nitrogen Plant (Building no 226)

The Nitrogen Plant is in good condition (CC 1). The building is constructed of rendered concrete with a steel framework and tall windows. Apart from some minor blemishes and moisture-exposed sections, it appears to be robust and in good condition. The windows show signs of corrosion. The floor of the building has been removed.

8.8 Compressor House (Building no 228)

The Compressor House is in good condition (CC 1). The building is constructed of rendered concrete with a steel framework and tall windows. Apart from some minor blemishes and moisture-exposed sections, it appears to be robust and in good condition. The footbridge leading into the building suffers from some corrosion, and the steel girder along the exterior southern wall has given rise to some moist sections. The building is used for manufacturing.

8.9 Synthesis Plant (Building no 229)

The Synthesis Plant is in good condition (CC 1). The building is constructed of rendered concrete. The windows have suffered some corrosion. The discharge pipes from the downpipes under the eaves are too short, so that the walls are exposed to excessive moisture.

8.10 Mechanical Workshop (Building no 230)

The Mechanical Workshop is in good condition (CC 1). The building is constructed of rendered concrete with a steel framework and tall windows. There are some local leakage problems in the roof, and the interior downpipes are occasionally blocked, which causes water to gather on the roof. The exterior walkway towards the north is exposed to moisture and the concrete on the underside is peeling. There are plans to repair it in the course of 2014. The building is empty.

9. Production equipment

In 2012, the attribute production equipment was assessed as being in CC 3 and in need of immediate measures. This was because three of seven objects are kept out in the open and thus suffer from accelerating moisture damage. Those three objects are regarded as the most important ones. Measures to stop further degradation are under way.

ID no	Object	Condition class	Measures
9.1	Ceramic pots	CC 3	Safeguarding planned in 2014
9.2	Electric Arc Furnace, Notodden	CC 3	Safeguarding planned in 2014
9.3	Electric Arc Furnace, Rjukan	CC 3	Safeguarding planned in 2014
9.4	Acid Tower	CC 1	
9.5	AEG pump	CC 1	
9.6	Tanks in the Hydrogen Plant (Building no 55)	CC 1	
9.7	Synthesis Furnace, Rjukan	CC 1	

9.1 Ceramic pots

The ceramic pots are in CC 3 and are in need of safeguarding against water damage. They are kept outdoors. The smallest pot has a leaking lid and is cracking all the way down the side to the base, in addition to standing in a pool of water. There is imminent danger that it will be further damaged when the water freezes. The biggest pot is damaged at one of the spouts that protrude from the top. A protective lid is missing, so that water runs into the pot. Both pots must be placed on dry foundations and covered to prevent ingress of water through openings and cracks.

9.2 Electric Arc Furnace, Notodden

The Electric Arc Furnace in Notodden is in CC 3 and needs to be moved under cover to safeguard it. The furnace was stored indoors until the mid-1990s, when it was moved to its current outdoor location. The furnace consists of four cast-iron shells, where the magnetic windings and electrodes are installed on the two outermost shells, while the two inner shells are lined with refractory chamotte bricks. The shells are supported by steel beams, to facilitate repair work and modification of the furnace. The two halves of the furnace have been taken apart, so that all parts can be easily viewed on both sides. A trussed framework at each of the four corners supports the steel beams that carry the shells. The furnace is standing on a flat concrete deck, where some water has collected underneath it. The cast and forged iron parts are in relatively good condition. Some corrosion can be observed in the steel rack and in the cast-iron shells, but it has not reached a critical stage. The refractory lining is worse off: The observed cracks entail a danger that water will enter and erode the lining in whole or in part over time. The cardboard insulation around the magnetic windings is partially dissolved and disintegrated. The mica insulation is also partially disintegrated. The furnace cannot be preserved for the future the way it is displayed today. Important details will be lost. The optimum solution is to move the furnace indoors. Preventive conservation can also be achieved by erecting a roof over the furnace in its present location and raising it from the concrete deck to lift all parts of it out of the water.

9.3 Electric Arc Furnace, Rjukan

The Electric Arc Furnace in Rjukan is in CC 3 and needs to be moved under cover to safeguard it. The cast-iron electric arc furnace consists of two identical halves that have been bolted together. Either side has a big, bolted-on cover of the same material. The magnetic windings are underneath these covers. After being left out in the open for more than 70 years, extensive corrosion is visible, particularly in the steel lid that is bolted to the cast-iron furnace. Water leaks out from the joint between the two halves of the furnace at the bottom, and on the sides, the two halves appear to be coming apart due to expanding rust and frost erosion. A gap of approximately 1–2 mm can be observed in the joint. There is extensive corrosion around most of the joints. The transition between the furnace and its feet appear to have been pointed before the final coat of paint was applied, presumably more than 30 years ago. Rust has eaten into and left holes in some of the steel lids. The furnace shows every sign of not having been maintained and is in urgent need of attention in order to become presentable. The structure has proved able to survive outdoor storage, but the joints are coming apart due to moisture and rust and it is only a question of time before the main part is damaged. The furnace is assessed as being in full and unhindered deterioration and is in urgent need of maintenance and repair if it is to be preserved for the future. The optimum solution would be to move the furnace indoors or erect a protective roof over it. Immediate measures must be to seal the joints in the upper half of the furnace through which water is ingressing, in order to slow down the rate of deterioration and the risk of crack formation in the cast iron due to expanding rust and water inside the joints between the parts. In the longer term, the furnace should be disassembled so that all corroded material can be removed from the joints.

9.4 Acid Tower

The Acid Tower is in good condition (CC 1). Today, the tower is standing outdoors, though it was originally indoors. This affects its maintenance condition. The granite tower itself appears to be in good condition, but the concrete foundations are crumbling in some places as a result of acid having leaked out. The concrete pointing in the joints between the foundations and the granite blocks is highly disintegrated. The granite surfaces and iron ties are coated with a marked layer of rust. Remnants of various surface coatings can be seen on the exterior concrete surfaces.

9.5 AEG Pump

The AEG Pump is in good condition (CC 1). The pump is kept indoors and is still in use and subject to regular maintenance. The original motor burned out and has been replaced by an equivalent motor taken from a neighbouring pump that was scrapped.

9.6 Tanks in the Hydrogen Plant

The tanks in the Hydrogen Plant (building no 55) are in good condition (CC 1). The tanks are kept indoors in a protected and infrequently used storage room. They are not in use and are empty. Patches of light surface corrosion can be seen.

9.7 Synthesis Furnace, Rjukan

The Synthesis Furnace in Rjukan is in good condition (CC 1). The solid-iron furnace is 12 metres high and weighs 80 tonnes. It has some surface corrosion, but is otherwise in good condition. The extent of corrosion inside the joint is unknown. Outdoor storage will cause increased corrosion over time.

Transport system

The two attributes comprised by the transport system component are in need of moderate to major repairs, both in order to achieve a good state of conservation and in order for them to be operational. They have been assigned CC 3 and CC 2, respectively, because of the condition of important elements. Most of the significant objects are in CC 1, however. Maintenance and repairs/restoration are carried out in accordance with heritage conservation principles in collaboration between the owners and Telemark County Authority.

10. The Tinnoset Line

The most important parts of the Tinnoset Line are in need of major repairs, and the attribute is thus in CC 3. The line is not operational and the state of conservation is poor. The track with signalling system and overhead line equipment is in a critical condition. There is a need for major examinations of the maintenance level in terms of heritage conservation, museum operation and regular operation of the line. The station areas along the line are generally in a good state of conservation. The same is true of the building stock. A management plan will be prepared for the Tinnoset Line.

ID no	Object	Condition class	Measures
10.1	Railway track with signalling system and overhead line equipment	CC 3	Prepare management plan
10.2	Notodden old railway station building	CC 1	
10.3	The Railway Quay/Rjukan Quay	CC 1	
10.4	Notodden Railway Station with eight buildings	CC 1	Repairs and reconstruction following floods in 2011–2012
10.5	Tinnoset Railway Station with three buildings	CC 1	Buildings repaired 2012

10.1 Railway track with signalling system and overhead line equipment

The railway track, the signalling system and the overhead line equipment are in need of major repairs and are thus in CC 3. The assessment is based on the owner's (the Norwegian National Rail Administration) condition report from 2011. Major repairs are required, both in order to achieve a good state of conservation and in order to make it operational. No maintenance has been carried out for many years and fatigue damage has not been repaired. There is a general need for extensive vegetation clearance and landslide protection. Some sections of the track and shoulders are overgrown. The substructure's cross and side drainage channels are in need of repairs. There is a need to replace ballast and sub-ballast material along some sections. Embankment failure and hollows due to uneven settlement of the foundations occur in several places. Drystone walls along the drains are giving way. The sleepers are generally in a visibly poor condition and need to be replaced. The sleeper fasteners need to be repaired. The rails are in good condition, but some joints are in need of maintenance. Damaged points need to be repaired and inspected before use. Further assessment must be carried out of the condition of the tree bridges, which are exposed to corrosion and other damage. There is extensive rot damage to platforms and footpaths for personnel. The level crossings are seriously decayed and highly exposed to vandalism. The signalling system has been extensively vandalised, leaving broken glass, and wrecked poles and signs. The signalling and road barrier systems are more or less completely destroyed for all practical purposes.

The overhead line equipment on the Tinnoset Line is largly gone due to theft. Photo: Per Berntsen.

The overhead line equipment is largely gone due to theft and vandalism. All poles (629 in number) date back to the 1950s and show signs of fatigue damage. They are dried out and cracked. The creosote with which they were impregnated has not penetrated to the core, which is rotting. Many of the poles have no cap and are thus exposed to further damage. Damage caused by woodpeckers or the absence of a protective cap has occurred in 70% of the poles. Some of the poles slant to one side and 14 have been cut down in connection with theft of the overhead line. At least 46, and probably the majority, need to be replaced. The 23 concrete masts as well as the steel masts appear to be in good condition. The fixings are corroded in some places. Along approximately 60% of the railway line, the contact wire, messenger wire and suspension wires have been stolen. Many equipotential bonding connections and other bonding devices are also missing. What is left suffers from degradation due to fatigue and lack of operational maintenance. Brackets are skewed and counterweights need adjustment. Several insulators are damaged. Traction bonds are broken or absent.

10.2 Notodden old railway station building

The old railway station building in Notodden is in good condition (CC 1). There is a need for some minor repairs, however. The balcony needs new brackets and better water drainage. There is a drainage problem on the northern side of the house, which has given rise to moisture and fungus in the cellar. Some of the windows need to be puttied and painted.

10.3 The Railway Quay/Rjukan Quay

The Railway Quay, also known as the Rjukan Quay, is in good condition (CC 1). It consists of two robust concrete foundations for freight cranes and the remains of pertaining rails. The rails are in good condition, but partly overgrown.

10.4 Notodden Railway Station with eight buildings

Notodden Railway Station, which comprises eight buildings, is generally in good condition (CC 1). The station area consists of the station facilities and eight buildings. The southern part of the area and a wagon weighing hut were thoroughly repaired in 2012 after having sustained flood damage and are in operational condition. The rest of the station area is in a good state of conservation, but there is a need for extensive replacement of sleepers and improvement of sleeper fastenings before it is ready for operation. In some parts of the area, the substructure does not provide sufficient drainage. Only one of the buildings is in need of repairs in the form of partial replacement of the cladding and the installation of new windows. The other buildings are in good condition.

10.5 Tinnoset Railway Station with three buildings

Tinnoset Railway Station, which comprises three buildings, is generally in good condition (CC 1). The station area is in a good state of conservation, but there is a need for extensive replacement of sleepers and improvement of sleeper fastenings before it is ready for operation. In parts of the area, the substructure does not provide sufficient drainage and the area is being increasingly overgrown by vegetation. The station building and outhouse were restored to a good state of conservation in 2012. They require ordinary maintenance. The freight house's foundations and ramp suffer from slump and settlement damage, and the freight house is thus in CC 2.

11. The Rjukan Line

The Rjukan Line attribute is in need of moderate repairs and is thus in CC 2. Nine objects have been assigned CC 1, five CC 2 and one CC 3. Several important objects are in need of what are in some cases costly repairs. With the exception of a few objects, the attribute is the responsibility of the Norwegian Industrial Workers Museum. Repairs and maintenance are carried out in accordance with the museum's annual project schedules. The Rjukan Line receives public funds for maintenance and repairs every year, with a view to restoring all parts of the line to an ordinary maintenance level. It is an aim to restore the line to an operational condition

ID no	Object	Condition class	Measures
11.1	Railway track with signalling system and overhead line equipment	CC 1	Separate action and maintenance plan
11.2	Tinnoset Ferry Quay with six buildings	CC 2	Separate action plan for major measures the coming year.
11.3	Slipway with winch house	CC 1	A number of measures to make the slipway ready for operation implemented in 2012.
11.4	Lighthouses	CC 2	
11.5	Mæl Ferry Quay	CC 1	Separate action plan for major measures the coming year.
11.6	Mæl Railway Station with four buildings	CC 1	
11.7	Mælsvingen 10–15	CC 1	
11.8	Ingolfsland railway station building	CC 2	
11.9	Rjukan railway station building, freight house and engine shed	CC 3	
11.10	Såheim engine shed	CC 1	
11.11	Vemork railway track	CC 1	Upgraded 2012
11.12	Rolling stock	CC 2	Maintenance and action plan to be prepared
11.13	'D/F Ammonia'	CC 1	
11.14	'M/F Storegut'	CC 2	Certification measures implemented 2011–2013
11.15	'D/F Hydro' – shipwreck	CC 1	

11.1 Railway track with signalling system and overhead line equipment

The railway track, signalling system and overhead line equipment are in a good state of conservation (CC 1). Moderate repairs must be carried out and ordinary maintenance procedures must be in place before the heritage railway can be put into operation as planned. A separate action and maintenance plan has been prepared. The substructure is in need of some minor repairs to cross and side drainage channels, but is otherwise in good condition. The bridges appear to be in good condition, but further assessment is required before they can be used. One abutment is in need of repairs. The quality of the sleepers is moderate to poor. A plan for systematic replacement over a 15-year period is being prepared. Priority will be given to curves. The rails are in good condition. The points are in good condition, but need to be inspected before the line is put into operation. A procedure for routine vegetation clearance must be established. The line is being increasingly overgrown. There are eight level crossings of public roads with signal lights and/or barrier systems. These are not currently intact. The systems must be certified by the Norwegian Railway Authority before the start of any heritage railway operation. The signalling system must be thoroughly reviewed and the subject of a separate report before it is in any way feasible to put it into operation. It has suffered vandalism and fatigue damage and no operational maintenance has been carried out.

Further inspections and repairs are required before the overhead line equipment can be used in the operation of a heritage railway. Many earth wires have broken or been removed and need to be replaced by new ones. Traction bonds are broken or absent. Two masts are damaged and need to be replaced, and many of them need to be righted at the foundations and guyed. On visual inspection, cantilevers, insulators and transformers appear to be in good condition. The same is true of suspension points, though new ones need to be established at Rjukan Railway Station.

11.2 Tinnoset Ferry Quay with six buildings

Tinnoset Ferry Quay with six buildings is in need of moderate repairs and is thus in CC 2. A separate condition report has been prepared, which includes an action plan. The actual ferry quay is somewhat worn, but relatively moderate measures are required for its continued use. There are three major problem areas in the years ahead: painting of the steel, repairs to the concrete surfaces and replacement of the woodwork. The woodwork is placed in CC 2. The six buildings are in need of moderate damage repairs as a consequence of irregular maintenance. They have broken gutters and downpipes, local rot damage, damaged wall panels and roofs in some places, and the foundations of one of the buildings is subsiding.

11.3 Slipway with winch house

Tinnoset slipway and winch house are placed in CC 1 and require ordinary maintenance only. The slipway and slipway machinery were repaired, reinforced, subjected to safety and functional tests and used in 2012. Nonconformities were closed. The winch house has broken gutters and downpipes and some of the plaster is peeling, but it is otherwise in good condition.

11.4 Lighthouses along Tinnsjøen lake

The condition of the lighthouses varies, but seen together, they are assessed to be in need of moderate repairs (CC 2). Five of them are assigned CC 1 with ordinary maintenance needs. Four are assigned CC 2 and have a need for moderate repairs as a result of rot damage, damaged ledges and windows and poor surface coating. One is assigned CC 3 and displays more of the same symptoms, in addition to broken hinges. In several places, the lighthouses are under threat of being overgrown.

11.5 Mæl Ferry Quay

Mæl Ferry Quay is in good condition (CC 1). A separate condition report has been prepared, which includes an action plan. The ferry quay is somewhat worn, but relatively moderate measures are required for its continued use. There are three major problem areas in the years ahead: painting of the steel, repairs to the concrete surfaces and replacement of the woodwork. The woodwork is placed in CC 2. Among other things, poles and supporting timber need to be replaced in several of the dolphins.

11.6 Mæl Railway Station with four buildings

Mæl Railway Station, which comprises four buildings, is in good condition (CC 1). The building stock is well maintained and repaired in recent years. One building has not yet been restored, however, and it is in need of repairs to the roof and rot-damaged sections, as well as surface treatment.

11.7 Mælsvingen 10-15 with five houses

Mælsvingen 10-15 is a well-preserved housing area, requiring ordinary maintenance only (CC 1). Some of the gutters need to be replaced. Repairs are carried out in collaboration between the owners and Tinn Municipality.

11.8 Ingolfsland railway station building

Ingolfsland railway station building is assigned CC 2 and is in need of moderate repairs. The building is constructed of rendered brick and stands on concrete foundations. Windows, doors, balconies and the foundation wall are in need of repairs. There is local rot damage in supporting columns.

11.9 Rjukan railway station building, freight house and engine shed

Rjukan railway station building, freight house and engine shed are in need of major repairs and are thus in CC 3. Both buildings have leaking roofs, and water and rot damage, and have unfortunately been left in this condition for some time. The freight house has damaged girders, among other things, and the station building has roofing that is in poor condition and a balcony with extensive damage. The station area is otherwise in good condition, but it is being increasingly overgrown and some of the sleepers are in need of replacement.

11.10 Såheim engine shed

Såheim engine shed is in good condition (CC 1) and only in need of ordinary maintenance. The building is currently in use as industrial premises, and it was repaired in the 1990s.

11.11 Vemork railway track

The route of the Vemork railway track is in need of maintenance and minor repairs (CC 1). The owner cleared the route of vegetation and upgraded it for use by heavy vehicles in 2012. It is therefore in moderately good condition. The route has become more decipherable in the landscape. The few remaining railway elements have not been restored, however, and the route is very exposed to landslides. The route is damaged by landslides several times every year. A separate report has been prepared on the risk of landslides, and the mountainside is being monitored to watch out for major landslides.

11.12 Rolling stock

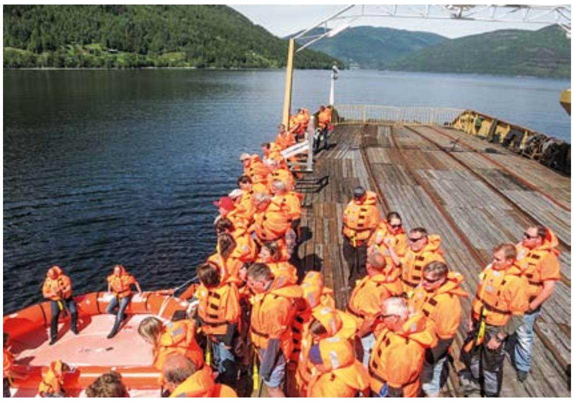
The rolling stock is generally in need of moderate repairs and assessed as being in CC 2. None of the units are in an operational condition, and several of them suffer from rot and/or exterior corrosion damage requiring measures to a varying degree. All units have clearly been without maintenance for many years. Plans for maintenance, repairs and use will be prepared by the Norwegian Industrial Workers Museum. A further assessment will be carried out to decide whether some of the units should be returned to an operational condition.

11.13 'D/F Ammonia'

'D/F Ammonia' is in good condition (CC 1). Both the wooden and steel elements are in good condition. Separate condition reports were prepared in 2012. The steel hull is in good condition. However, some damage was found to exist by the forepeak tank where the steel is so poor that it warrants replacement. The extent of damage is not clear. The other issue that needs to be addressed is general maintenance, including cleaning and painting of the steel, which must be carried out regularly to remove early signs of corrosion. The interior steel appears to be in good condition. The steel shows few signs of leakages or moisture damage. The same applies to the wood, which is in good condition. Insofar as there is damage, it is surface damage that can be repaired by painting. Doors and panelling are in need of maintenance. In general, the ferry is in need of surface treatment, maintenance and minor repairs.

11.14 'M/F Storegut'

'M/F Storegut' is in need of moderate repairs and is thus in CC 2. Separate condition reports were prepared in 2012. The wood is generally in good condition, but the wheelhouse and lounge below have been damaged by leakages, and there is surface damage due to moisture in several places. The steel hull is generally in good condition. Ingress of water to the interior of the superstructure has created serious problems, however. The damage is extensive. The whole interior must be pulled down to detect where the water comes in and determine the scope of damage. A number of certification measures were carried out in 2011, 2012 and 2013. The ferry is certified to carry 99 passengers.



Testing evacuation procedures on M/F Storegut in 2013 for certification of the ferry. Photo: Trond Taugbøl.

11.15 'D/F Hydro'

'D/F Hydro' is in good condition (CC 1). The steel ferry is submerged in fresh water at a depth of 430 metres. It stands on its keel in the transition between a slope and a plain. The bow is partially buried in mud, but the ferry appears to be otherwise complete. Degradation is very slow, due to the stable environment.

Company towns

The two company towns are considered to be in good condition and require ordinary maintenance only. Both attributes are assigned CC 1. Very few (around 12 %) of the individual buildings associated with the significant objects are in need of moderate or major repairs in order to attain an ordinary maintenance level. Repairs/alterations over and above ordinary maintenance require municipal approval and is done in consultation with Telemark County Authority in its capacity as conservation authority. Repairs to individually protected buildings are subject to approval by Telemark County Authority.

12. Notodden Hydro Town

The attribute Notodden Hydro Town is in good condition (CC 1) and is only in need of ordinary maintenance. Only one of four housing areas requires more than ordinary maintenance. No parts of the urban area are deemed to be in need of moderate or major repairs. The area comprised by this attribute includes 50 main houses, which, together with other urban elements and green areas, are considered to be in good condition overall.

ID no	Object	Condition class	Measures
12.1	Grønnebyen (the 'Green Town') housing area	CC 1	
12.2	Villamoen housing area	CC 1	
12.3	The Admini (administration) building in Notodden	CC 1	Fire-protection installed in 2010
12.4	The Casino with four buildings	CC 2	

12.1 Grønnebyen (the 'Green Town')

The attribute Grønnebyen is in good condition (CC 1) and is only in need of ordinary maintenance. Only 1 of 28 houses is assessed as being in CC 2 as a result of having a malfunctioning gutter and downpipe, giving rise to moisture damage in the building. Some individual houses have suffered minor local damage to the chimney, cladding or windows, which should be repaired as part of the ordinary maintenance. The buildings have otherwise been well-maintained technically since they were converted in the 1950s. Other elements in the area, such as fences, rubbish bins, clothes driers and lamp posts, are in need of surface coating and repairs. The trees along the avenues need regular care. Some plots are at risk of becoming overgrown by large garden trees and bushes. The way down to the factory is overgrown and has fallen into disuse.

12.2 Villamoen housing area

Villamoen is in good condition (CC 1) and is only in need of ordinary maintenance. All the 17 main houses are in good condition. The trees along the avenues need regular care.

12.3 The Admini building in Notodden

The Admini building in Notodden is in good condition (CC 1) and requires ordinary maintenance only. However, one of the columns on the southern side of the building has sustained local moisture damage as a result of the poor condition of the flashings. The building is otherwise well preserved, and fire protection was installed in 2010.

12.4 The Casino with four buildings

The Casino buildings are generally in need of moderate repairs and are thus in CC 2. Most of the main house is in good condition and well maintained, but there is extensive rot damage in the north-western corner. There may be concealed damage in the walls in this area. The foundation wall is in good condition, but the use of cement for pointing causes crack formation and moisture damage in the long run. The chimney is in need of surface treatment. The outhouse/garage is in good condition, but the downpipe is too short, large trees are affecting the roof and some of the roof tiles need to be secured. The villa furthest to the south has poorly functioning gutters and downpipes, so that the walls are exposed to excessive moisture. Surface damage is clearly visible in one patch. Minor local rot damage and visibly moist patches can be observed at some of the corners. The paint is worn. The villa to the north is in good condition. It has been repaired and renovated.

13. Rjukan Hydro Town

The attribute Rjukan Hydro Town is in good condition (CC 1) and is only in need of ordinary maintenance. The whole historical urban area consists of around 650 buildings erected up until approximately 1930, of which 590 are houses and the rest are public buildings and factory buildings. The area is generally in good condition. Of the 23 significant objects, 18 are assigned CC 1, 4 CC 2 and 1 CC 3. Approximately 15 % of the 198 buildings/objects that form part of significant objects are in need of moderate or major repairs.

ID no	Object	Condition class	Measures
13.1	Krosso housing area	CC 1	
13.2	Krosso Aerial Cableway	CC 1	
13.3	Fjøset farm building with housing	CC 3	
13.4	Villaveien-Flekkebyen housing area	CC 1	
13.5	The old town centre	CC 1	
13.6	The Admini (administration) building in Rjukan	CC 1	
13.7	Gatehouse and fire station	CC 1	

ID no	Object	Condition class	Measures
13.8	Construction building in Hydro Industrial Park	CC 1	
13.9	Office building in Hydro Industrial Park	CC 1	
13.10	The Rjukan House (the People's House)	CC 1	Repaired and restored 2012
13.11	Såheim private school with teacher's residence	CC 2	Repaired 2012–2013
13.12	Rødbyen (the 'Red Town') and Tyskerbyen (the 'German Town') housing areas	CC 1	
13.13	The Market Square	CC 1	
13.14	New Town (house type O)	CC 1	
13.15	Baptist Church	CC 1	
13.16	Rjukan Church	CC 1	
13.17	Rjukan Hospital with Chief Physician's residence	CC 1	
13.18	Tveito School with five teachers' houses	CC 1	
13.19	Tveito Park and Tveito Avenue	CC 1	
13.20	Mannheimen single men's home and Paradiset housing complex	CC 2	
13.21	Sing Sing housing quadrant	CC 2	Repairs/restoration in 2013 and 2014
13.22	Triangelen housing complex in Ligata	CC 1	
13.23	Fabrikkbrua Bridge, Birkeland Bridge and Mæland Bridge	CC 2	

13.1 Krosso housing area

The Krosso housing area is in good condition (CC 1). All eight rendered brick buildings require ordinary maintenance. They have new windows and chimneys.

13.2 Krosso Aerial Cableway

The Krosso Aerial Cableway is in good condition (CC 1). It is a suspended cableway, where the cables pass over a mast that divides the span in two. The two station buildings are of rendered concrete and have been repaired in the course of the past ten years. The cableway runs all year round, and safety and function testing and inspections are a prerequisite for the licence to operate. The cableway's machinery and other technical installations have been replaced.

13.3 Fjøset farm building with housing

The farm building and housing are in need of major repairs and are thus in CC 3. The actual farm building is in need of major repairs. The roof is in poor condition, the gutters and downpipes are not functional and the walls are exposed to excessive moisture in places. The walls have been exposed to moisture and water for some time and have been damaged as a result. The extent of the damage needs to be examined. Windows and doors are in need of maintenance. The roof structure with sections of roof that meet at an angle is vulnerable. The three brick buildings that contain housing units and the garage building require ordinary maintenance.

13.4 Villaveien–Flekkebyen housing area

The Villaveien–Flekkebyen housing area is in good condition (CC 1). The cultural environment and overall appearance, including the differences in terrain, the building types, the infrastructure, kerbstones and footpaths and walkways are in good condition. A growing vegetation problem is a disturbing factor, however, which damages the footpaths. The condition of the 71 buildings in the area varies between CC 1 and CC 2. The just over 30 buildings in Villaveien require ordinary maintenance, while there are greater differences in Flekkebyen. Flekkebyen has reached the limit of what it can withstand of conversions and alterations.

13.5 The old town centre

The old town centre is in good condition (CC 1). The six buildings of brick and wood have local rot damage and some worn surfaces, but require ordinary maintenance. The environment has been well preserved.

13.6 The Admini building in Rjukan

The Admini building in Rjukan is in good condition (CC 1). The Admini and its surrounding buildings require ordinary maintenance. Fire protection was installed in 2010. The buildings are currently not in use and may in future be under threat of insufficient maintenance.

13.7 Gatehouse and fire station

The gatehouse/fire station is in good condition (CC 1). The brick building requires ordinary maintenance and is in daily use.

13.8 Construction office in Hydro Industrial Park

The construction office in Hydro Industrial Park is in good condition (CC 1). The wooden building has been restored during the past five years with new roofing and newly painted surfaces. The windows were replaced by new ones in 1991.

13.9 Office building in Hydro Industrial Park

The office building in Hydro Industrial Park is in good condition (CC 1). The rendered brick building has new roofing and the windows have recently been repaired. It is in use and well maintained.

13.10 The Rjukan House

The Rjukan House is in good condition (CC 1). The building was repaired and restored in 2012. The walls were repaired and the newer windows were replaced by windows identical in appearance to the original ones. The roof was repaired with new roofing felt and flashings. Fire protection was also installed.

The Rjukan House with the old emblem on the facade was restored back to its original appearance in 2012. Photo: Eystein M. Andersen.

13.11 Såheim private school with teacer's residence

Såheim private school and teacher's residence are in need of moderate repairs and are thus in CC 2. The teacher's residence requires ordinary maintenance. The school building is in need of repairs to the roof. The building also suffers from minor rot damage and moisture problems in the cellar. The roof is being repaired in the course of 2012 and 2013.

Såheim private school under restauration in 2013. Photo: Bjørn Iversen.

13.12 Rødbyen (the 'Red Town') and Tyskerbyen (the 'German town') housing areas

The Rødbyen and Tyskerbyen housing areas are in good condition (CC 1). All 36 buildings require ordinary maintenance. Some of the houses are being repaired during the period 2012–2013, including the transformer kiosk.

13.13 Market Square

The Market Square is in good condition (CC 1). The two buildings have recently been restored and require ordinary maintenance. There are some minor moisture problems in the cellar. The square itself will be upgraded in the years ahead. A dedicated architects' competition has been announced in 2013.

13.14 New Town (house type O)

The New Town is in good condition (CC 1). The rows of 32 wooden tenement buildings require ordinary maintenance.

13.15 Baptist Church

The Baptist Church is in good condition (CC 1). The flashings on the roof need to be repaired and some broken window panes need to be replaced, but the building is otherwise in good condition.

13.16 Rjukan Church

Rjukan Church is in good condition (CC 1). This stone church underwent extensive repairs after a fire in 1965, after which it has been kept at an ordinary maintenance level.

13.17 Rjukan Hospital with Chief Physician's residence

Rjukan Hospital and the Chief Physician's residence are in good condition (CC 1). The hospital building is in use and has been repaired in the course of the past five years. The Chief Physician's residence suffers from lack of maintenance and disuse, and the gutters and downpipes are in a poor condition. The roof needs to be examined in more detail.

13.18 Tveito School with five teachers' houses

Tveito School and the five teachers' houses are in good condition (CC 1). The school building was restored in 2009. Four of the teachers' houses are lived in and subject to ordinary maintenance, while one stands empty and is in need of major repairs.

13.19 Tveito Park and Tveito Avenue

Tveito Park and Tveito Avenue are in good condition (CC 1). The municipality sees to regular maintenance of the park and avenue.

13.20 Mannheimen single men's home and Paradiset housing complex

Mannheimen and Paradiset are in need of repairs and are assigned CC 2. The six rendered brick tenement buildings that make up the Paradiset housing complex require ordinary maintenance. The brick building that was once a single men's home, on the other hand, is in need of major repairs to the roof, downpipes, façades and windows.

13.21 Sing Sing housing quadrant

The Sing Sing housing quadrant is in need of moderate repairs and is thus in CC 2. The walls of this building complex, which consists of five rendered brick buildings, are extensively damaged in places where the plaster is dropping off in patches. This can mainly be ascribed to use of the wrong type of paint. Repairs are being done in 2013 and 2014. Some of the windows and gutters are also in need of repairs.

13.22 Triangelen housing complex in Ligata

Triangelen in Ligata street is in good condition (CC 1). The five wooden tenement buildings require ordinary maintenance. Some of the barge boards need to be replaced and one of the chimneys should be repaired.

13.23 Fabrikkbrua Bridge, Birkeland Bridge and Mæland Bridge

These bridges are in need of moderate repairs and are thus in CC 2. In addition to minor cracks and peeling, the structures are being attacked by vegetation/moss. Birkeland Bridge was restored in 2012 with the installation of original lighting.

Original lighting on Birkeland Bridge, restored in 2012. Photo: Bjørn Iversen.

4b. Factors affecting the area

Given its considerable size and diverse content, the nominated area will be affected by a number of different factors. They mainly fall into two categories: the impact of forces of nature, on the one hand, and social structural changes, on the other.

(i) Development pressures

The two towns are or will be exposed to general development pressure. However, Notodden and Rjukan are situated outside the central part of Eastern Norway and the lowland along the Oslofjord where population growth is expected in the next decade. They are therefore not exposed to the same, strong development pressure as towns and built-up areas in the Lillehammer-Skien-Halden triangle, with Oslo as the hub. This centralisation is fuelled by migration from other regions and districts. In this context, both Notodden and Tinn are outlying districts that are being drained of people, especially Tinn due to its location. Both Tinn Municipality as a whole and the administrative centre of Rjukan are in steady decline, while Notodden Municipality as a whole has a stable population with a slight increase in Notodden town. The latter is due, among other things, to the short distance and good road connection to Kongsberg, which is part of a belt of towns in the southern part of Buskerud County (Drammen – Hokksund – Kongsberg) and offers many high-tech jobs. In the longer term, the E 134 road, which constitutes an important link between Eastern and Western Norway, will be upgraded. This will entail crossing the World Heritage Site, either through or slightly north of Notodden's town centre. The planning process will seek to reach consensus on solutions that emphasise consideration for World Heritage values.

The impact of development pressure varies, including in relation to the nomination proposal's different thematic components. In the following, an overview is provided of development pressure that is deemed to have an impact on the nomination proposal's values in the areas of hydroelectric power, industry, transport system and company towns.

Hydroelectric power

The facilities in **Notodden** are mainly located on the periphery of the areas that are under ordinary pressure of being developed for other purposes. The introduction of new technical and safety-related requirements for installations, dams etc. is the factor that is expected to bring the greatest need for changes. A certain need for minor modifications due to changes in use over time must also be expected for the relevant parts of the Tinfos area (Tinfos I and Tinfos II power plants).

The power production plants in **Tinn** Municipality are situated along the Månavassdraget watercourse between Møsvatn lake and Tinnsjøen lake. The plants are mainly located on the periphery of the areas that are under great development pressure. Along the upper part of the string (Møsvatn – Vemork), new holiday homes are the most likely development. No specific development plans exist that represent a threat to the cultural heritage. Modernisation of the plants to meet new safety requirements and upgrades for increased production are deemed to be the biggest development threats.

Conclusion: Low development pressure is expected in relevant areas in both Notodden and Tinn municipalities. Good plans are in place and there is good planning capacity in both municipalities, which will be strengthened by supplementary protection orders under the Cultural Heritage Act.

ID no	Attribute	Threat	Degree
1	Tinfos power plants	Building alterations	Minor
2	Hydro's power plants in the Tin-nelva river	Building alterations	Medium
3	Vemork Power Plant	Overgrowth, particularly along the penstock	Medium
4	Såheim Power Plant	Building alterations	Minor
5	Regulating dams	Building alterations	Minor
6	Power transmission	Building alterations	Minor

Industrial areas

Hydro's former industrial site in **Notodden** is currently used for industrial, office and service activities. Reorganisation, and thus alterations, is always necessary in industrial enterprises. Buildings will also have to be upgraded for other activities, in line with modern technical requirements for such workplaces. Both in the regulated areas and in the areas where land use is governed by the municipal master plan, there is room for new developments, especially in the car park in the south-eastern corner. The cultural history analysis that was carried out in accordance with the DIVE method concluded that, on certain conditions, the area can tolerate the erection of new buildings in this car park. The analysis also concluded that the area may be able to tolerate minor building alterations. The current municipal master plan sets out guidelines for preservation of four buildings in the area. Work has been started on a new municipal sub-plan for the whole area that was recommended as a zone requiring special consideration in the conclusion of the DIVE analysis. In 2013, the county authority has prepared protection proposals pursuant the Cultural Heritage Act for the area and the most important buildings.

Hydro's former industrial site in **Rjukan** is an area used by industrial, office and service enterprises. Manufacturing in the area leads to requirements for reorganisation and thereby modifications to the buildings. Closing of businesses and a decline in the level of activity (negative development) may constitute a greater threat than the accommodation of new activities. Some large buildings were demolished by Norsk Hydro when production ceased, and the factory area can therefore tolerate densification. New business premises in the form of large data centres (server farms) in unbuilt parts of the factory area are being considered. A plan for this has been prepared in consultation with conservation authorities, and it is considered that new buildings of the right design can support the values in the area. Reduced accessibility for the public may be a challenge in connection with the establishment of new businesses.

Conclusion: Relatively great development pressure must be expected in the Notodden area. Plans and planning capacity are fairly good in relation to major projects, which are subject to a zoning plan requirement, but less good in relation to smaller projects. Small projects may be within the area's tolerance limit, however. Protection will improve planning for the area included in the protection order. Development pressure in the Rjukan area is not expected to exceed the normal level. Good plans are in place and planning capacity is excellent and will be strengthened by protection of the industrial park under the Cultural Heritage Act.

ID no	Attribute	Threat	Degree
7	Hydro Industrial Park in Notodden	Building alterations	Major
8	Hydro Industrial Park in Rjukan	Building alterations	Minor
9	Production equipment	Various consequences as a result of weather-exposed location	Major

Transport system

The railway areas in Notodden are owned by the State. Notodden Railway Station and Railway Quay are located in such a central urban area that use for other purposes than today, and thus a need for making changes, must be expected in the long term. The Railway Quay is demarcated for urban development purposes in the current plan.

Development pressures on the railway track itself and its technical systems, and on the lighthouses, must be expected to be negligible as they are mainly located in sparsely populated, inaccessible areas. Some pressure for making changes to privately owned station buildings must be expected, however. Theft of overhead lines in uninhabited areas has been a huge problem in recent years when the system has not been under voltage.

The Rjukan Line with associated installations in both Tinn and Notodden is owned and managed by the Norwegian Industrial Workers Museum as a heritage line. As far as we know, the railway line is not threatened by development pressure. It may be exposed to minor encroachments, for example in the form of access roads crossing the railway track. Some of the buildings in the area of Rjukan Railway Station are being considered for new use.

Conclusion: The areas and attributes of the transport system in both municipalities are expected to be under what would normally be regarded as modest development pressure. One exception is the Railway Quay in Notodden. Good plans are in place and planning capacity is excellent in both municipalities. Parts of the areas are already regulated for conservation and the values are otherwise protected or in the process of being protected under the Cultural Heritage Act.

ID no	Attribute	Threat	Degree
10	The Tinnoset Line	General deterioration of railway track and signalling system. (10.1)	Medium
		Theft of overhead lines. (10.1)	Major
		Building alterations in station areas (10.2–10.5)	Medium – minor
11	The Rjukan Line	General deterioration (11.1)	Major
		General deterioration (11.2–11.15)	Medium

Company towns

The areas in **Notodden** consist of buildings and some residences used for hospitality purposes. Today, the buildings are mainly privately owned by many different individual owners, involving a wide range of diverging needs and inadequate knowledge of rules and regulations. A demand for alterations will always arise in connection with private houses: changes to façades, verandas/terraces, extensions, outhouses and new, bigger garages. The trees lining the streets are very characteristic and require considerable maintenance every year. Modern technical requirements and adaptation to universal design requirements are issues that need to be addressed by the relevant authorities. When the buildings are painted, tiles replaced etc., there is a certain risk that the colour will change from the original.

Rjukan has retained its small-town character, and no shopping centres have been built outside the town centre. In 2012, the municipal council turned down a request to establish a retail shop in the Svadde area approximately three kilometres outside the town centre, on the grounds that it was desirable to preserve a living town centre. Although the population of Rjukan has been reduced to two-thirds of the original figure, the whole town and most of the buildings are still in use. The town is long and narrow, with relatively little land available for expansion. The town has room for densification, which may potentially come into conflict with cultural heritage values.

Modernisation and upgrading of older buildings are deemed to constitute the greatest development pressure. The built-up area, which was largely developed by Hydro under its ownership, is now on the hands of many private owners with different wishes and needs and a varying degree of knowledge about regulations. Alterations are being made in the form of extensions, changes to façades, outhouses/garages, terraces and in relation to vegetation (rows of trees, hedges).

New buildings/densification may be relevant in the older parts of the town as well as in the new housing areas built outside the town centre during the past 40 years as the built-up area has been expanded towards the east. Plans are under way for new housing developments within the town, through densification of poorly utilised or unbuilt land. Rebuilding existing small housing units into bigger ones is also being considered. New housing may come into conflict with cultural heritage values and must be carefully evaluated through planning processes.

Maintenance of the *parks and facilities lining the streets and squares* of the town is demanding. One example are the retaining walls of natural stone that have suffered many impacts through 100 years. Parts of the urban landscape are being overgrown by vegetation, partly in steep areas that are not easily accessible. To some extent, the streetscape is also affected by the town being planned before private cars were common, while they now number two per household. There are plans to upgrade public spaces, starting with the Market Square in Rjukan. A sun mirror has been installed on the mountainside to reflect sunlight down to the square in winter.

Conclusion: Moderate development pressure is expected in the **Notodden** area. Plans and planning capacity are reasonably good in relation to handling this, with the exception of a possible new building to the east of the square, which may have to be postponed pending a new zoning plan should such a building be proposed in accordance with the current zoning plan. A protection order will improve planning in the area it protects.

Normal development pressure is expected in the **Rjukan** area as a whole, with greatest pressure in the central areas. Plans and planning capacity must be said to be normal for this type of area. Although municipal sub-plans have previously been adopted for Rjukan and the Vestfjorddalen valley, planning will be significantly improved once new plans are in place.

ID no	Attribute	Threat	Degree
12	Notodden Hydro Town	Building alterations (12.1) (12.4)	Medium
		(12.2–12.3)	Major
13	Rjukan Hydro Town	Building alterations (13.1–13.5) (13.17–13.18)	Medium
		(13.6–13.16) (13.19–13.23)	Minor

Supporting values and buffer zone

The buffer zone contains objects of supporting value for the nomination's outstanding universal value and important sightlines to the core values. Some values within the World Heritage Site are also classified as supporting values, due to insufficient integrity and/or authenticity in their present condition. They are generally exposed to the same threats as the part of the World Heritage Site to which they belong. This was discussed above and is therefore not specified in more detail.

Notodden Municipality

The southern part of the buffer zone includes large parts of Notodden town and housing areas. The area north of the town centre is less built-up and consists partly of uninhabited forest areas. Fairly strong development pressure must be expected in the urban areas as a result of the general development of society. Moderate to low development pressure must be expected outside the central area. Development pressure in relation to sightlines mainly takes the form of varying degrees of vegetation overgrowth.

Sightlines to the central areas and values in Notodden Municipality:
(See also map no 3.2 in Annex 1)

Viewed from	OUVs in field of vision	Impact
A boat on Heddalsvatnet lake	Hydro Industrial Park, the seafront, Admini	Remote/ overview
A train on the Bratsberg Line	Hydro Industrial Park, Admini	
Tveiten – Brattrein	Hydro Industrial Park, Admini	
Eikeskartoppen peak	Hydro Industrial Park, Admini, Villamoen	
Tinneberget	Hydro Industrial Park, Grønnebyen, Villamoen	
Ramsflog	Hydro Industrial Park, Grønnebyen, Villamoen	
Vestsidavegen Rd	Hydro Industrial Park, Grønnebyen, Villamoen	
Våladalen valley, 'the dam'	Notodden Railway Station	Close-up
Notodden Church	Villamoen	
The Admini park	Hydro Industrial Park, Grønnebyen	
Market Square	Grønnebyen	
Grønnebyen	Hydro Industrial Park	
E 134 roundabout	Grønnebyen, Hydro Industrial Park	
E 134 stretch	Railway, Hydro Industrial Park	
Tinnesøyren	Tinfos I and II	
County road, Lisleherad	Svælgfos lightning arrester house and cultural environment	
Railway, Lisleherad	Svælgfos lightning arrester house and cultural environment	

Plan status: Construction activities in the town centre and housing areas, the centre of Gransherad and Tinnoset railway station area are almost completely governed by zoning plans. Other areas are governed by the land-use element of the municipal master plan. Several buildings and some areas in the town centre, including some outside the World Heritage Site, have already been regulated for conservation. The current municipal subplan for the town centre also sets out guidelines for conservation of several buildings and areas from the town's early pioneering period. The Tinfos area is covered by a comprehensive protection order that also includes areas outside the World Heritage Site. A dedicated felling plan has been prepared to restore the view from the Tinnoset Line. A consultation round has been completed on three alternative zoning plan options for the Svelgfossmoen area, affording varying degrees of protection of the old Hydro houses.

Tinn Municipality

The mountainsides along the valley between Møsvatn and Tinnsjøen lakes and verging on Tinnsjøen are part of the buffer zone. The terrain is steep and consists mostly of unbuilt areas not exposed to development pressure. The holiday homes in the area by Kvitåvatn lake, where the development pressure is significant, are mainly at the periphery of the buffer zone, while part of the alpine skiing facility extends down into the buffer zone. Tourism-related developments here may have an impact on the landscape when viewed from Rjukan town centre. None of this is visible from the railway on the valley floor. There is moderate pressure to build holiday homes by Frøystul, although of a more traditional form than those by Kvitåvatn.

Newer parts of Rjukan and the cultural landscape in the valley between Rjukan and Tinnsjøen lake are in the buffer zone. This area is under some development pressure, especially near the town centre and the industrial area in Svadde. Because of the distance to the core values and position in relation to sightlines, the pressure is deemed to be moderate and manageable. By the mouth of Måna at Mæl in Vestfjorden, a proposal to dump rock in the lake has so far been rejected.

Development pressure in relation to sightlines mainly takes the form of varying degrees of vegetation overgrowth.

Sightlines to the central areas and values in Tinn Municipality:
(See also map no 3.1 in Annex 1)

Viewed from	OUVs in field of vision	Impact
Dale – Tuddal county road	Rjukan town and Hydro Industrial Park	Remote/ overview
Krosso Aerial Cableway, Gvepseborg	Rjukan town and Hydro Industrial Park	
Trunk road 37 by Krosso	Rjukan town and Hydro Industrial Park, the New Production Facilities	
Trunk road 37 by Våer	Vemork Power Plant	
Maristigen road	Rjukanfossen, the gorge	
A boat on Tinnsjøen lake	Mæl Ferry Quay and railway station	
A boat on Tinnsjøen lake	Lighthouses	
Market Square	Såheim Power Plant	Close-up
Villaveien	Hydro Industrial Park	
Såheim Power Plant	Tyskerbyen, Market Square	
The Factory Bridge	Villaveien – Flekkebyen	

Plan status: The natural and cultural landscapes are defined as farming, nature and recreation areas in the municipal master plan, or in municipal sub-plans. Built-up areas are regulated by municipal sub-plans. Large parts of the mountainside north of Rjukan belong to the Vestfjorddalen and Øverland nature reserves, which are protected pursuant to the Nature Diversity Act. Some parts of the mountainside to the north-east of Mount Gaustatoppen and down towards the eastern part of Rjukan have been zoned for downhill skiing and holiday cabin construction.

(ii) Environmental pressures

Climate change:

Models used to calculate the impact of climate change as the result of increased global carbon emissions all predict a wetter climate in Norway. There may be some regional differences, but the south-eastern part of the country, which includes Telemark County, is expected to receive more precipitation in the winter, spring and autumn, and to a lesser extent in summer. The average temperature will increase during all seasons. Extreme values can be expected more frequently relating to both precipitation and temperatures. More turbulent weather in general may also involve more frequent periods of strong winds.

The impact of the estimated climate change will be to increase *erosion and overgrowth*. Erosion will have an impact where the landscape is steep, exemplified by the Vestfjorddalen valley. In general, water erosion may also increasingly affect the infrastructure, including railway tracks. A greater number of temperature variations around zero degrees will cause mechanical degradation, which will affect buildings and other man-made structures in particular. Higher temperatures and greater humidity will also increase biodegradation as a result of rot, fungi, insects and other harmful organisms. Woodwork will be particularly exposed. Vegetation tends to take over the landscape, due to a longer growing season combined with a decline in animal husbandry and landscape maintenance.

Pollution:

There is deemed to be little air and water pollution in the area. The threat of such pollution has been reduced in step with the restructuring of particularly industry, but also agriculture. Hydroelectric energy production, which is the dominant industrial activity in the area, does not pollute the natural environment. The energy-intensive processing industry has all but moved to other areas. In the industrial areas, there may be old pollution in the ground, but harmful run-offs to watercourses have not been recorded. Tinnsjøen lake is a source of drinking water. New industrial establishments in the energy-intensive sector will typically focus on clean environment technology. For example, data storage (server farm) has been considered in Rjukan, where favourable factors include a stable climate, and clean water and air for cooling, in addition to a secure energy supply.

Conclusion:

Because the nominated area is located in an inland-climate region, the threat posed by climate change is deemed to be lower than in nearby and more central areas. Ordinary procedures for maintenance of buildings and facilities take account of degradation resulting from environmental threats, but the procedures can be improved. Systematic plans will have to be prepared for vegetation control and maintenance. Beyond this, the nominated World Heritage Site and its buffer zone are exposed to environmental threats in the form of increased risk of floods, landslides and avalanches. These factors are discussed in the section on natural disasters.

(iii) Natural disasters and risk preparedness

The area has a moderate inland climate with wet autumns and cold and relatively dry winters. There are considerable local variations between the metering stations in the area, largely depending on their height above sea level. Notodden stands out with the highest average temperature and lowest precipitation, because it lies furthest to the south and east and belongs to the lowland areas of Eastern Norway. The areas around Møsvatn lake have a cool inland climate with short summers. Mount Gaustatoppen has an extreme climate, with values typical of the Arctic zone. Gaustatoppen also has the most precipitation by far, peaking in autumn and winter. Rjukan in the Vestfjorddalen valley is low in altitude but surrounded by mountains. It benefits from being sheltered and has high summer temperatures. For five to six months of the year, it lies in the shadow of the mountains, however, and the valley can be exposed to powerful katabatic winds.

Natural disasters that may occur include *floods, landslides, avalanches, gusty winds and fire.* For generations, the communities in the nominated area have lived with and adapted to the risk of floods, landslides and avalanches, which means that a form of emergency preparedness exists, among other things demonstrated by the location of the houses. In accordance with developments in society, the responsibility for emergency preparedness has been formalised. Floods are a cyclical phenomenon with an annual rhythm; the variable is the size of the flood, typically described as 50-year, 100-year, 200-year floods etc. The documented increase in annual precipitation and in the amount of snow that falls on the Hardangervidda plateau will increase the size of spring melt-water floods. In the nominated area, flood preparedness is largely ensured through the watercourses being regulated. Facilities for hydroelectric power production, one of the core values in the nomination proposal, ensure that water can be retained and released in a controlled manner to even out the extremes during periods of natural floods or drought. Central government authorities require watercourse regulators to have a regime for the discharge and the flow of water, that is capable of handling defined extreme values.

The risk of dam failure is present, but it has been reduced to a theoretical possibility through dam reinforcement imposed by the authorities. The whole area is geologically stable and the possibility of earthquakes is minimal. Warning systems are in place so that evacuation can be carried out in the time in takes before any uncontrolled discharge of water reaches densely populated areas.

Several geological processes are active in today's landscape. Landslide sediments are deposits formed as the result of rockfall, clay and silt slides triggered by heavy rainfall, slush slides/avalanches or landslides. All occur regularly in the region and leave abundant depositions. Rockfalls and rockslides form 'dry' depositions with a visible texture of rocks and stones. Historically, rock, earth, snow and ice (separately or in combination) have been deposited by landslides, avalanches etc. many times and in several places in the nominated area and the buffer zone. Experience has shown that these are likely to occur after prolonged periods of heavy precipitation (landslides) or heavy snowfall followed by an increase in the temperature (avalanches). In Vestfjorddalen valley, landslides and avalanches occur so frequently that special risk zones are defined in the land use plans.

As regards emergency preparedness in the general sense, the municipalities are responsible for first-line response, while second-line response is the responsibility of the County Governor.

Hydroelectric Power

In the event of a 200-year flood in **Notodden**, the lower parts of the Tinnfoss area will be flooded. Since there is running water in the area, some damage to outdoor areas must be expected. The power plants are inspected regularly, and the municipality assumes that they are designed for large floods and that they therefore will not suffer any damage worth mentioning.

Emergency preparedness:

The enterprises have a normal level of fire preparedness, and the municipality has a 24-hour fire service. Improved warning procedures are now in place for flooding, and movable material can be moved to higher areas in the event of a flood. No procedures are so far in place to secure the buildings prior to a flood.

In **Rjukan**, some of the production plants are in an area potentially at risk of landslides and avalanches.

Emergency preparedness:

The energy company has emergency response plans and procedures in place. Environmental threats appear to be limited to the risk of landslides and avalanches. General procedures are in place for monitoring and removing debris in connection with heavy precipitation.

ID no	Attribute	Flood	Avalanche / landslide	Fire	Gusty winds
1	Tinfos power plants	Low risk	-	-	-
2	Hydro's power plants in the Tinnelva river, Svelgfoss lightning arrester house	-	-	-	-
3	Vemork Power Plant with the Skarsfoss Dam	Medium risk	-	-	-
4	Såheim Power Plant	-	Low risk	-	-
5	Regulating dams	Low risk	-	-	-
6	Power transmission	-	Low risk	-	-

Industrial areas

Notodden:

Some of the industrial activity in the area involves the use of chemicals and other processing materials that may give rise to unfortunate situations. The threat is particularly associated with fires in buildings. The buildings are mainly constructed of concrete/brick and steel and are thus not easy to ignite. Steel structures may nonetheless be affected by heat and be deformed, which in the worst case could cause buildings to collapse.

Floods are a natural disaster to be expected and will submerge parts of the area from time to time. It is estimated (NVE, 2002) that a 200-year flood will flood the whole area except the two buildings in the north-western corner of the park. In the event of such a flood, the water will rise up to approx. 1.5 metres above the floor in the most exposed buildings near the lake. Water will enter the lowest-lying buildings even in a 50-year flood.

The impact of a flood exceeding a 200-year flood and dam failure, a large rockslide into Tinnsjøen lake or blocking of the Sauheradelva river by a large landslide/avalanche may be major, but these events are currently considered so unlikely that no preparedness has been established for such an emergency.

Emergency preparedness:

The whole Hydro Industrial Park is defined as a special fire object – class C pursuant to Norwegian fire safety legislation, which means that the buildings are classified as being of great historic value and that the enterprises are required to implement special fire-technical measures, including training and drills. The fire service also has a duty to carry out inspections every year. Improved warning procedures are now in place for flooding, and movable material will be moved to higher areas. No procedures are so far in place to secure the buildings prior to a flood.

Rjukan:

Large parts of the town of Rjukan have been mapped in relation to the risk of landslides and avalanches. (Geological Survey of Norway report 2004.023: *'Skredfarekartlegging i Vestfjorddalen'* – *'Landslide susceptibility mapping in Vestfjorddalen valley'* – in Norwegian only.) The mapping shows that a relatively large part of the housing is within risk zones that fail to satisfy the Planning and Building Act's requirements for the safety of new buildings. In quantitative terms, landslides/avalanches represent the biggest risk. Uncertainty factors associated with large rockslides are not taken into account when the risk zones are defined.

Emergency preparedness:

The risk zone maps are important tools in preparing land use plans and emergency response plans, and in planning safety measures. The report's recommended emergency response measures have or will be implemented. Parts of the industrial area are regulated with a zone requiring special consideration in relation to the risk of landslides/avalanches. The zoning plan for Rjukan Industrial Park includes the construction of landslide/avalanche protection before new industrial buildings can be built.

There are two processing enterprises (Yara Praxair and Eka Chemicals) in Rjukan, which produce gases and hydrogen peroxide. We know of one accident involving a gas explosion, which occurred in 1968. The enterprises are now required by regulation to have very stringent and extensive safety procedures relating to both production and transport. Yara Praxair and Eka Chemicals are also deemed to be special fire objects. Yara Praxair in Rjukan Industrial Park is subject to regulations on major accidents that set out a requirement for round-the-clock watch-keeping, and a dedicated and specialised industrial safety organisation. The Directorate for Civil Protection and Emergency Planning (DSB) is the supervisory authority.

ID no	Attribute	Flood	Avalanche/ landslide	Fire	Gusty winds
7	Hydro Industrial Park in Not-odden	Minor to major risk	-		-
8	Hydro Industrial Park in Rjukan	-	Low risk		-
3	Production equipment	-	-		-

Transport system

Notodden:

In the event of a flood, Heddalsvatnet lake will affect the lower railway plateau (Notodden old railway station and the Railway Quay) and Hydro Industrial Park in the same way. Vålabekken stream, which flows through the station area, represents a threat. The stream flows overground down to the north-western corner of the station area and continues in a closed culvert down to the level of Hydro Industrial Park. In summer 2011, large parts of the railway area was washed away when the stream found a new course during a flood after a prolonged period of rain. In the event of an exceptionally large flood (1 000-year flood) in Tinnsjøen, surface water will overflow the track of the Tinnoset Line and may cause extensive damage at Tinnoset. Buildings and installations on the station, ferry quay and slipway may also be damaged by flowing water.

In summer 2011, large parts of Notodden railway station was washed away, when the stream found a new course during a flood after prolonged period of rain. The area was rebuild and flood protection improved.
Left photo: Unn Yilmaz. Right photo: Eystein M. Andersen.

Emergency preparedness:

The municipality is currently working on measures relating to Vålabekken stream. The estimated recurrence interval for a damaging flood event at Tinnoset is so long that no particular emergency response measures have been initiated to prepare for such an event.

Rjukan:

Part of the Rjukan Line's track runs through an area mapped as potentially at risk of landslides and avalanches. The Vemork track is particularly exposed to avalanches/land-slides. Gusty winds from the high mountains have caused accidents before. In 1926, a train with wagons was blown off the track near Miland. This led to the erection of a 350-metre long wind wall in 1927.

Emergency preparedness:

General procedures are in place for monitoring and removing debris in the event of heavy precipitation.

ID no	Attribute	Flood	Avalanche / landslide	Fire	Gusty winds
10	The Tinnoset Line	Medium risk	-		-
11	The Rjukan Line, including the ferry section	-	Low risk		-

Company towns

Notodden:

Marine clay has been found to exist under Villamoen, with an associated risk of clay and silt slides. The areas in question are otherwise not known to be under threat of damage from any other natural events. The buildings are wooden and may be exposed to fire in the same way as other such buildings.

Emergency preparedness:

The fire and rescue services are organised in accordance with norms for towns of this size. No special emergency response measures have been initiated over and above a 24-hour fire service. However, the Admini buildings are defined as a special fire object – class C pursuant to Norwegian fire safety legislation (cf. section 4.b – III, 1 above). The municipality is in the process of preparing an expert report on ground conditions in connection with the ongoing planning work relating to Notodden town centre.

Rjukan:

Part of the town is in an area mapped as potentially at risk of *landslides and avalanches*. cf the section above for Industrial areas.

Rjukan is a town with many timber houses and may be at risk of *fire*. In parts of the town, the buildings are far apart, which lessens the risk of a fire spreading. Large brick housing complexes dividing the length of the town (the Sing-Sing quadrant) were designed to serve as fire barriers. Strong winds in the valley can have an adverse impact on the spread of fire.

Risk preparedness

The risk zone maps are important tools in preparing land use plans and emergency response plans, and in planning safety measures. The emergency response measures recommended in the geological report have or will be implemented. Emergency response plans have been prepared. Precipitation is recorded using a separate meter, and procedures are in place for inspection and removal of debris from streams after heavy precipitation.

The fire preparedness in Rjukan is generally good. The fire service in Tinn Municipality is on duty 24/7 and has 10 minutes' response time from the service is notified until it is in operation at the scene of the fire. A requirement for rapid response (10 minutes) applies to three types of risk objects:

- built-up areas exposed to a particular risk of rapid and extensive fire spread
- hospitals/nursing homes etc. (care institutions that require assisted escape)
- areas of concentrated and extensive business/industrial activity etc.

Requirements for response time are decisive in relation to where fire stations are located. When planning new objects or converting old objects of the type mentioned above, the municipality must take the fire service's response time into consideration. According to the fire regulations, the response time may be longer in specific cases if measures have been implemented to compensate for the increased risk. The municipality must document how this has been done. The response time in built-up areas must otherwise not exceed 20 minutes. Response in other than built-up areas is divided between the services in the region to ensure complete coverage. In such cases, the response time should not exceed 30 minutes.

The network of fire hydrants for water extinguishing is extensive, especially in the upper part of the town. The fire service inspects a total of 60 special fire objects, many of them historic buildings. Some of the protected and historic buildings in Rjukan are fully or partially protected by sprinkler systems (the Rjukan House, Såheim Power Plant, the Town Hall, Mannheimen etc.) The fire service in Rjukan prepares fire response plans for special objects. Protected buildings and historic areas can be included in such plans.

ID no	Attribute	Flood	Avalanche/ landslide	Fire	Gusty winds
12	Notodden Hydro Town	-	-	Medium risk	-
11	Rjukan Hydro Town	-	Low risk	Medium risk	-

To the left: Some fire hydrants of the distinctive Rjukan type have been equipped with modern internal component as a trial project to preserve the hydrants instead of replacing them with new models.
To the right: Fire ladders were placed in strategic locations , and many of them are still in place. Photos: Bjørn Iversen.

(iv) Sustainable tourism

Description of the current situation for the area in general

Telemark has long-standing traditions in tourism and became an international and national tourist destination at an early stage. This was due to its dramatic scenery with special attractions, of which the Rjukanfossen waterfall and Mount Gaustatoppen were among the most important. Tourism contributed to the development of transport links, both roads and shipping. In addition to posting stations, large timber hotels were built where the routes met. Located at the end of the Telemark Canal's eastern course and near an important overland route between Eastern and Western Norway, Notodden received many visitors as an important transit and transfer location. This has changed significantly with today's travel patterns. There are currently no big tourism enterprises in Notodden. In the upper parts of the county, especially in Tinn and the neighbouring municipality of Vinje, travel and tourism are still an important part of business and industry. In Tinn, about 40% of the tourists are non-Norwegian. Danes represent the biggest market in winter, while people from Germany and the Netherlands dominate during summer. In Tinn, the Gaustablikk area has gone through a massive development as a year-round destination, with hotels, apartments and high-standard cabins. It has a modern alpine skiing facility with 12 ski lifts and many downhill runs. Telemark has nonetheless lost market shares to other big tourism counties with the passage of time.

Notodden

Notodden is a typical area that travellers pass through and lacks significant visitors' attractions. This is true of the town itself and of the municipality as a whole. Heddal stave church (by the E 134 road) receives a substantial number of day visitors during the tourist season (approximately 20 000 paying visitors). What used to be the biggest tourism enterprise in the area, the tourist and conference hotel in Bolkesjø, has now closed down. Both the town and the municipality offer limited accommodation, through the capacity for receiving day visitors is extensive. It its overriding planning strategy, the municipality has decided to prepare a 'strategic tourism plan' as a separate municipal sub-plan by 2014, with a view to attracting more visitors to the municipality.

Notodden Municipality – Overnight stays at hotels, campsites and rental cabins[1]

Market	Overnight stays at hotels		Overnight stays at campsites and in rental cabins	
	2000	2009	2011	2012
Total	58 068	21 835	72 984	87 152
Norwegians	51 963	20 606	65 258	74 166
Foreign nationals	6 105	1 229	7 726	12 986
Sweden	594	205	570	681
Denmark	279	145	751	1 121
Finland	15	46	68	100
Iceland	0	60	16	1
The UK	76	20	39	253
The Netherlands	1 468	82	2 531	4 034
Germany	987	271	2 424	3 845
France	133	80	116	139
Switzerland	1 670	12	111	297
Italy	61	112	48	108
Poland	3	20	349	306
Lithuania	0	0	365	1 092
Other countries in Europe	50	81	306	869
The USA	135	43	16	112
Other countries	508	9	16	22

1 http://www.statistikknett.com/telemark/

No figures exist for overnight stays at hotels in Notodden Municipality after 2009. Figures from 2000 have been included, as they give a clear picture of a downward trend. Overnight stays at campsites and in rental cabins show an increase in recent years, however. The high figures for campsites/cabin rental to people from Poland and Lithuania probably include job-seekers, including seasonal agricultural workers (berry-pickers etc.). Notodden receives many visitors during the annual blues festival.

The general conclusion for Notodden in terms of visitors and tolerance limits is that the town has the capacity to accommodate a substantial increase. It has infrastructure that previously accommodated a larger number of visitors than today, and that can be re-established. The town's spatial structure is robust. Increased tourism could potentially stimulate activities within sustainable limits.

Rjukan and Tinn

Rjukan attracts many tourists. In recent years the trunk roads from the east, west and south have been significantly improved to a good standard, and they have sufficient capacity to accommodate through-traffic in the summer season. In summer, the tourism is related to nature-based experiences, war history and industrial history. In winter, the tourism is related to nature-based experiences, skiing and ice-climbing. In the cabin areas there are holiday homes that during some periods house a population as big as the municipality's regular population, not least in winter. Tourism is a strategic focus area in Tinn Municipality. Reference is made to the description of the municipality's travel and tourism strategy in sections 5.h and 5.i.

Tinn Municipality –Total overnight stays at hotels, campsites and rental cabins[2]

Market	Number Overnight stays			Share of the regional market	Share of the Norwegian market
	2010	2011	2012	2012 %	2012 %
Total	149 917	143 216	125 904	1.8	0.4
Norwegians	90 810	89 309	77 618	1.4	0.4
Foreign nationals	59 107	53 907	48 286	2.9	0.6
Sweden	7 384	6 818	4 581	1.6	0.5
Denmark	27 073	25 093	24 447	5.3	2.9
Finland	259	190	202	1.3	0.2
The UK	6 450	5 532	3 824	7.5	0.7
The Netherlands	7 261	7 263	6 164	3.1	0.9
Germany	4 831	4 869	5 181	2.2	0.4
France	629	437	524	1.1	0.2
Spain	1 086	754	452	3.6	0.2
Switzerland	229	408	344	1.7	0.2
Italy	321	201	170	1.3	0.1
Eastern Europe	-	1 288	1 302	0.8	0.1
Other countries in Europe		588	625	-	-
The USA	179	168	166	0.7	0.1
Other countries	-	298	304	-	-

2 Taken from http://www.statistikknett.com/telemark/

The figures for Tinn Municipality show a slight decline in the number of tourists, both from Norway and abroad. Most of the accommodation capacity is found in the mountains, by Kvitåvatn/Gaustablikk and the Møsvatn Dam in areas bordering on the World Heritage Site's buffer zone, and in Rjukan town. Most of the tourists who spend the night in the mountain areas also visit Rjukan, for access/thoroughfare and/or shopping and services.

In Rjukan, the **Krosso Aerial Cableway** carries approximately 60 000 passengers a year. A new café building has been erected at the upper station Gvepseborg.

Traffic on the **Gaustabanen funicular** which runs inside the mountain to an altitude of 1 800 metres has reached approximately 25 000 passengers a year. Equally many make the journey to Mount Gaustatoppen on foot.

At Gaustablikk, there is a mountain lodge and alpine skiing facility. Corresponding facilities are found at Møsvatn (Skinnarbu), and at Vierli and Rauland in Vinje Municipality. The 'M/B Fjellvåken' boat service on Møsvatnet lake departs from Skinnarbu near the Møsvatn Dam.

The general conclusion for Rjukan in relation to visitors and tolerance limits is that the town has the capacity to accommodate an increase without negative consequences. There is infrastructure with great capacity close by. The town's spatial structure is robust and spacious. Increased tourism could potentially stimulate activities within sustainable limits.

The view towards Rjukan from the lift at Gaustablikk Ski Centre. Photo: Marianne Folmer.

Description of the current situation for the nominated areas and objects in particular

Hydroelectric power

Notodden

The number of visitors to the *Tinfos area* varies considerably. The football pitch currently receives the highest number of visitors, followed by the public swimming pool and Tinnesøyren park area. These are visits targeting activities and areas unrelated to the proposed World Heritage. More relevant is the Lysbuen Museum and Art Gallery in the former paper factory, which currently receives between 10 000 and 15 000 visitors per year. These visitors have a cultural interest in the place and may also be interested in the World Heritage issue. Now that Hydro's Industrial Museum has moved into Lysbuen Museum and

Gallery (2013), it is estimated that synergies will increase the number of visitors to this complex to about 20 000 a year. The building in which Lysbuen is located is on the edge of the World Heritage Site and, as a result of the short distance, visitors can be expected to also visit the World Heritage Site. A likely long-term effect of obtaining World Heritage status provides a basis for increasing the number of visitors to approximately 25 000.

Other parts of the power plants receive few visitors and the number will probably not increase much even if World Heritage status is granted. The timber flume from Lisleherad to the Tinfos area has a certain potential for more visitors if active steps are taken to facilitate this, provided that the flume is not allowed to deteriorate further and steps are taken to repair it.

Capacity: The area assumed to attract most visitors is the Tinnfoss area with Lysbuen Museum and Gallery. The buildings that are inside the proposed World Heritage Site are the two old power plants. They are currently not open to the public, but as old industrial buildings, they are able to withstand a substantial number of outdoor visitors. The estimated number of visitors is well within the buildings' tolerance limits.

Tinn and Rjukan

The Norwegian Industrial Workers Museum in Vemork Power Plant receive approximately 30 000 visitors a year. The power plant is in a spectacular location some distance from the town centre. There is limited parking in the area. During the high season in summer, access is facilitated by a vintage bus across the suspension bridge over the gorge. Såheim Power Plant has access to the premises that used to house Birkeland/Eyde furnaces. They are used for sports activities (ball games, climbing etc.), among other things. The generator hall is normally not open to the public. The noise level is high, and requirements for access to turbines take up much of the floor space, but the premises have great potential for dissemination purposes, such as storage and a display of unique production equipment. The underground turbine generator hall (generator set 12), accessible via the penstock shaft, has similar potential.

Mår Power Plant (supporting value), which is in a cavern in the buffer zone, is owned by Statkraft and opened for visitors during summer.

Capacity: Vemork, which houses the Norwegian Industrial Workers Museum, can accommodate far more visitors than today. Other power production plants are accessible and visible, but they lack an organised visitor scheme. Safety restrictions may apply to dams and other installations, but the area is generally accessible as far as to the safety zones.

Industrial areas

Notodden

Unlike in the manufacturing era, no access restrictions currently apply to Hydro Industrial Park, which is largely accessible. The Hydro area used to accommodate Hydro's corporate history collection, which had regular opening hours and between 2 000 and 3 000 visitors a year. This collection has been moved into Lysbuen Museum and Gallery (see above). This means that the Hydro area will lose one of its attractions. Hydro Industrial Park nonetheless has great potential for dissemination of industrial history and the company's history. The area is spacious and robust, with attractive areas verging on Heddalsvatnet lake. The number of visitors will depend on what activities and services are established here, and the extent to which the individual buildings are made available to the public. If World Heritage status is granted, it is assumed that the number of visitors will be maintained. The estimated number of visitors is 2 000–3 000.

Capacity: The area is a robust industrial area that technically speaking will be able to sustain a substantial number of visitors without damaging the buildings or the area in general. In the event of a large influx of visitors, some areas may be closed off to tourists for safety reasons associated with the current industrial activities (traffic and forklift truck driving).

Rjukan

Unlike when Hydro operated the factories, no access restrictions currently apply to Hydro Industrial Park, and it is mostly accessible with the exception of the New Production Facilities, which Yara Praxair uses for gas production. Hydro Industrial Park has great potential for dissemination of industrial history and the company's history in Rjukan. The area is spacious and robust. The number of visitors will depend on what activities and services are established here, the extent to which the individual buildings are made available to the public, and any safety/security needs that new industrial establishments may have.

Capacity: The industrial area is robust and able to tolerate many visitors. Part of the area must be expected to remain off limits to the public because of safety regulations

Transport system

Notodden

The number of visitors will vary greatly, but the area could potentially attract a substantial number of visitors if railway and ferry activities were offered (train and ferry trips). If not, the number of visitors will probably be highest in the railway area in Notodden, with figures corresponding to the Hydro area, while they must be expected to be considerably lower further north. At the lower end of the scale are the lighthouses, most of which will be largely inaccessible with close to zero visitors.

Tinnoset Station will be a hub in the area of the World Heritage Site, and if 'M/F Storegut' remains moored here, the estimated number of visitors will be about half as many as in the railway area – i.e. between 1 000 and 1 500, even if there is no ferry/railway traffic. There is currently no basis for specifying the number of visitors that would be attracted by train/ferry operations.

Work is under way on establishing Notodden Railway Centre in the new railway station in Notodden. Activities will include Notodden as a basis for historical train journeys in Norway and as the centre for repairing and restoring historical railway rolling stock. Infrastructure is in place for combined trips by vintage train and boat, including through the nominated area, for example from Lower Telemark – where the port of Brevik can accommodate cruise ships – or from the Oslo area. Combining such trips with trips by tourist boats on the Telemark Canal will provide several opportunities for round trips, with World Heritage sites and historical means of transport as attractions.

Capacity: The railway areas are built for passenger traffic and have a tolerance limit that far exceeds all realistic estimates relating to the future number of visitors.

Tinn and Rjukan

The number of visitors will vary greatly, but a substantial numbers of visitors could potentially be attracted if railway and ferry activities were offered (train and ferry trips). In either case, the number of visitors will probably be highest at Mæl, where the railway and ferry meet and where buildings and areas can accommodate visitors' facilities. 'DF Ammonia' will be berthed at Mæl. Rail bikes for rent are already on offer at Mæl (Tinnsjø Kro) for cycling on the Rjukan Line. At the lower end are the lighthouses, which will be largely inaccessible with close to zero visitors.

There is currently no basis for specifying the number of visitors that would be attracted by train/ferry operations.

Capacity: The railway areas are built for passenger traffic and have a tolerance limit that far exceeds all realistic estimates relating to the future number of visitors. Compared with how the railway was originally used, with round-the-clock transport of heavy loads and many passengers, future tourism traffic will be modest and will as such not represent any serious threat. Controlled access to 'DF Ammonia' can also be arranged regardless of whether the vessel is certified for sailing with passengers. Capacity limits will have to be defined out of consideration for the risk of wear and tear.

Company towns

Notodden

Grønnebyen and Villamoen are used as ordinary housing areas, with access to streets and squares. The history group's house in Grønnebyen has been open to the public in recent years, but only on request and based on voluntary work. The most recent visitor figures are from 2002, with approximately 700 visitors. It is reasonable to assume that the number of visitors will be about the same as in the Hydro area, since it is likely that the same people are interested in both areas – i.e. approximately 2 000–3 000. No figures are available that can say anything certain about the number of visitors that are attracted to the town area. In general, the number of visitors in Notodden town centre varies strongly with the events that take place. At the upper end of the scale is the Blues Festival, which attracts more than 20 000 paying visitors in the course of 3–4 days, while few or no tourists visit the town on weekdays outside the tourist season. A new culture centre ('the Book and Blues House') has been built on the ironworks site, in the immediate vicinity of Hydro Industrial Park.

Capacity: The areas mostly consist of private properties that visitors will not naturally enter. Visitors will stay on the streets, where the capacity for receiving visitors is very high. The capacity in the history group's house can easily be regulated by adjusting the opening hours.

Rjukan

The streets, squares and parks in the various parts of Rjukan are accessible to the public. No figures are available that can say anything certain about the number of visitors to the area. It will vary greatly with what the events that take place. The accommodation capacity in the town of Rjukan is somewhat limited. The number of guest nights at hotels is approximately 100 000, while the number of overnight stays in rental cabins is approximately 50 000 (figures from 2010). The town has a lot of through traffic in summer, consisting of day visitors or tourists en route to or from the fjords of Western Norway.

Capacity: The areas mostly consist of private properties that visitors will not naturally enter. Visitors will stay on the streets, where the capacity for receiving visitors is very high. The current level of tourism does not represent a threat to the World Heritage values. It also seems unrealistic that the number of visitors should increase so much that the World Heritage values would be at risk.

(v) Population in the area and buffer zone

The official population statistics are based on areas defined by Statistics Norway used in population censuses. These units do not correspond to the borders of the proposed World Heritage Site. Certain calculations can be made on the basis of the number of housing units in the area of the World Heritage Site. In theory, the same calculations can be made for the buffer zone, but with considerably greater uncertainty, since the buffer zone consists mostly of Notodden's coherent urban agglomeration and the newer parts of Rjukan (the post-war period expansion of the agglomeration), in addition to large areas that are very scarcely populated and partly uninhabited.

Notodden

The area for power production (Tinnfoss) comprises a tenement building of 12 flats, one small institution, 35 detached houses (Kanalveien – Lienveien) and 29 small houses (Hyttebyen). Assuming that there are 2.5 people per detached house and 1.5 per small house and per apartment, plus eight in the institution, the total number of residents in the area is *approximately* 160. There are no residents in the industrial area (Hydro Industrial Park). As far as we know, Notodden Railway Station (three houses) is the only place with residents within the transport system. Based on the same assumption regarding the number of people per housing unit (2.5), eight people must be assumed to live here. The Hydro district of Grønnebyen comprises a total of 25 two-family houses and three detached houses. Assuming that there are 2.5 residents per detached house and 1.5 residents per two-family house, approximately 82 people live here. Villamoen currently has 20 houses in the area of the World Heritage Site. Based on the same assumption regarding the number of people per housing unit (2.5), the area is home to approximately 50 people.

Notodden	Tinn-foss	Hydro Industrial Park	Railway stations	Grønnebyen housing area	Villamoen housing area	Total
Estimated number of residents	160	0	8	82	50	300

Based on the above estimates, the total number of inhabitants in the area of the World Heritage Site is around 300. Based on the distribution between areas defined by Statistics Norway in the most recent census (2001), the estimated population in the buffer zone on the periphery of the World Heritage Site is around 6 300 people.

Rjukan

Areas defined by Statistic Norway; nos. 305, 306, 307, 308, 309, 310 and 312 roughly cover the nominated Rjukan Hydro Town, 314 covers the houses in Våer/Vemork and 313 (called Veset) covers the area between Våer and Rjukan. Area no 207 (Rollag) covers the built-up area at Mæl, in addition to Rollag and Håkanes. By adding up the figures from the 2001 census (the most recently published), we get a very roughly estimated population figure of 2 700 for the nominated area in Tinn Municipality.

The buffer zone comprises basic statistical units nos 101, 105, 205, 206, 207, 315, 317, 318 and 319. The houses at Mæl that are in the area of the World Heritage Site must be deducted from unit 207. This gives a total of almost 850 inhabitants in these areas.

Population in Notodden and Tinn municipalities, in the coherent urban areas of Notodden and Rjukan, and in Mæl and Våer in Tinn

Year	Notodden (the town)	Notodden Municipality	Rjukan (the town)	Mæl	Våer (Ve-mork)	Tinn Municipality
2001	8 321	12 343	3 616	171	65	6 490
2011	8 762	12 396	3 277			6 037

5 PROTECTION AND MANAGEMENT OF THE SITE

5a. Ownership

Ownership in the area of the World Heritage Site

The power plants and industrial areas are mainly owned by private enterprises. The transport systems in Notodden are owned by the Norwegian State, and in Rjukan mainly by museums. The cultural heritage associated with the company town is mainly in private ownership. Many of these are organised as housing cooperatives. (A housing cooperative is a cooperative enterprise that aims to provide shareholders with the right to occupy their own home on the enterprise's property. The housing cooperative is a separate legal entity, organised the same way as a limited company.)

Overview of ownership of the attributes in the area of the World Heritage Site:

ID no	World Heritage attribute	Ownership
Hydroelectric power		
1	Tinfos power plants	Private (business)
2	Hydro's power plants in the Tinnelva river	Private (business)
3	Vemork Power Plant	Private (business)
4	Såheim Power Plant	Private (business)
5	Regulating dams	Private (business)
6	Power transmission	Private (business)
Industry		
7	Hydro Industrial Park in Notodden	Private (business)
8	Hydro Industrial Park in Rjukan	Private (business)
9	Production equipment	Private (business) Public (municipality) Private (museum)
Transport systems		
10	The Tinnoset Line	Public (state)
11	The Rjukan Line	Private (museum) Private (business) Public (state)
Company town		
12	Notodden Hydro Town	Private (individuals) Private (business)
13	Rjukan Hydro Town	Private (housing cooperative) Private (individuals) Private (business) Public (state, municipality)

Ownership in the buffer zone

Notodden Municipality

Ownership in the buffer zone is largely held by private individuals and housing cooperatives. There are also some bigger properties that are owned by private enterprises. The state owns the national road, the municipality owns several private properties, while the natural areas are in private ownership.

Tinn Municipality

There are extensive natural areas in the buffer zone that are in state and private ownership.

5b. Protective designation

Legal tools, legislation

The most important law relating to the protection of the World Heritage Site and the buffer zone is the Planning and Building Act. The Act was recently revised, and the new Act entered into force on 1 July 2009. In addition, special acts are relevant for the protection of the World Heritage Site and the buffer zone. This applies in particular to the Cultural Heritage Act. The Nature Diversity Act also contains provisions that may be of relevance for the protection of natural areas, especially the buffer zone. The Energy Act and other acts and provisions relating to watercourse regulation and power transmission are relevant for the power production plants.

The Planning and Building Act. Act relating to planning and the processing of building applications, last amended on 8 October 2012.

The Act shall promote sustainable development in the best interests of individuals, society and future generations. Planning pursuant to the Act shall help to coordinate government, regional and municipal tasks and form the basis for decisions relating to the use and protection of resources. Processing of building applications pursuant to the Act shall ensure that measures are in compliance with laws, regulations and planning decisions. Planning and decisions shall ensure transparency, predictability and participation for all affected parties and authorities. Emphasis shall be placed on long-term solutions, and consequences for the environment and society shall be assessed.

The aesthetic design of the surroundings shall be taken into account in planning and in individual building projects. The same applies to the principle of universal design.

The Act emphasises early involvement to ensure that cultural and natural values are protected. Within areas that are regulated for the purpose of conservation, and within the new Planning and Building Act's equivalent zones requiring special consideration, all building applications shall be referred to the regional cultural heritage authority for consideration before a building permit is granted. In order to preserve areas and buildings that are not protected or regulated, the municipalities are able to prohibit building work and the subdivision of plots or buildings in anticipation of zoning plans, in order to prevent the loss of cultural history values. This ensures that the municipalities have sufficient control, with the exception of projects that do not require a permit.

If a higher administrative level learns that a municipality has failed to attend to this responsibility as provided for by law, it may raise objections to the plan. This entails mediation, and matters are often resolved using this method. If the matter is not resolved, a final decision is made by the Ministry of Local Government and Modernisation.

There are three ways of protecting cultural heritage, cultural environments and landscapes through municipal master plans:

- Zones requiring special consideration, with provisions or guidelines, Section 11-8
- Provisions relating to land-use objectives, Sections 11-10 and 11-11
- General provisions, Section 11- 9

There are three ways of protecting cultural heritage, cultural environments and landscapes through zoning plans:

- Land-use objectives (agricultural, nature and outdoor recreation objectives) with the sub-objective for the protection of cultural heritage sites and monuments and cultural environments, Section 12-5 (5)
- Zones requiring special consideration with provisions, Section 12-6
- Provisions relating to land-use objectives, Section 12-7

The Cultural Heritage Act. Act of 9 June 1978 no 50 relating to cultural heritage, last amended on 19 June 2009.

The purpose of the Act is to protect cultural heritage and cultural environments in all their variety and detail, both as part of our cultural heritage and identity and as an element in the overall environment and resource management. It is a national responsibility to safeguard these resources as scientific source material and as an enduring basis for the experience of present and future generations and for their self-awareness, enjoyment and activities.

The purpose of the Act must also be taken into account in any decision taken pursuant to another act that may affect the cultural heritage resources.

- The Cultural Heritage Act Section 14

The State shall have right of ownership of boats that are more than 100 years old, ships' hulls, gear, cargo and anything else that has been on board. Excavating any such findings from ships is prohibited, as are other measures that could cause damage to the object. This is a strong protective measure, although the finding itself is not protected as such.

- The Cultural Heritage Act Section 14 a

provides for the protection of boats, irrespective of age, if these have a particular cultural history value.

- The Cultural Heritage Act Section 15

provides for the protection of structures and sites or parts of these that are valuable from an architectonic or cultural history perspective. The protection order includes fixed inventory. The Act also provides for the protection of large pieces of movable furniture. The protection order may prohibit or otherwise regulate all measures that may counteract the purpose of the protection.

D/F Ammonia and M/F Storegut are both protected by The Cultural Heritage Act. Photo: Alexander Ytteborg

- The Cultural Heritage Act Section 19

provides for the protection of an area around a protected monument or site if this is necessary to preserve the effect of the monument in the environment or to safeguard scientific interests associated with it.

The Directorate for Cultural Heritage is the body that makes decisions pursuant to Sections 14a, 15 and 19. Before a decision is made, the owner, municipality and county authority shall give their comment on the case. The decision can be appealed to the Ministry of Climate and Environment.

- The Cultural Heritage Act Section 20

provides for the protection of a large-scale cultural environment. Following extensive consultation with owners, the municipality, the county authority and government agencies with an interest in the area, the final decision shall be made by the King in Council. Such decisions cannot be appealed.

- The Cultural Heritage Act Section 22a

provides for the protection of state-owned structures and sites. Cases are processed in accordance with the provisions of the Public Administration Act's Chapter VII regarding regulations. It is a condition that the state owner and the Directorate for Cultural Heritage are in agreement. The decision cannot be appealed.

Pursuant to Section 22.4 the Directorate for Cultural Heritage and the county authority can impose a temporary protection order if a cultural heritage monument or site is threatened by demolition or extensive alteration. A permanent protection process must then be initiated immediately.

All changes of importance to the cultural history values must be considered by the cultural heritage authority. Formal decisions are made pursuant to Section 15 a. They can be appealed. The appeal case will be considered at a higher government administrative level.

The Act provides long-term protection and safeguards the cultural history values.

Royal Decree of 15 August 2006

The protection of state-owned cultural heritage is the responsibility of the individual state sector. Pursuant to the Royal Decree of 15 August 2006, all state owners are obliged to prepare a protection plan for their properties and to prepare good management plans for the most important of these properties. This provides good administrative protection. The most important properties will be protected pursuant to the Cultural Heritage Act.

The Nature Diversity Act. Act of 19 June 2009 relating to the management of biological, geological and landscape diversity

The Nature Diversity Act is the most important act with regard to nature management. The Act regulates the management of species, protected areas, alien organisms, selected habitat types, and it protects the habitats of priority species. Nature shall be protected through the protection of areas and by ensuring that areas are used sustainably.

The Outdoor Recreation Act. Act of 28 June 1957 relating to outdoor recreation, last amended on 19 June 2009.

The Act regulates the relationship between landowners and the public, and it defines what is meant by cultivated and uncultivated land. Public access is a central element of this act.

The Nature Inspection Act. Act of 21 June 1996 relating to nature inspection (in Norwegian only), last amended on 17 September 2010.

The purpose of the Act is to ensure that nature inspection activities are regulated in a uniform and coordinated manner. Inspections shall supervise that acts and regulations are complied with, and the Act provides guidelines regarding the function of inspection activities. Information and guidance are key elements, as well as upkeep and facilitation in protected areas.

The Pollution Control Act. Act of 13 March 1981 concerning protection against pollution and concerning waste.

The purpose of the Act is to protect the outdoor environment from pollution. The Act shall ensure that the quality of the environment is satisfactory, so that pollution and waste do not result in damage to human health or adversely affect welfare, or damage the productivity of the natural environment and its capacity for self-renewal.

The Concession Act. Act of 28 November 2003 relating to concession in the acquisition of real property, last amended on 27 January 2012.

The purpose of the Act is to regulate and control the sale of real estate in order to achieve an effective protection of agricultural production areas and such conditions of ownership and utilisation as are most beneficial to society, inter alia, in order to provide for: the needs of future generations, the agricultural industry, the need for development sites, consideration for the environment, general interests of nature conservation and outdoor recreation, and consideration for settlements.

The Act relating to regulation of watercourses. Act of 14 December 1917.

The Act applies to the regulation of watercourses. It includes facilities or measures used to regulate the flow of a watercourse, and it also covers the extension or modification of older regulation facilities. Measures that are covered by the Act are also covered by the Water Resources Act if the measures are not covered by particular provisions of the Act.

The Water Resources Act. Act of 24 November 2000 relating to river systems and groundwater, last amended on 27 January 2012.

The purpose of the Act is to ensure the socially proper use and management of river systems and groundwater. According to the Act, any measures in a river system that may be of appreciable harm or nuisance to any public interest must be licensed.

The watercourse authorities will be focusing on a review of terms and conditions in older watercourse regulation concessions over the next few years. Review requirements will be submitted via the municipalities concerned. The main purpose of the review is to improve the environmental conditions in regulated watercourses.

Standard terms and conditions have been included in more recent concessions that provide the legal authority to impose various environmental measures. The Norwegian Water Resources and Energy Directorate (NVE) will include the current standard conditions in all the reviewed concessions. These allow environmental measures to be imposed that do not have any consequences for energy production.

The Energy Act. Act of 1 January 1991 relating to the generation, conversion, transmission, trading, distribution and use of energy etc., last amended on 1 November 2013.

The Act applies to the generation, conversion, transmission, trading and distribution of energy. The Act shall ensure that the generation, conversion, transmission, trading, distribution and use of energy are conducted in a way that efficiently promotes the interests of society, which includes taking into consideration any public and private interests that will be affected. No one but the State may engage in trading in electrical energy without a licence. In case of doubt, the Ministry decides whether a licence is mandatory.

The Act relating to the acquisition of waterfalls, mines and other real estate (the Industrial Licensing Act) of 14 December 1917, last amended on 27 December 2012.

The Act concerns concessions as a condition for the acquisition of waterfalls and mines. The Act also contains provisions regarding the right of reversion of waterfalls on expiry of the concession period, the right of pre-emption for public entities, and the transfer of waterfalls for which concessions have been granted.

The Railways Act. Act of 11 June 1993 on the establishment and operation of railways, including tramways, underground railways, suburban railways etc., last amended on 20 January 2012

The Act applies to the establishment and operation of railways, including tramways, underground railways, suburban railways, and similar modes of guided transport. The Act also applies to fixed and movable appliances that are connected to railway operations.

The Railway Investigation Act. Act of 3 June 2005 on Notification, Reporting and Investigation of Railway Accidents and Railway Incidents etc., last amended on 17 June 2005.

The purpose of the Act is to improve safety and prevent railway accidents through the investigation of railway accidents and railway incidents.

The Norwegian Maritime Code of 24 June 1994

The Act applies to shipping on large inland lakes. In accordance with Regulations no 1451 concerning excise duties, vessels that have been given formal status as historic vessels by the Directorate for Cultural Heritage are exempt from some of the duties. These include VAT on electric power, CO_2 tax on mineral oil duty on heating oil etc., sulphur tax, duty on lubricating oil etc., on products subject to duty that are supplied for the purpose of operating historic vessels, NO_x (nitrogen oxides).

Regulations relating to protected vessels

Each state sector is responsible for environmental challenges in its own area of responsibility. In the Norwegian Maritime Authority's area of responsibility, this applies to historic and protected vessels. The main objective of the regulations is to preserve historic vessels with their original layouts and technical arrangements as far as possible. The Directorate for Cultural Heritage and the Norwegian Maritime Authority are working together to find good solutions that preserve the vessels as cultural heritage monuments and promote safety at sea. When adopted, the regulations will affect two of the World Heritage Site's significant objects: 'D/F Ammonia' and 'M/F Storegut'.

The Road Act. Act of 21 June 1963 relating to roads, last amended on 22 June 2012.

The Act covers roads that are maintained by the State, county authorities or municipalities. The purpose of the Act is to ensure the safe planning, construction, maintenance and operation of public and private roads. The road authorities have an overriding objective to ensure a safe, good quality road transport network, and to consider the environment and other social interests.

The Fire and Explosion Prevention Act. Act of 14 February 2002 relating to the prevention of fire, explosion and accidents involving hazardous substances and the fire services, last amended on 19 June 2009.

The purpose of the Act is to safeguard human life, health, the environment and material assets against fire and explosion, against accidents involving hazardous substances and dangerous goods and other acute accidents or unintentional incidents.

The Anti-Discrimination and Accessibility Act. Act of June 20 2008 relating to the prohibition against discrimination on the basis of disability

The purpose of the Act is to promote equality and ensure equal opportunities for and rights to social participation for all persons regardless of disabilities and to prevent discrimination on the basis of disability.

The Act shall help to dismantle disabling barriers created by society and to prevent new ones from being created.

Table of facilities that are legally protected through the Cultural Heritage Act and the Planning and Building Act:

ID no	World Heritage attribute	Significant objects/ parts	Type of protection
Hydroelectric power			
1	Tinfos power plants		
1.1		Tinfos I with Myrens Dam	The Cultural Heritage Act Section 20 (2013)
1.2		Tinfos II and the Holta Canal	The Cultural Heritage Act Section 20 (2013)
2	Hydro's power plants in the Tinnelva river		
2.1		Svælgfos lightning arrester house	General legislation
3	Vemork Power Plant		
3.1		Power station building	The Planning and Building Act of 1985 Section 20-4
3.2		Penstock	The Planning and Building Act of 1985 Section 20-4
3.3		Penstock valve house	The Planning and Building Act of 1985 Section 20-4
3.4		Skarsfos Dam I with intake gate house	General legislation/the Planning and Building Act of 1985 Section 20-4 (intake gate house)
3.5		Tunnel system with six waste rock dumps	General legislation/the Planning and Building Act of 1985 Section 20-4 (waste rock dumps)

ID no	World Heritage attribute	Significant objects/ parts	Type of protection
4	Såheim Power Plant		
4.1		Power station building	The Cultural Heritage Act Sections 15 and 19
4.2		Underground turbine generator hall	General legislation
4.3		Underground penstock	General legislation
4.4		Tunnel system with seven waste rock dumps	General legislation
4.5		Workshop building	General legislation
5	Regulating dams		
5.1		Old Møsvatn Dam	General legislation
6	Power transmission		
6.1		Cable House	The Planning and Building Act of 1985 Section 20-4
6.2		Control room in Furnace House I	The Cultural Heritage Act Section 15 (2013)
6.3		Transformer and distribution station	The Cultural Heritage Act Sections 15 and 19 (2013)
6.4		Power line 16/17	The Cultural Heritage Act Section 15 (2013)
Industry			
7	Hydro Industrial Park in Notodden		
7.1		Furnace House A	The Cultural Heritage Act Sections 15 and 19 (2013)
7.2		Tower House A	The Cultural Heritage Act Sections 15 and 19 (2013)
7.3		Calcium Nitrate Plant	The Cultural Heritage Act Sections 15 and 19 (2013)
7.4		Packaging Factory	The Cultural Heritage Act Sections 15 and 19 (2013)
7.5		Warehouse A	The Cultural Heritage Act Sections 15 and 19 (2013)

ID no	World Heritage attribute	Significant objects/ parts	Type of protection
7.6		Furnace House C	The Cultural Heritage Act Sections 15 and 19 (2013)
7.7		Testing Plant and Electrical Workshop	The Cultural Heritage Act Sections 15 and 19 (2013)
7.8		Testing Plant and Blacksmith	The Cultural Heritage Act Sections 15 and 19 (2013)
7.9		Laboratory and Workshop	The Cultural Heritage Act Sections 15 and 19 (2013)
7.10		Hydrogen Plant	The Cultural Heritage Act Sections 15 and 19 (2013)
7.11		Nitrogen Plant and Gas Cleaning Plant	The Cultural Heritage Act Sections 15 and 19 (2013)
7.12		The Minaret	The Cultural Heritage Act Sections 15 and 19 (2013)
7.13		Compressor and Synthesis Plant	The Cultural Heritage Act Sections 15 and 19 (2013)
7.14		Nickeling Plant	The Cultural Heritage Act Sections 15 and 19 (2013)
7.15		Ammonium Water (ammonium hydroxide) Plant	The Planning and Building Act of 1985 Section 20-4
8	Hydro Industrial Park in Rjukan		
8.1		Furnace House I	The Cultural Heritage Act Sections 15 and 19 (2013)
8.2		Boiler House	The Cultural Heritage Act Sections 15 and 19 (2013)
8.3		Barrel Factory	The Cultural Heritage Act Sections 15 and 19 (2013)
8.4		Pump House	The Cultural Heritage Act Sections 15 and 19 (2013)
8.5		Laboratory	The Cultural Heritage Act Sections 15 and 19 (2013)
8.6		Såheim II Hydrogen Plant	The Cultural Heritage Act Sections 15 and 19 (2014)
8.7		Nitrogen Plant	The Cultural Heritage Act Sections 15 and 19 (2013)
8.8		Compressor House	The Cultural Heritage Act Sections 15 and 19 (2013)

ID no	World Heritage attribute	Significant objects/ parts	Type of protection
8.9		Synthesis Plant	The Cultural Heritage Act Sections 15 and 19 (2013)
8.10		Mechanical Workshop	The Cultural Heritage Act Sections 15 and 19 (2013)
9	Production equipment		
9.1		Ceramic pots	The Cultural Heritage Act Sections 15 and 19 (2013)
9.2		Electric Arc Furnace, Notodden	The Cultural Heritage Act Sections 15 and 19 (2013)
9.3		Electric Arc Furnace, Rjukan	General legislation
9.4		Acid Tower	The Cultural Heritage Act Section 15
9.5		AEG pump	The Cultural Heritage Act Section 15 (2013)
9.6		Tanks in the Hydrogen Plant	The Cultural Heritage Act Section 15 (2013)
9.7		Synthesis Furnace, Rjukan	The Cultural Heritage Act Section 15 (2013)
Transport system			
10	The Tinnoset Line		
10.1		Railway track with signalling system and overhead line equipment	The Cultural Heritage Act Section 22a
10.2		Notodden old railway station building	The Cultural Heritage Act Sections 15 and 19
10.3		The Railway Quay/Rjukan Quay	General legislation/the Cultural Heritage Act Section 22 a (railway tracks)
10.4		Notodden Railway Station with eight buildings	The Cultural Heritage Act Section 22a
10.5		Tinnoset Railway Station with three buildings	The Cultural Heritage Act Sections 15 and 19

ID no	World Heritage attribute	Significant objects/ parts	Type of protection
11	The Rjukan Line		
11.1		Railway track with signalling system and overhead line equipment	The Cultural Heritage Act Sections 15 and 19 (2013)
11.2		Tinnoset Ferry Quay with six buildings	The Cultural Heritage Act Sections 15 and 19 (2013)
11.3		Slipway with winch house	The Cultural Heritage Act Sections 15 and 19 (2013)
11.4		Lighthouses	The Cultural Heritage Act Sections 15 and 19 (2013)
11.5		Mæl Ferry Quay	The Cultural Heritage Act Sections 15 and 19 (2013)
11.6		Mæl Railway Station with four buildings	The Cultural Heritage Act Sections 15 and 19 (2013)
11.7		Mælsvingen 10-15 with five houses	The Planning and Building Act of 1985 Section 20-4
11.8		Ingolfsland Railway Station building	The Cultural Heritage Act Sections 15 and 19 (2013)
11.9		Rjukan Railway Station building, freight house and engine shed	The Cultural Heritage Act Sections 15 and 19 (2013)
11.10		Såheim engine shed	The Cultural Heritage Act Sections 15 and 19 (2013)
11.11		Vemork railway track	The Cultural Heritage Act Sections 15 and 19 (2013)
11.12		Rolling stock	The Cultural Heritage Act Section 15 (2013)
11.13		'D/F Ammonia'	The Cultural Heritage Act Section 14 a
11.14		'M/F Storegut'	The Cultural Heritage Act Section 14 a
11.15		'D/F Hydro' – shipwreck	The Cultural Heritage Act Section 14

ID no	World Heritage attribute	Significant objects/ parts	Type of protection
Company towns			
12	Notodden Hydro Town		
12.1		Grønnebyen (the 'Green Town') housing area	The Planning and Building Act of 1985 Sections 25-6 and 26
12.2		Villamoen housing area	The Planning and Building Act of 1985 Sections 25-6 and 26
12.3		The Admini (administration) building in Notodden	The Planning and Building Act of 1985 Sections 25-6 and 26
12.4		The Casino with four buildings	The Planning and Building Act of 1985 Sections 25-6 and 26, and general legislation
13	Rjukan Hydro Town		
13.1		Krosso housing area	The Planning and Building Act of 1985 Sections 25-6 and 26
13.2		Krosso Aerial Cableway	The Planning and Building Act of 1985 Section 20-4
13.3		Fjøset farm building with housing	The Cultural Heritage Act Sections 15 and 19 (2014)
13.4		Villaveien-Flekkebyen housing area	The Planning and Building Act of 1985 Section 20-4
13.5		The old town centre	The Planning and Building Act of 1985 Section 20-4
13.6		The Admini (administration) building in Rjukan	The Cultural Heritage Act Sections 15 and 19
13.7		Gatehouse and fire station	The Planning and Building Act of 2009 Sections 12-6 and 12-7-6
13.8		Construction office in Hydro Industrial Park	The Planning and Building Act of 2009 Sections 12-6 and 12-7-6
13.9		Office building in Hydro Industrial Park	The Planning and Building Act of 2009 Sections 12-6 and 12-7-6
13.10		The Rjukan House (the People's House)	The Cultural Heritage Act Sections 15 and 19
13.11		Såheim private school with teacher's residence	The Planning and Building Act of 1985 Section 20-4

ID no	World Heritage attribute	Significant objects/ parts	Type of protection
13.12		Rødbyen (the 'Red Town') and Tyskerbyen (the 'German Town') housing areas	The Planning and Building Act of 1985 Section 20-4
13.13		Market Square	The Planning and Building Act of 1985 Sections 25-6 and 26
13.14		New Town (house type O)	The Planning and Building Act of 1985 Section 20-4
13.15		Baptist Church	The Cultural Heritage Act Section 15
13.16		Rjukan Church	General legislation
13.17		Rjukan Hospital with Chief Physician's residence	General legislation
13.18		Tveito School with five teachers' houses	General legislation/the Planning and Building Act of 1985 Section 20-4 (houses)
13.19		Tveito Park and Tveito Avenue	General legislation
13.20		Mannheimen single men's home and Paradiset housing complex	General legislation/the Planning and Building Act of 1985 Section 20-4 (Paradiset)
13.21		Sing Sing housing quadrant	The Planning and Building Act of 1985 Section 20-4
13.22		Triangelen housing complex in Ligata	The Planning and Building Act of 1985 Section 20-4
13.23		Fabrikkbrua Bridge, Birkeland Bridge and Mæland Bridge	General legislation

Improvements in the statutory protection of the objects pursuant to both the Cultural Heritage Act and the Planning and Building Act are scheduled to take place in the period 2014-16.

5c. Means of implementing protective measures

Follow-up dedicated to the World Heritage Site

Declaration of Intent

The Norwegian Government, Telemark County Council and Notodden, Tinn and Vinje municipalities have signed a declaration of intent, in which they undertake to protect the outstanding universal values in the area. They will also ensure that the buffer zone is protected by ensuring that no permits are issued for measures that will have a detrimental effect on the values of the World Heritage Site. The Declaration of Intent can be found in Annex 3, Management plan.

World Heritage Council

A provisional World Heritage Council is established in order to prepare an agreement securing a permanent organisational structure that will come into effect when World Heritage status has been achieved. The council consists of representatives from the Directorate for Cultural Heritage, the county authority and the municipalities. The representatives include political representatives of both the ruling parties and the opposition, and experts from the administration (World Heritage coordinators). The World Heritage Council shall be a coordinating meeting point for the various management levels and will have an important role in the follow-up of the management plan. The World Heritage Council shall organise annual meeting forums for stakeholders.

Political governing documents

Report to the Storting no 16 (2005–2006) 'Living with our Cultural Heritage'.

In the report to the Parliament, the Government emphasises that Norwegian World Heritage sites should be examples of best practice in terms of protection and management. The Government has determined that management is most effective when applicable Norwegian legislation and public administration systems are used to define the division of responsibility between administrative levels and sectors. A separate management system for the World Heritage Site will therefore not be established.

Report to the Storting no 35 'Future with a foothold' (2012–2013, in Norwegian only)

The report is based on Report to the Storting No 16, and it emphasises that Norwegian World Heritage sites shall be developed as 'beacons of best practice in nature management and cultural heritage administration'. The World Heritage sites shall be assured the best possible condition, management and formal protection. The Ministry of Climate and Environment will organise the World Heritage work so as to ensure that the various authorities coordinate the work of managing the World Heritage Site in an optimal way, ensuring that roles and responsibilities are clarified and that skills, resources and quality are assured. There are plans to set up a ministerial World Heritage Committee. Coordination between government, county authority and local parties shall be made a priority.

All World Heritage sites shall have dedicated management plans. The plans shall describe the parties involved, the roles and responsibilities of each party and the tasks to be performed. Responsibility for the World Heritage sites shall be clearly stated in all relevant municipal master plans and county authority plans. All sites shall be assessed to determine whether they require a buffer zone.

Easy, streamlined reporting to the State shall ensure that the areas are monitored as effectively as possible. Measurable indicators shall be developed for all the World Heritage values.

Presentation of the World Heritage Site shall be improved. The education authorities shall become more involved, and learning about World Heritage shall become part of the curriculum. Supplementary training programmes and a guide for teachers shall be developed. The World Heritage sites shall become a resource for the schools in their region. Training options for craftsmen shall also be provided, in order to increase skills in this area.

The municipalities and other parties involved shall work together to ensure that good-quality centres are developed for the presentation of the World Heritage sites and World Heritage values.

Parties and bodies; their responsibilities and roles

Ministry of Climate and Environment

The Ministry is secretariat for the Minister of Climate and the Environment, and it is the most senior authority on issues concerning cultural heritage protection. The Ministry also submits proposals to the King in Council regarding the protection of areas that are important from a cultural history perspective. It is also the appeals body for resolutions adopted by the Directorate for Cultural Heritage.

Ministry of Petroleum and Energy

The Ministry's main task is to facilitate a coordinated, coherent energy policy. The Ministry is also responsible for managing Norway's water resources and has overall responsibility for preventing all types of floods and landslides/avalanches.

It also has overall responsibility for Norway's power supply. Operational responsibility has been delegated to the Norwegian Water Resources and Energy Directorate, which is the emergency preparedness authority.

Ministry of Transport and Communications

The Ministry of Transport and Communications has overall responsibility for the framework conditions for the railway sector in addition to, among other things, roads and air traffic.

The Ministry manages the following subordinate agencies: the Norwegian Public Roads Administration, the Norwegian National Rail Administration, the Civil Aviation Authority Norway, the Norwegian Railway Authority, the Norwegian Post and Telecommunications Authority, the Cableway Supervisory Authority, the Road Supervisory Authority and the Accident Investigation Board Norway. The Ministry also manages the state's ownership interests in the state-owned railway company NSB AS and Baneservice AS, among others.

Ministry of Culture

One of the main goals of the government's cultural policy is to facilitate cultural diversity. Cultural policy shall promote the protection and presentation of cultural heritage, artistic renewal, and quality and cultural diversity, nationally and internationally. The Ministry is the authority to which most museums in Norway report.

Ministry of Trade and Industry

Among other things, the Ministry has overall responsibility for the travel and tourism industry. A strategy for the travel and tourism industry was prepared in 2012. Among other things, it emphasises the Ministry's work on coordinating travel and tourism policies by establishing a coordination forum. This is in line with the work that the Ministry of Climate and Environment will give priority to in its World Heritage initiative.

Ministry of Education and Research

The Ministry of Education and Research is responsible for kindergartens, primary and lower secondary education, upper secondary education, higher education and research.

Directorate for Cultural Heritage

The Directorate for Cultural Heritage is the Ministry of Climate and Environment's advisory and executive expert agency for the management of cultural heritage and cultural environments.

The Directorate is responsible for providing the Ministry with expert support in its work on cultural heritage protection as an integrated part of environmental protection policy. The Directorate also has an advisory function in relation to other public administrations, the general public and business and industry. In cases where the Directorate exercises authority pursuant to special legislation, it shall base its decisions on both cultural heritage-related considerations and other social considerations.

The Directorate is responsible for ensuring that government cultural heritage policy is implemented, and the institution has overall responsibility for the work of the county authorities, the archaeological museums, the Governor of Svalbard and the Sami cultural heritage council in their roles as regional cultural heritage authorities. Through facilitation and incentive measures, the Directorate shall help the municipalities to devote sufficient consideration to cultural heritage and cultural environments as important local elements and resources.

The Directorate shall ensure that it is possible to use cultural heritage and cultural environments as important learning experiences and for their utility value, as well as helping to provide conditions for sustainable use of natural and cultural heritage resources in a changing society. The objective is to ensure that any changes result in a minimal loss of cultural heritage values.

Norwegian Maritime Museum

The Norwegian Maritime Museum (Norsk Sjøfartsmuseum foundation) is a national institution, the goal of which is to increase knowledge about Norwegian shipping and activities relating to the coast, lakes and river systems. The Museum is responsible for the management of archaeological maritime cultural heritage in the ten southernmost counties in Norway.

The administrative responsibility covers both the coastline and inland fresh water.

Telemark County Authority

Telemark County Authority is a politically controlled administrative body at a regional level. The county authority's most senior controlling body is the County Council. The County Mayor is the most senior political official, while the County Chief Executive is the most senior administrative official.

As the highest body elected by the people, it is the County Council that makes decisions. The representatives are elected every four years in the county council elections, which are held at the same time as local elections. The county authority attends to tasks across municipal borders.

The county authority is responsible for preserving important cultural heritage in its area. It provides advice and guidance to owners who need help to restore/repair their properties. It is also responsible for following up cultural heritage protected by the Cultural Heritage Act by providing advice, making decisions pursuant to the Act and distributing government grants. The work is carried out by a dedicated department consisting of highly skilled professionals in the area of cultural heritage administration. Telemark County Authority will be responsible for much of the day-to-day administration associated with the World Heritage Site.

It has an important advisory role towards the museums and works very closely with them.

The county authority is the closest advisor to the municipalities, and it shall contribute towards their planning work. It shall ensure that cultural heritage is protected and may object to any plans in which it has been insufficiently taken into consideration.

The municipalities

The municipalities are independent, politically controlled entities at the local level. They have the chief responsibility for planning in their area. Through planning pursuant to the Planning and Building Act, they can safeguard objects requiring protection and provide good guidelines for their further management.

In areas that form part of a conservation zone, all building applications shall be submitted to the regional cultural heritage authority for comments before a building permit is granted. This generally ensures that cases are well managed and that the values are protected. Cases concerning protected cultural heritage shall be approved by the regional cultural heritage authority, and this ensures that building applications are very well managed. Facilities that do not fall under either of these two areas are only covered by the general provisions of the Planning and Building Act, which provide relatively weak protection against demolition or modification. However, the municipalities can prohibit building work and the subdivision of plots or buildings in anticipation of new zoning for an area, and this provides greater protection.

Experience shows that it has not always been possible to follow up the provisions as intended, and that exemptions have been granted that have had less desirable results. The development of new plans will help to ensure that these cases are better managed in the area of the World Heritage Site and the buffer zone. World Heritage status will also give the municipalities an argument enabling them to enforce the current provisions better.

Owners

Owners have a very important role in the management of the country's cultural heritage. Their understanding, efforts and initiative are very important if the cultural heritage is to be properly managed. The owners are responsible for maintaining their property pursuant to the Planning and Building Act.

County Governor of Telemark

The County Governor reports to the Ministry of Local Government and Modernisation. The County Governor is the State's representative in the county and is responsible for following up decisions, goals and guidelines from the Storting and the Government. The County Governor carries out administrative tasks and is the appeal body and supervisory authority for several ministries. Each ministry has the power to issue direct instructions to the County Governor in its field. The County Governor's areas of responsibility concerning nature management, rural and land-use planning as well as forestry and agricultural issues are important in relation to the World Heritage Site and the buffer zone.

Norwegian Environment Agency

On 1 July 2013, the Directorate for Nature Management and the Norwegian Climate and Pollution Agency were merged into one agency, the Norwegian Environment Agency. It is an advisory and executive government agency reporting to the Ministry of Climate and Environment. It will contribute expertise to the Government's national and international environmental work and will be responsible for ensuring that the Government's policy is implemented. The agency's areas of responsibility are the climate, regulation of emissions from industry, environmental toxins and waste. It is also responsible for the natural diversity of plants, animals and landscape. One important task is to combine protection and sustainable use of nature.

Norwegian Nature Inspectorate (SNO)

SNO is organised as a part of the Directorate for the Environment. It has supervisory authority in accordance with eight different environmental protection acts, including the Cultural Heritage Act. It is responsible for supervising the national parks and other major conservation areas. It is also responsible for preventing environmental crime. It works to promote knowledge about nature in order to improve people's insight and to help to increase their respect and care for nature and the cultural environment.

Norwegian Water Resources and Energy Directorate (NVE)

The Directorate reports to the Ministry of Petroleum and Energy. It is responsible for ensuring that watercourses are managed uniformly and in an environmentally friendly manner, and for ensuring efficient energy trading. When power lines, power plants and wind turbines are developed, they must undergo assessment by NVE for the benefits of growth versus conservation. Open consultations must be held, as well as public meetings with local and regional authorities and the local population, ensuring that every aspect of the issue is represented.

Norway is a country that is subject to landslides and flooding. Our steep cliffs and deep valleys increase the risk of landslides and avalanches. NVE surveys areas for landslides and works to prevent damage. The results are important for the municipalities when they are to develop plans for land use and consider building applications.

Norwegian Railway Authority

The Norwegian Railway Authority (NRA) is an independent body that reports to the Ministry of Transport and Communications. It is responsible for supervising the various bodies involved in railways, whether public or private. Since 2012, the NRA has also been responsible for cable car supervision.

Norwegian National Rail Administration

The Norwegian National Rail Administration (NNRA) is an administrative body reporting to the Ministry of Transport and Communications. On behalf of the state, the NNRA shall operate, maintain and develop the national rail infrastructure with its associated installations and facilities. The NNRA has its own museum/cultural heritage department.

The Norwegian Railway Museum was established in Hamar in 1896. That was 42 years after the first section of Norwegian railway had opened. The museum has a unique collection of objects from Norwegian railway history. Its tasks include documenting and communicating developments in Norwegian railway history, and helping to increase people's knowledge of railway history.

Norwegian Maritime Authority

The Norwegian Maritime Authority (NMA) is an administrative body reporting to the Ministry of Trade and Industry and the Ministry of Climate and Environment. It is the authority responsible for Norwegian-registered vessels and foreign vessels calling at Norwegian ports. It is also responsible for shipping on Norwegian inland lakes. The NMA's overriding goal is to achieve a high level of safety to protect life, health, the environment and material assets.

Norwegian Public Roads Administration

The Norwegian Public Roads Administration (NPRA) reports to the Ministry of Transport and Communications. It is responsible for planning, constructing, operating and maintaining national and county roads. It shall work to ensure a safe, environmentally friendly, efficient transport system that is accessible to all, in order to meet society's needs for transport and promote regional development. Its work with other parties involved in the sector is important, and collaboration between the NPRA and cultural heritage authorities is good. When new roads and major improvements to the existing road network are planned, this takes place via an open planning process. The county roads are administered jointly by the NPRA and the county authorities. The roads in the area of the World Heritage Site are primarily county roads.

Norwegian Directorate for Civil Protection and Emergency Planning

The Directorate reports to the Ministry of Justice and Public Security. The Directorate's responsibilities regarding civil protection cover national, regional and local preparedness and emergency planning, fire and electrical safety, safety in business and industry, safety regarding hazardous substances, as well as product and consumer safety.

The Equality and Anti-discrimination Ombud

The Ombud shall promote equality and combat discrimination, regardless of gender, ethnicity, disability, language, religion, sexual orientation and age. The Ombud enforces legal prohibitions against discrimination, provides guidance and promotes equality and diversity.

Table of institutions with responsibility for legislation that is significant to the protection of OUV (core values)

Institution	Legislation	Relevant to
Tinn Municipality	The Planning and Building Act	Buildings and land, historic cultural heritage
Notodden Municipality	The Planning and Building Act	Buildings and land, historic cultural heritage
Vinje Municipality	The Planning and Building Act	Buildings and land, historic cultural heritage
The Directorate for Cultural Heritage	The Cultural Heritage Act	Protected cultural heritage. Protection orders
Telemark County Council	The Cultural Heritage Act	Protected cultural heritage. Temporary protection orders
The Norwegian Maritime Museum	The Cultural Heritage Act	Marine cultural heritage
The Norwegian Environment Agency	The Nature Diversity Act, the Act relating to nature inspection, the Pollution Control Act, etc.	Nature conservation, environmental protection, climate and pollution
The County Governor of Telemark	The Planning and Building Act, the Nature Diversity Act, various environmental protection acts etc.	Buildings and land (appeals and objections), civil protection, environmental protection monitoring, nature and agriculture, cultural landscape, cableway concessions
The Norwegian Water Resources and Energy Directorate (NVE)	The Energy Act, the Water Resources Act, the Watercourse Regulation Act and the Industrial Concession Act	Water, energy, landslides etc.
The Norwegian Railway Authority	The Railways Act, the Railway Investigation Act and a number of regulations	Railways and cableways
The Norwegian Maritime Authority	The Seamen's Act, the Norwegian Maritime Code and a number of regulations	Vessels
The Norwegian Public Roads Administration	The Road Act etc.	Roads, transport, vehicles

Institution	Legislation	Relevant to
The Norwegian Directorate for Civil Protection and Emergency Planning	The Act relating to the prevention of fire, explosion and accidents involving hazardous substances, the Act relating to the inspection of electrical installations (in Norwegian only), the Act relating to the control of products and consumer services, the Norwegian Civil Defence Act and a number of regulations.	Fire and electrical safety, hazardous substances, civil protection, municipal and regional emergency preparedness etc.
The Equality and Anti-discrimination Ombud and the Norwegian Equality Tribunal	The Anti-Discrimination and Accessibility Act	Universal design

5d. Existing plans related to the municipality or region in which the proposed property is located

Government plans

National Transport Plan

A report has been prepared on the choice of concept for the future E 134 road. The report identifies four alternatives. One alternative proposes that the road be laid north of Notodden, crossing the World Heritage Site and the buffer zone in the area between Kloumannsjøen lake and the northernmost buildings at Skogen in Notodden. The report draws attention to the cultural environment at Tinnfoss and to the application for World Heritage status.

Regional plans

Regional plan for Hardangervidda National Park 2011–2025, adopted by the county councils of Hordaland on 18 October 2011, Telemark on 7 November 2011 and Buskerud on 8 December 2011, confirmed by the Ministry of Climate and Environment on 16 July 2012.

In 2007, the Ministry of Climate and Environment began preparing regional plans for the most important areas for wild reindeer in Norway. The regional plan is intended to serve as a guide. If the plan's intentions are to be achieved, the guidelines provided in the planning map, regulations and action plan must be followed up by the local and regional authorities in their future planning and management work. Møsvatn lake has been defined as coming within the scope of the plan. The purpose is that the area shall be preserved as a relatively unspoilt natural area. For parts of the area near Møsvatn lake, there is a wish to attract more people to the villages. Tourism and green business development are also mentioned.

County master plans

County road plan for Telemark 2011–2019, adopted by the County Council on 21 June 2010.

The county road plan clarifies goals and strategies for the management and development of the county road network, and, through the action plan, it forms the basis for annual prioritisations during the period 2011–2014. It is based on the National Transport Plan for the period 2010–2019. The road network is divided into the categories of strategically important county roads, important county roads and other county roads, based on the criteria of connective function for business and industry, tourism and other value creation, the volume of traffic and importance for public transport. These categories form the basis for the prioritisations. The plan identifies county road 37 to Rjukan and county road 360 to Notodden as strategically important county roads.

County sub-plan for central urban functions adopted by the County Council on 9 December 2004, confirmed by the Ministry of Climate and Environment on 18 March 2005 (without period of effect)

The plan coordinates the development of central structures and the location of central urban functions in Telemark county. The plan is particularly important in relation to the establishment and development of businesses. The plan defines urban centres in Telemark and provides guidelines regarding where various commercial enterprises can be established. The plan forms the basis for commercial development and land use in the municipalities.

Regional plan for innovation and business development 2011–2024, adopted by the County Council on 15 June 2011.

The regional plan for innovation and business development was adopted in June 2011. In the development of regional plans that apply to the whole of Telemark county, the county authority shall, as a social entrepreneur, pursue an active, coordinating role and issue guidelines in relation to goals and overall strategies. The plan provides guidelines for the county authority's work, gives signals to other parties in the public and private sectors, and encourages cooperation in the development of the commercial areas. The plan focuses on the opportunities and potential in Telemark, and how these can best be utilised to form the basis for sustainable business development.

Regional plan for tourism and experiences 2011–2024, adopted by the County Council on 15 June 2011.

The plan provides guidelines for the county authority's work, gives signals to other parties in the public and private sectors, and encourages cooperation in the development of the commercial areas. It focuses on the opportunities and potential in Telemark, and how these can best be utilised. Mount Gaustatoppen and Hardangervidda National Park are strong natural and cultural attractions. Telemark has cultural heritage, roots and traditions in cultural history. The plan highlights the Telemark Canal Regional Park, use of the waterways, stave churches and the region's unique industrial heritage.

One of the focus areas in the action plan is 'attractions in Telemark'. It includes funds for tourism projects that promote the application for World Heritage status. The measure applies to the period 2013–2016.

Strategy for culture and cultural heritage in Telemark

Telemark County Authority is preparing a strategy that is scheduled to be ready for political consideration by the end of 2013. The plan will contain objectives and measures related to the World Heritage.

Long-term priorities for the period 2013–2016

The cultural heritage protection gives priority to the continuation of the World Heritage work. The World Heritage work will be used to increase the level of knowledge and focus relating to cultural heritage in Telemark, and craftsman training will be given priority. Focus will also be given to the World Heritage Site as a tourist destination. The work on facilitating the sustainable use of cultural heritage when creating attractions. The World Heritage will also be used in connection with international work.

Long-term priority for the period 2014–2017

The document is scheduled for political consideration in the course of 2013. The cultural heritage protection gives priority to the continuation of the World Heritage work.

Local authority plans

Notodden Municipality

Municipal master plan 'Mål for utviklingen' (Development goals) 2007–2018

The plan is an overriding, long-term planning document that stipulates goals and guidelines for social development and uses these as a basis to conclude with a municipal strategy that sets out important guidelines for the municipality's long-term work during the planning period.

The plan provides guidelines important to the protection of cultural heritage values. It must be emphasised that any new projects must take the local cultural heritage into account, and that balancing the protection and use of the physical environment is important.

In the context of experiences, the municipality shall ensure that experiences are developed that are based on the taming of the Tinnelva river, focusing on timber flumes, the history of timber floating, and Hydro's transport route from Rjukan to Notodden. The plan is scheduled to be revised by the end of 2015.

The land-use part of the municipal master plan (the whole municipality) 2004–2015

This land-use plan covers the whole municipality, with the exception of areas for which municipal sub-plans have been adopted. It is an overriding long-term planning document with important guidelines relating to cultural heritage protection. It also contains provisions stipulating that all applications for alteration work for buildings more than 60 years old must be submitted to the county authority's cultural heritage department for comments before any permits are granted. A new revision of the plan shall be prepared by the end of 2015.

Municipal sub-plan – town centre – Heddal 2004–2015

This land-use plan covers the whole built-up area in the town centre, as well as the area between Heddal and Nordbygda, with the exception of the areas covered by the municipal sub-plans for the town centre and the Tuven area. Conservation guidelines apply to the Tinfoss area with Kanalveien and Hyttebyen ('cabin town') plus the Femrader'n ('five-row') houses and the big Tinneby houses.

Municipal sub-plan – Gransherad–Tinnoset 2004–2015

This land-use plan covers Gransherad and Tinnoset and the area between. There are conservation guidelines regarding the Tinnoset Line and Tinnoset Railway Station.

Municipal sub-plan – town centre 2007–2018

This plan includes guidelines regarding the conservation of several areas. They apply to four buildings in the Industrial Park, the Grønnebyen and Villamoen housing areas and the area around the market square. There are conservation guidelines regarding the most characteristic features of the old Art Nouveau town, and guidelines for the development of the central housing areas, in line with the original development intentions indicated in the very first plans.

A new version of the municipal sub-plan for the town centre is being prepared. The planning programme has been adopted, and a DIVE analysis has been prepared based on the World Heritage values as the basis for further planning work.

Zoning plans

Grønnebyen in Notodden is protected by a zoning plan. Photo: Trond Taugbøl.

Zoning plans have been prepared for several areas for the purpose of conservation. This applies to the Grønnebyen and Villamoen housing areas with the Admini administration building, the Casino, the Tinnfoss area and the area around Tinnoset Railway Station. In the buffer zone, important Art Nouveau buildings in the town centre have been regulated for protection.

Strategic tourism plan

In 2009, it was agreed that the planning work would be initiated in cooperation with Notodden Utvikling A/S. It is scheduled to be completed by 2015.

Cultural plan 2006–2010

The plan sets out goals and guidelines for work in the cultural field. One of the goals is for the local cultural heritage to be protected and preserved, made available and brought to life for the public. Notodden wishes to provide more opportunities for people to experience the old transport system by extending the transport options on the Telemark Canal to link it with the Tinnoset Line, thereby creating a continuous transport line from the exporting port in Skien to Rjukan. The plan is scheduled to be revised by the end of 2015.

Cultural heritage plan

The plan is scheduled for completion by 2015.

Municipal emergency response plan

The plan provides a systematic review of the threats that the municipality may be exposed to and what measures should be implemented to address these. The plan is being prepared and is scheduled for completion by 2015.

Tinn Municipality

Municipal master plan for Tinn 2006–2018

The plan focuses on Tinn as a centre of tourism and has two main strategic areas: 1. Business development and expertise. 2. Aesthetics, culture and identity.

The results shall be shown in the three focus areas of town, villages and mountains. The municipal master plan emphasises the importance of a future World Heritage status and its requirements, stipulating that the architectural quality must be safeguarded in existing and future buildings. The plan states that nominating Rjukan for inscription on the World Heritage List will provide new opportunities for showing the world the unique buildings and historical environment in Rjukan. The plan is scheduled to be revised by the end of 2013.

Municipal sub-plan

Tinn Municipality has commenced the work of revising two municipal sub-plans. The work is in accordance with the provisions of the new Planning and Building Act. This work is highly significant to the task of safeguarding the OUV. The work is scheduled for completion by the end of 2015.

Municipal sub-plan for Rjukan

The existing municipal sub-plan for Rjukan from 1997 is being revised. In 2010, the municipal council adopted a planning programme for work on a new municipal sub-plan. The planning programme is a working and governing document detailing how the planning work is to be conducted, and it includes a clarification of the most important topics and guidelines for this work.

'*World Heritage status'* is the main topic of the municipal planning work. '*Business development'* and '*urban development'* are two sub-topics that are intended to develop and support the work towards achieving World Heritage status. The developments of industry, tourism and a living community in Rjukan have common interests and will be developed in parallel.

The municipality is actively working on business investments in Rjukan, primarily through the company Rjukan Næringsutvikling AS. It is working to bring new industrial jobs to Rjukan, and the company wishes to develop skilled jobs and advanced production technology. Hydro Industrial Park in Rjukan is an important area for further development, and the municipality stresses the importance of developing it in a way that ensures that the OUVs are safeguarded as well as possible.

It is important for the people of Tinn that the municipality facilitates the continuing development of the town of Rjukan as a central area for business and service, and as a housing area. Developing Rjukan as an attractive place to live is therefore an essential element. Rjukan is a long, thin town, and the municipality is focusing on giving the town centre a sense of cohesion by providing pleasant meeting places, urban public spaces, and by linking together the districts on both sides of the Måna river.

Tourism is key for Tinn, and the social element of the 2008 municipal master plan highlights one main focus area: *'Tinn as a centre of tourism'.* Tinn Municipality is involved in the project 'Travel and tourism in the cradle of industry', the objective of which is to develop tourism as a complementary industry in industrial towns. It is using the project as a means of developing experiences related to the area's industrial history.

A DIVE (Describe, Interpret, Valuate, Enable) analysis has been prepared based on the World Heritage values as the basis for further planning work.

Municipal sub-plan, the Vestfjorddalen valley

Work on the plan is ongoing. The objective of the municipal sub-plan for the Vestfjorddalen valley is to safeguard values relating to the railway route and the port area in Mæl in relation to a potential World Heritage status. Work on the plan will also include an assessment of whether there are any other areas or elements in the planning area that are of major cultural heritage value.

Municipal sub-plan for the upper part of Månavassdraget (watercourse), adopted in 2009

The land-use plan that covers the area between Møsvatn lake and Rjukan was adopted in 2009. There is a huge potential in this area for demonstrating the connection between nature and culture. The major natural resources in the area are the reason why the town of Rjukan was built in the first place. The stretch of water from the high mountains down to the coast, and the related cultural heritage are important parts of the application for World Heritage status, and the objective of the plan is to safeguard these values. Parts of the plan cover the buffer zone.

Municipal sub-plan – Gausta-Rjukan, 2002–2012

The municipal sub-plan for the Gausta-Rjukan area covers the tourist destination of Mount Gaustatoppen. A small part of the planning area is in the buffer zone and is visible from Rjukan.

Zoning plan for Hydro Industrial Park in Rjukan, adopted in 2012

The zoning plan regulates the industrial area, which is one of the attributes of the World Heritage Site. The objective of the plan is to make the Hydro Industrial Park in Rjukan a modern, attractive growth area for industry and a place where businesses can establish industry. Skilled jobs and advanced production technology will be established based on the 'primary' input factors in Rjukan.

The plan shall form the basis for how to reconcile the requirements of a modern industrial facility with major cultural heritage values and landslide protection. The plan examines the principles on which new building projects are based, ensuring that the values of the World Heritage Site are safeguarded as well as possible.

Within areas that are regulated for the purpose of conservation, and within the new Planning and Building Act's equivalent zones requiring special consideration, all building applications shall be referred to the regional cultural authority before building permits are granted. This ensures that the municipalities have sufficient control, with the exception of projects that do not require a permit. Exemptions may be granted, however, counter to expert advice, for political reasons. In order to preserve areas and buildings that are not protected or zoned, the municipalities are able to prohibit building work and the subdivision of plots or buildings in anticipation of zoning plans, in order to prevent the loss of cultural history values.

In general

A number of plans regulate smaller areas for conservation pursuant to the 1985 Planning and Building Act Section 25.6.

Tourism strategy for Tinn

This plan is an overriding tourism strategy for the municipality. The plan's vision is for Tinn to become Norway's most attractive year-round tourist destination. One of the subordinate goals of the strategy is for Rjukan to be inscribed on UNESCO's World Heritage List.

Travel and tourism in the cradle of industry

The Norwegian Hospitality Association, the Federation of Norwegian Industries, the Norwegian Association of Local and Regional Authorities and Color Line have launched a national tourism project: *'Travel and tourism in the cradle of industry'* in which Rjukan, Odda, Narvik and Kirkenes have been selected as relevant destinations. The project shall examine the possibility of combining the long and traditional industrial history with tourism, by facilitating experiences in line with the experience economy.

Cultural plan

This plan coordinates the municipality's work in the cultural field.

The cultural plan has one focus area: Rjukan – the cradle of industry. The most important cultural priority area of the almost four-year period is to intensify the work of preserving and improving Rjukan's industrial and cultural history. By focusing on Rjukan's industrial and cultural history, we will improve an international product that makes Rjukan more attractive for the local population, people new to the area, entrepreneurs, people with holiday homes and tourists.

Strategic business plan

The plan coordinates the municipality's business development work and indicates that a future World Heritage status would be positive for business and tourism development and for developing thriving communities.

Emergency response plan

An overriding risk and vulnerability assessment has been carried out.

The buffer zone

There are important supporting values in the buffer zone that are connected to the four pillars. These are safeguarded through the Planning and Building Act. Krokan cabin is also in this area, and it is protected pursuant to the Cultural Heritage Act. The same applies to other parts of the Tinfos cultural environment that are to be protected. The buffer zone also contains important visual axes towards the World Heritage Site. These must also be safeguarded.

Parts of the buffer zone are covered by the municipal master plan for Notodden Municipality and by the town centre municipal sub-plan. The zoning plan for Svelgfossmoen has now gone out for a second round of public consultation. The plan contains three alternatives. One alternative involves demolishing the old Hydro houses. This case is being considered by Notodden Municipality. A licence application regarding small power plants within the buffer zone in Notodden and Tinn municipalities is awaiting comments. This case is being followed up by Telemark County Authority.

The buffer zone in Rjukan covers the mountainsides in the valley and 'newer' parts of the town. The natural landscape between Rjukan and Møsvatn and the cultural landscape between Rjukan and Tinnsjøen are also in the buffer zone, along with Tinnsjøen itself.

The natural and cultural landscapes in Notodden and Tinn are areas designated for farming, nature or recreational activities in the municipal master plans. These are areas that shall not generally be built on, and any new buildings shall either be connected with agriculture or facilitate use of the area for outdoor recreation. Møsvatn and the surrounding area come under the plan for Hardangervidda National Park, and it is protected pursuant to the Nature Diversity Act. The areas shall be maintained as relatively unspoiled natural

Notodden and its buffer zone, seen from Eikeskard. Photo: Egil Rye-Hytten.

areas, with the exception of areas that have been developed for the purposes of tourism and green business development.

The Gausta–Rjukan municipal master plan has zoned parts of the mountainside north east of Mount Gaustatoppen and down towards the east side of Rjukan for downhill skiing and holiday cabin construction. Tourism-related developments here may have an effect on the landscape seen from Rjukan town centre.

5e. Management plan or other types of public management system

The management plan for the Rjukan–Notodden industrial area is included as Annex 3 to the nomination document. The plan has been prepared in accordance with the guidelines specified in Report No 35 to the Storting (2012–2013).

The plan reviews the area's OUV and refers to the criteria for inscription. It reviews the condition of the individual values, i.e. their status and vulnerability. The plan also reviews the area's impact factors, including development pressure, the need for change and environmental threats. It provides an overview of institutions important to the management of the area, and legislation that is key to the task of protecting it. It examines the institutions that have a responsibility to protect cultural heritage, and institutions that can provide funds for financing various measures. It presents core plans for the World Heritage Site and buffer zone.

The plan has one vision and six goals regarding the management of the site. The overall vision for the site is:

The distinctiveness, cultural heritage values and traditions characterising the Rjukan – Notodden World Heritage Site shall form the basis for business development, social development, identity-building and good living conditions. The World Heritage Site has preserved cultural heritage and cultural landscapes to show why the industrial community was founded and how it developed and functioned.

One goal is to preserve and improve the OUV, and this objective emphasises the importance of maintaining and improving the area's authenticity and integrity. The goal of preserving and legally securing the OUV indicates the necessity of having a legal basis for safeguarding all attributes and significant objects, to ensure that future developments are properly managed. Another goal is to preserve and improve any relevant supporting values, ensuring that these are repaired or restored and that any future developments safeguard their historical values.

The plan emphasises protection through use. The municipalities and the cultural heritage authorities have extensive experience in assessing tolerance limits to ensure that any development takes place according to the principle of sustainability.

The goal of competence-building and research stresses the importance of increasing cooperation with primary schools, lower and upper secondary schools, university colleges, universities and research institutes. It also highlights the importance of developing knowledge bases. This is important in the context of both research and dissemination. Further education for specialist craftsmen will also be provided.

Collaboration with international parties is stressed as important. The exchange of experience with other World Heritage sites and specialists in different fields is an important factor in properly maintaining a World Heritage Site.

Information and dissemination are important goals. A World Heritage Centre will be developed and presentation arenas established on many levels, ensuring that information about the World Heritage Site and its various aspects becomes well known.

Information to the local community is emphasised as important in terms of knowledge-building and in order to create pride and a sense of ownership. There are plans to create educational programmes for kindergartens and schools. Courses will also be held to train local people in providing information to visitors. The internet is already being used actively to provide information. Many people in the local community are active on the Internet, and many excellent stories about working and living in the industrial community are emerging. Raising awareness is important in terms of continued sustainable development.

Providing all visitors with easy access to information and a good selection of cafes, restaurants and accommodation is also a goal. The tourist organisations are working together to offer a range of experiences. The basic conditions are in place to enable the Notodden – Rjukan transport route to become a unique experience.

An action plan has been prepared, showing the tasks, responsible institutions, partners, deadlines and funding options.

The plan has been prepared jointly by the municipalities, county authorities and the Directorate for Cultural Heritage. It has been presented to politicians and the interim World Heritage Council.

5f. Sources and levels of finance

Ministry of Climate and Environment/the Directorate for Cultural Heritage

Every year, the Directorate for Cultural Heritage is allocated a sum for the work on the World Heritage sites. The funds are mainly used for practical restoration/repair work, but they can also be used for other measures that indirectly contribute to safeguarding the World Heritage.

Total funding for 2013 has been set at NOK 46 mill, to be divided between all the Norwegian World Heritage sites. The funds are distributed on the basis of applications and needs assessments. Funds are also available for technical and industrial heritage, which are mainly distributed to 12 selected sites. The total for 2013 is NOK 60 mill. Total funds for ship preservation amount to NOK 47 mill.

Norwegian Cultural Heritage Fund

The fund shall contribute towards the work of preserving historic and protected cultural heritage and help to ensure that a variety of cultural heritage and cultural environments can be used as the basis for future experiences, knowledge, development and value creation. The Cultural Heritage Fund's grants can be used for measures right across the cultural heritage field. Private owners and voluntary organisations may apply for funds. In special cases, municipalities may apply for funds for cultural heritage that they own. For 2013, the Cultural Heritage Fund has NOK 61 mill to distribute, mainly to sites that are not protected under the Cultural Heritage Act.

Telemark County Authority

The county authority manages regional development funds. The regional development funds amount to a total of NOK 60 million. Grants may be allocated on application to tourism enterprise businesses, restoration crafts courses, for the upkeep, adaptation and promotion of cultural heritage, and for culture-based business development. A decision has been made to allocate funds for tourism projects that support the World Heritage application and the regional park. It also has various grant funds for cultural initiatives and running funds for museums, totalling NOK 600 000. NOK 1,8 mill is allocated to the Norwegian Industrial Workers Museum. NOK 33 million is also allocated to sports facilities and local environmental facilities that may be relevant to the Hydro towns of Rjukan and Notodden.

Telemark development fund

The fund shall be an instrument for creating and supporting positive population growth and business development in all parts of Telemark county. The fund shall contribute towards ensuring that Telemark has and maintains systems and organisations that contribute to high-quality community development, culture, public health, sports, outdoor pursuits, museums, libraries, voluntary work and integration across the county.

The municipalities

In terms of the municipalities' management of their own properties, the annual operating budgets are essential in determining the level of maintenance. The municipalities need considerable amounts of money to maintain their properties.

Notodden Municipal Council has decided to establish a fund with pertaining guidelines, to which private owners can apply for grants for the refurbishment and restoration/repair of buildings worthy of preservation.

Tinn Municipality manages a grant scheme for private owners with pertaining guidelines from which grants can be allocated for the refurbishment and restoration/repair of buildings worthy of preservation. The grant scheme has improved the technical condition of several private buildings. Grants have also been allocated for the restoration of façades.

Tinn Municipality allocates annual operating grants of NOK 1 million to Norwegian Industrial Workers Museum, which it uses to manage the Rjukan Line transport service.

Ministry of Culture

One of the main goals of the government's cultural policy is to facilitate cultural diversity and ensure that stimulating, challenging cultural options are available to the entire population. Cultural policy shall promote the protection and presentation of cultural heritage, artistic renewal, and quality and cultural diversity, nationally and internationally.

The Ministry of Culture distributes grants to museums and other cultural preservation initiatives. Norwegian Industrial Workers Museum was allocated NOK 13 mill. for 2013.

Arts Council Norway

The Arts Council Norway manages the Norwegian Cultural Fund. Part of the fund's assets can be allocated to initiatives that preserve, document and present cultural heritage.

Innovation Norway

Innovation Norway contributes to innovation in business and industry, regional development and developing competitive Norwegian businesses. Innovation Norway markets Norwegian business and industry and Norway as a tourist destination. It has regional offices, and Innovation Norway in Telemark provides assistance for establishing new and developing existing businesses. It offers financing, advice and other services that make it possible to build a better business or to bring goods and services to new markets. The annual sum for allocation to Telemark county is NOK 200 million. This sum covers all types of innovation.

Research Council of Norway

The Research Council of Norway is a national strategic and funding agency for research activities. It is the most important research policy adviser to the Government, the ministries and other important institutions and environments associated with research and development.

The Research Council shall identify needs for research and propose priorities. Through targeted financing schemes, the Research Council shall contribute to implementing national research policy measures. The Research Council has NOK 30 million for allocation to the counties of Telemark, Vestfold and Buskerud. Funds may be granted on application for projects of importance to cultural heritage.

Private foundations

There are several not-for-profit private foundations that may allocate grants on application for cultural heritage initiatives for private institutions and individuals. The annual total varies each year.

International cooperation

Through the EEA Agreement, Norway is entitled to participate in most programme areas for regional development (INTERREG) established in the EU. The Ministry of Local Government and Regional Development funds Norwegian participation through allocations for the various programme areas with 50% co-funding. Rjukan – Notodden will have the opportunity to enter into partnerships with other European World Heritage sites to exchange experiences and learn from each other. The INTERREG portfolio includes the URBACT programme, which is aimed at collaborations between cities/towns and experience sharing, and the ESPON research programme. Such projects are fully financed by the EU. All these programmes will be activated and be relevant for Rjukan – Notodden. The EU's cultural programme, the education programmes and the youth programmes for informal learning will be of interest to Rjukan – Notodden. The programmes will be able to ensure that the World Heritage Site is marketed and will contribute to the continuous development of the area.

5g. Sources of expertise and training in conservation and management techniques

Central government level

Directorate for Cultural Heritage

The Directorate for Cultural Heritage's staff include specialists in history, ethnology, art history, archaeology, technical conservation and architects. They have broad experience in cultural heritage administration.

Norwegian Institute for Cultural Heritage Research (NIKU)

The institute, which receives government support, has specialist expertise in archaeology, building history, conservation and planning. Other areas of expertise are environmental impact assessments, protection and management plans, cultural history site analysis (DIVE), participation processes in planning and transformation of urban and industrial areas. NIKU has prepared cultural heritage analyses based on the DIVE method for the Rjukan – Notodden World Heritage Site.

The ship conservation centres

There are three ship conservation centres in Norway with specialist expertise in ship conservation, including documentation and restoration/repair, covering the different techniques for ship building.

Regional level

County authorities

The county authorities have expertise in important sectors such as planning and cultural heritage protection. They have specialist expertise in architecture, history and archaeology.

Local level

Municipalities

The municipalities have expertise in planning and building works in ordinary construction and maintenance projects.

Extensive restoration work has been carried out on brick buildings in recent years, which has provided local building contactors with experience.

The municipalities encourage upper secondary schools to build competence and develop teaching programmes for timber-clad house architecture.

There are local craftsmen with experience of conservation guidelines for restoration and repair, but further developments are needed in this area, and more craftsmen need to be trained.

The Norwegian Industrial Workers Museum

The museum staff is knowledgeable about hydroelectric power and the industrial development. They have expertise in dissemination, archives and photographs. The museum staff are also knowledgeable about the war history associated with heavy water.

Educational institutions

Architectural studies

The Oslo School of Architecture and Design (AHO) is a specialised university institution and a leading international school of architecture and design that offers study programmes in architecture, landscape design, urbanism and design.

Bergen School of Architecture offers a comprehensive study programme for sustainable development that focuses on landscape and climate as the basis for architecture.

The Norwegian University of Science and Technology in Trondheim offers architectural studies. The goal of the Department of Architectural Design, History and Technology is to contribute to the development of high-quality, integrated and sustainable architecture through teaching in two main areas: the technical and environmental aspects of the design and use of buildings, and the preservation and development of existing built environments, where history, cultural understanding and protection or preservation are important aspects.

University programmes in cultural history

The universities in Norway offer study programmes in archaeology, history, art history and ethnology, which provide a foundation for careers in the area of cultural heritage protection.

The University in Trondheim offers a bachelor programme in cultural heritage that provides a basic introduction to a general historical understanding and methodology, in addition to insight into important archaeological work methods, cultural heritage legislation, the history of architecture, statutory framework and management theory, the relationship between nature and culture (cultural geography), dissemination and museum work. It is aimed at practical cultural heritage work.

Technical conservation studies

The University of Oslo offers technical conservation studies at bachelor and master's level.

There are two programme options at bachelor level: archaeology, which provides knowledge based on man's material culture, and cultural heritage and preservation, which deals with conservation as a profession, management of collections and preventive conservation.

There are four programme options at master's level: archaeology, project-based conservation, conservation of paintings and conservation of objects. Students are required to have their own place of work. They receive guidance from the department's staff and can take exams in different topics at the department.

The Norwegian University of Life Sciences

The university offers two five-year master's programmes: urban and regional planning, and landscape design. Sustainable development is emphasised.

Vocational training and education

Vocational training and education consists of four-year study programmes that aim to provide basic knowledge about new buildings and modern methods, techniques and materials. There is little room for including knowledge about older techniques and practical work on techniques and materials.

Sør-Trøndelag University College offers a bachelor programme in technical building conservation and restoration. The length of study is four years and tuition is session-based. Work placement constitutes 50% of the course. The university college also offers further education in building preservation on assignment from clients.

The Western Norway Cultural Academy has held courses in building tradition and building preservation for many years. The courses are aimed at craftsmen, owners of buildings and the public authorities. Several building preservation centres, museums and upper secondary schools around the country provide courses in traditional craftsmanship and restoration.

The Telemark County Authority is working with Telemark Technical College to establish a two-year study programme in building preservation. The application for approval was submitted to the Norwegian Agency for Quality Assurance in Education (NOKUT) on 15 February 2013. The study programme is intended to be web-based, but with several sessions during the period of study. The curriculum that forms the basis for the NOKUT application focuses on old timber buildings (stave, cog-joint etc.), but the intention is to extend the programme in order to allow students to choose modules/specialisation in other types of buildings and materials, including buildings of a more recent date. Telemark County Authority will assist with syllabus preparation and teaching. According to the plan, the college will offer tuition from autumn 2014.

5h. Visitor facilities and infrastructure

Access and accessibility

The World Heritage Site is centrally located in Eastern Norway and is easily accessible by both car and public transport. The area around the World Heritage Site offers a variety of outdoor pursuits in both summer and winter and receives many visitors.

By air

Notodden Airport has direct flights to and from Stavanger and Bergen. This makes it easily accessible from Western Norway. The same applies to Skien Airport Geiteryggen. Torp Airport near Sandefjord is an international airport that is a good starting point for travel to the World Heritage Site. There is a bus service from Torp to Notodden. The drive from Torp takes about two hours. From Skien, it takes 1–1.5 hours. Travel time from Oslo Airport Gardermoen is approximately three hours.

Ferry

There is a car ferry service from Frederikshavn in Denmark to Larvik. The drive from Larvik to Notodden takes about two hours. There is also a bus service from Larvik to Notodden.

Rail

There is a train service from Notodden to Skien. The service connects with the Sørlandet Line (Stavanger, Kristiansand and Oslo) in Nordagutu Railway Station. From Skien, the Vestfold Line continues to Oslo. Travel time by train from Skien to Notodden is approximately one hour.

Bus

There is a regular public bus service from Oslo to Notodden and Rjukan. The bus takes approximately 2 hours to Notodden and 3.5 hours to Rjukan. There is also a bus service to Skien and Larvik.

Car

Notodden is situated along the E 134 road, with Kongsberg, Drammen and Oslo to the east and Seljord, Odda, Haugesund and Bergen to the west. The drive from Haugesund to Notodden takes about 5.5 hours, and approximately 2 hours from Oslo. The drive from Notodden to Rjukan takes approximately one hour if you drive along Tinnsjøen lake, where you pass Tinnoset. There are also alternative routes to Rjukan from both Kongsberg and Notodden. There are summer roads across the mountain from Sauland through Tuddal to Rjukan and from Tinn Austbygd to Uvdal and Veggli.

Parking

There is good parking in Notodden at Grønnbyen, in the Hydro Park, by the railway, in the Tinfos area and the area by Tinnoset Railway Station. Parking is not permitted at the lightning arrester house.

There is good parking in the built-up area in Rjukan. The museum at Vemork has a dedicated car park some distance away, but those who need to can drive all the way to the museum. There is a bus service from the car park to the museum during the tourist season. Krosso Aerial Cableway has a large car park both for day visitors and for long-term visitors who intend to go hiking in the mountains. There is a free bus service between the Krosso Cableway and the Gausta area during winter.

Universal design

Legislation sets stringent requirements for universal design for all public buildings and buildings that are to be accessible to the public.

Universal design will ensure that there is access from the car parks to the presentation centres in Notodden. The same applies to the walkways between the presentation centres. Universal design ensures that the Hydro Park, Grønnebyen, Villamoen and the Tinnfoss area are accessible from the nearby car parks.

The Norwegian Industrial Workers Museum at Vemork meets the requirements for universal design. The same applies to public buildings in the town centre such as the Rjukan House and the buildings by the market square where the Tourist Information Office and library are located. Universal design will be prioritised in any further arrangements for visitors to the World Heritage Site.

Accommodation and cafés/restaurants

Accommodation – hotel capacity

Accommodation facilities in and near **Notodden** are the Norlandia Hotel Notodden (59 rooms) and Brattrein Hotel (27 rooms). Gransherad Gjesteheim (guest house) also offers

The new café at Gvepseborg on the top station of Krosso Aerial Cableway. Photo: Per Berntsen.

accommodation. In addition, Notodden Camping offers accommodation in 16 cabins. A temporary camper van car park is available on Nesøya.

Tinn Municipality has a hotel, a farm guest house and a cabin village in **Rjukan**. Outside the populated area, basic accommodation is provided at Rjukan mountain lodge and at Mæl. Outside the city centre is Rjukan Cabin and Caravan Park. Excellent mountain hotels are located on the outskirts of the World Heritage Site, catering mainly to visitors interested in outdoor pursuits. Skinnarbu Hotel is located by Møsvatn lake and Gaustablikk Hotel by Mount Gaustatoppen. There are also many rental cabins in the Gausta area.

Cafés/restaurants

Notodden Municipality comprises a total of 16 cafés/restaurants. In addition, many temporary catering facilities are available during the blues festival. Two of the cafés/restaurants are in the area of the World Heritage Site.

There are seven cafés/restaurants in the centre of **Rjukan**. A new café opened in summer 2013 at Gvepseborg, at the top of the Krosso Cableway. There are several cafés/restaurants outside the area in relation to the outdoor recreation areas.

Tourist attractions

The Norwegian Industrial Workers Museum is found in Vemork Power Plant. It was the biggest power plant in the world when it was built in 1911. The museum shows the fantastic success story of the energy industry and exhibitions on the industrial development in Norway and in Rjukan. The museum also contains a presentation of Rjukan's war history. Vemork was the scene of one of the most important sabotage operations during World War II, when Norwegian saboteurs prevented the Germans from developing nuclear weapons from the heavy water that was produced here. Hydro's corporate history collection will be made available to the public in new premises in Notodden.

Hydroelectric Power

The entire cultural heritage relating to hydroelectric power production and power transmission, except the lightning arrester house, are available to the public, making it easy to experience how important water was as a location factor and to see the big facilities required for the production and transfer of power. There is limited access to the facilities. The number of visitors can be increased without causing wear and tear on the cultural heritage.

Mår power plant, which is situated in a cavern inside the buffer zone, is a visitor centre in summer.

Industry

The Hydro Parks in Rjukan and Notodden are robust structure and comprise large areas that can easily be adapted for the public. The large structures clearly show the production lines and provide a good impression of the size of the facilities needed in fertilizer production and the essential development of the methods. Restrictions may apply to visitors to parts of the facilities, depending on future use of the areas for new industry.

Transport system

Both the railway facility and the ferries on Tinnsjøen lake are robust structures made to accommodate many travellers. The offer that is being developed will provide a good way to experience the transport of industrial products and the normal way of travel for the local population. Steps will be taken to make the Tinnos Line and the Rjukan Line more suitable for tourists, providing return travel to and from Notodden – Rjukan by train and ferry. All cultural heritage sites are accessible by car, except the lighthouses on Tinnsjøen lake, which can only be reached by boat.

Urban communities/company towns

Walking around Notodden and Rjukan and experiencing the structure and architecture of important housing areas is easy. Most properties are owned by private individuals, so access to the interior of houses is not possible. The history group's house in Grønnebyen is open to the public. A walk around the town will give visitors a good feel for the ideas of the time and how the industrialists used international ideas in the development. They were also concerned with using skilled Norwegian architects to design the buildings. An increase in the number of visitors will not cause wear and tear. However, a substantial increase may be a nuisance to the people who live in the houses. Rjukan has a vintage bus service ('Snutebussen') that offers guided tours during the summer, providing information about history and architecture.

The Krosso Cableway in Rjukan is testament to how the industrial developers focused on providing good living conditions and found a way to bring the local population into the sun when it was obscured by the surrounding mountains. Travelling on the cableway also provides excellent views of the entire industrial area and large parts of the town.

Other attractions for the public

Heddal stave church is situated just outside Notodden on the way to Rjukan. Parking is good. A rural museum with several protected buildings is located nearby.

Lysbuen Museum and Art Gallery is situated in Tinnfoss right next to the World Heritage Site.

One of the end stops of the Telemark Canal is in Notodden. There used to be a tourist boat with scheduled departures from Notodden to Lunde. It now only offers chartered tours.

There are many traces of war history that are important in Rjukan because of the heavy water sabotage operation.

There are also a number of regular tourist activities available in the vicinity of the World Heritage Site, such as swimming/bathing, kayaking/rowing, cycling as well as an air sports facility. There are many marked trails and catering and accommodation available in tourist cabins. In the winter, there are prepared skiing tracks, a slalom resort and ski jumping hills as well as a skating rink. Hunting and fishing is possible in the area. Hardangervidda National Park can easily be reached from Rjukan. A bus service runs in winter from the town centre to the large alpine skiing centre at the foot of Mount Gaustatoppen. The Gaustabanen funicular, going inside the mountain to the top of Gaustatoppen, is a new attraction. The funicular was built as a military transport facility and was not opened to the public until 2004. It is now estimated that approximately 60 000 take the funicular every year. In addition, many climb the mountain on foot. The Vestfjorddalen valley near Rjukan is ideal for ice climbing. The many streams and waterfalls freeze and provide many climbing opportunities, which is also well-known internationally. During the summer, the boat service on Møsvatn lake brings tourists to Mogen

Lysbuen Museum and Art Gallery in Notodden. Photo: Linda Nordseth.

tourist cabin on the border of the national park. Hardangervidda can also be accessed by taking the Krosso Cableway. In summer, travelling from Rjukan across the Gaustaråen mountain area to Tuddal is a beautiful experience.

Notodden Blues Festival is held once a year and is one of the biggest blues festivals in Europe. Every year, the 'Fotspor' town walk is organised with the intention of increasing local knowledge and integrity. Several events attract visitors to Rjukan. Examples include the 'Solfesten' festival to celebrate the return of the sun to Rjukan as the sunlight hits the Factory Bridge. 'Kjerringsveiven' is a women's walk that started in 1999. Approximately 2 000 women take part every year. The 'Marispelet' play takes place in the area near Rjukanfossen falls, and the waterfall is released for the four days of the play to give an impression of how it looked before the power development.

The Hardangervidda National Park Centre is situated by Møsvatn lake and is the southern gate to the Hardangervidda National Park.

5i. Policies and programmes relating to the presentation and promotion of the property

The network 'Travel and tourism in the cradle of industry' is a collaboration between several industrial communities. Its goal is to promote travel and tourism as a business in industrial towns that are also interesting from an international market perspective. The municipal network for environmental and social development is a member of the European Route of Industrial Heritage (ERIH), an international information network for tourism that shows industrial heritage. The Norwegian Industrial Workers Museum Vemork is a central part of this.

In its regional plan for tourism and experiences, Telemark County Authority has highlighted the dissemination of industrial history and investments in World Heritage tourism.

In the tourism/experience industry project in Notodden, it is important to note that Notodden is focusing its efforts on three main experiences: Notodden as a Blues Town, opportunities related to UNESCO's World Heritage List and Heddal stave church.

In its cultural plan, Tinn Municipality emphasised that it will intensify the work of preserving and presenting Rjukan's industrial history.

Information – digital techniques – other methods of presenting the site

Information about the application for World Heritage status and the World Heritage Site has been posted on the municipality's website and other local and regional information tourist-oriented websites. Rjukan – Notodden will prepare a joint website for the World Heritage Site. This website shall contain links to the websites of the Directorate for Cultural Heritage and Telemark County Authority. A local history website has been created on Facebook, onto which photos and stories can be posted.

If the site obtains World Heritage status, the information will be updated and further developed. There will be a strong focus on digital information.

Good signposting will be prepared for visitors on their way to the area and inside the area, and brochures will be placed in hotels, cafés etc. in the local community. Both the Tourist Information Office in Notodden, which will be established in the Book and Blues House, and the Tourist Information Office in Rjukan, which has a central location by the market place, will provide information about the World Heritage.

The Norwegian Industrial Workers Museum Vemork is an important institution for the dissemination of the history of the site. The museum will be given specialist responsibility for further development at Lysbuen Museum and Art Gallery at Tinnfoss. The focus for this area will be on the history of the technical innovations and the entrepreneurs, while the focus for Vemork will be on the workers' history.

There are plans for developing a vistor centre at Rjukan Railway Station, the aim of which will be to provide information about the World Heritage. The station is close to both the industrial area and the company town. Two nearby houses owned by the museum will be restored to represent homes from 1920 and 1960.

A conservation depot for railway stock is also planned in this area. There are plans to use the old engine shed as a building conservation centre.

The 'D/F Amonia', which is berthed at Mæl Railway Station, will be open to visitors. A visitor centre is planned at Mæl.

The plan is to offer trips on the Rjukan Line from Rjukan Railway Station to Mæl and then onwards by the 'M/F Storegut' to Tinnoset. Basic information will be provided at Tinnoset, emphasising the history of the slipway and the shipbuilding industry.

The history group in Notodden runs the municipality's Grønneby house and is knowledgeable about the history of Notodden.

Local newspapers

The local newspapers *Telen* and *Rjukan Arbeiderblad* are deeply involved in the World Heritage project and disseminate a lot of historical material. The regional newspapers *Varden* and *Telemarksavisa* are also very involved. They are read throughout Telemark county.

An example of promotion of the World Heritage nomination in the regional newspaper Varden. The headline reads "A history of world class....".

Voluntary organisations

The Telemark branch of the Society for the Preservation of Norwegian Ancient Monuments has several members in Notodden who are actively involved in conservation work. The history group in Notodden is active. It is working to increase the involvement of volunteers by setting up a history group in Rjukan as well. Friends of the Rjukan Line play an important role in the protection of the Rjukan Line. Work is also under way to establish a voluntary group associated with the 'D/F Amonia' and 'M/F Storegut' ferries.

Information to children and young people

Work is under way on developing a local curriculum for Rjukan – Notodden that will cover the whole course of education from kindergarten to upper secondary education. Telemark University College is involved as a partner in this work. Telemark University College is also working on putting in place doctoral degrees of relevance to the World Heritage Site, and for Rjukan and Notodden to be able to order master's theses of relevance to cultural dissemination and travel and tourism. Notodden and Rjukan are working together to develop a joint teaching programme for the Cultural Rucksack. The Cultural Rucksack is a national programme that is intended to give all school pupils in Norway the opportunity to experience, become familiar with and appreciate different forms of professional artistic and cultural expression.

5j. Staffing levels and expertise

The county authority plays an important, direct role in the management of the World Heritage Site and the buffer zone. It has specialist expertise in cultural heritage administration and can also utilise other essential expertise from its own organisation.

The municipalities are generally knowledgeable about building construction subjects, both on the architectural/engineering side and on the craftsmen side. Specialist expertise in relation to conservation and restoration work is limited. The local level is adequate for most of the maintenance work that is to be carried out, but specialist expertise will be required in quite a few cases.

The local knowledge is probably not high enough to care fully for the values. Knowledge should therefore be obtained from outside, or developed locally or at county level. The ship preservation centres are a key partner when it comes to the ferries, and the Railway Museum and the Norwegian National Rail Administration are key in relation to the Rjukan Line and the Tinnoset Line.

6 MONITORING

6a. Key indicators for measuring the state of conservation

Knowledge about the condition of the cultural heritage and cultural environments, how they develop and causes of change are basic requirements needed for fact-based policy-making and management. In Norway, environmental monitoring produces results through the systematic, long-term collection of data and thereby helps to develop this knowledge. The Directorate for Cultural Heritage established environmental monitoring as a permanent field in 2001. Through environmental monitoring, the Directorate monitors quantitative and qualitative changes to cultural heritage and cultural environments.

Environmental monitoring is an important tool for cultural heritage administration as a basis for assessing the extent to which we reach the national goals set for cultural heritage and cultural environments. Through standardised methods, data are produced that can be interpreted and analysed. The results shall contribute to predictable environmental conservation work that avoids conflicts. They shall also provide indications of the cultural heritage and cultural environments' tolerance limits in relation to natural and man-made wear and tear. Early notification of a development that may have a negative effect on cultural heritage and cultural environments is also an important intention behind environmental monitoring.

Nationwide monitoring programmes have been initiated that provide important information about various topics and levels, including archaeology, buildings, cultural deposits in mediaeval towns, protected cultural environments and the cultural landscape of agriculture. There is also a focus on developing methods, including those using high technology, to ensure efficient cultural heritage administration. Environmental monitoring forms an important knowledge basis for deciding what measures to initiate when cultural heritage is threatened. Through systematic monitoring and continuous reporting, we will be able to determine whether the measures are effective. We will also be able to identify what consequences the measures will have, which will allow us to control developments towards reaching national environmental targets.

The results of the environmental monitoring programmes are presented every year in the Ministry of Climate and Environment's proposition to the Storting, and on the website www.miljøstatus.no. State of the Environment Norway was developed by the environmental directorates on assignment for the Ministry of Climate and Environment, and it presents the most recent information about the state and development of the environment. The website is continuously updated, and all information and data in State of the Environment Norway are quality assured twice a year.

Norway has well-established monitoring activities at the national level, the responsibility for which is organised under the various ministries and their subordinate directorates. Various research communities are important suppliers of data from the monitoring programmes.

The selection of indicators for Rjukan – Notodden is based on experience and well-established methods from existing monitoring programmes for cultural heritage and cultural environments. The indicators are presented in the following tables:

World Heritage Site (attributes 1–13):

Indicators	Period	Tentative method
Number of significant objects with acceptable level of authenticity and integrity.	Every three years + reporting every six years	Photo documentation and professional assessment of change over time
Number of significant objects in acceptable state of conservation.	Every three years + reporting every six years	Photo documentation and professional assessment of change over time
Number of significant objects in active use	Every three years + reporting every six years	Quantification of change over time

Buffer zone:

Indicators	Period	Tentative method
Number of key sight lines with visibility of the World Heritage Site	Reporting every six years	Assessment photos with GPS coordinates

6b. Administrative arrangements for monitoring the site

The Directorate for Cultural Heritage, Telemark County Authority, Tinn Municipality and Notodden Municipality will decide on the division of responsibilities and where the documentation is to be stored. Some areas in which there is a basis for establishing a monitoring regime will be described in more detail in the management plan for the World Heritage. A decleration of intention has been signed.

6c. Results of previous condition exercises

Condition surveys have been carried out for some protected objects during the period 2008–2011, and further work will be done during 2014. Reference is otherwise made to Chapter 4.a Present state of conservation.

7 DOCUMENTATION

7a Photographs and audiovisual image inventory and authorization form

List of illustrations in Annex 2

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
1	Digital photo	Notodden facing north	2013-09-28	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
2	Digital photo	Notodden facing north west with Gaustatoppen behind	2013-10-12	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
3	Digital photo	Tinnsjøen Lake facing north with Gaustatoppen to the left	2013-10-12	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
4	Digital photo	Rjukan and Gaustatoppen facing west	2013-01-25	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
5	Digital photo	Rjukan and Gaustatoppen facing west	2013-10-12	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
6	Digital photo	Rjukan and Gaustatoppen facing east	2013-09-28	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
7	Digital photo	Rjukan and Gaustatoppen facing east	2012-08-29	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
8	Digital photo	Møsvatn Lake, Vinje, facing north west	2013-10-12	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
9	Digital photo	Tinnfoss cultural environment, facing north	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
10	Digital photo	Tinnfoss waterfall	2012-05-23	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
11	Digital photo	Tinfos I power plant	2012-09-30	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
12	Digital photo	Tinfos II power plant	2012-09-30	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
13	Digital photo	Tinfos II power plant	2013-02-25	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
14	Digital photo	Tinfos II power plant	2013-02-25	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
15	Digital photo	Svelgfoss gorge with the Lightening Arrester House on the cliff	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
16	Digital photo	Rjukanfossen waterfall	2012-07-24	Trond Taugbøl	Trond Taugbøl	Trond.taugbol@ online.no	Yes
17	Digital photo	Skarsfos Dam I	2012-07-05	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
18	Digital photo	Skarsfos Dam I with intake gate house	2012-07-05	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
19	Digital photo	Waste rock dumps between Skarsfos Dam and Vemork Power Plant	2012-09-21	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
20	Digital photo	Penstock valve house at Vemork Power Plant	2012-09-10	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
21	Digital photo	Penstock at Vemork Power Plant	2013-09-10	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
22	Digital photo	Penstock and Vemork railway track at Vemork Power Plant	2011-08-31	Eystein M. Andersen	Directorat for Cultural Heritage	postmottak@ ra.no	Yes
23	Digital photo	Vemork Power Plant		Trond Taugbøl	Trond Taugbøl	Trond.taugbol@ online.no	Yes
24	Digital photo	Vemork Power Plant	2012-05-31	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
25	Digital photo	Vemork Power Plant	2013-02-20	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
26	Digital photo	Vemork Power Plant	2013-02-20	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
27	Digital photo	Vemork Power Plant	2013-02-20	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
28	Digital photo	Vemork Power Plant	2009-06-28	Ingvild Andersen	Ingvild Andersen	ingvildand@gmail.com	Yes
29	Digital photo	Måna river and Såheim Power Plant	2012-08-01	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
30	Digital photo	Såheim Power Plant	2012-05-01	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
31	Digital photo	Såheim Power Plant	2012-09-12	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ra.no	Yes
32	Digital photo	Såheim Power Plant	2010-08-30	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ra.no	Yes
33	Digital photo	Såheim Power Plant	2012-06-19	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
34	Digital photo	Såheim Power Plant	2013-02-22	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
35	Digital photo	Såheim Power Plant, underground turbine generator hall	2010-11-05	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ra.no	Yes
36	Digital photo	Power line 16/17	2012-05-08	Eystein M. Andersen	Directorat for Cultural Heritage	postmottak@ra.no	Yes
37	Digital photo	Power line 16/17	2012-05-08	Eystein M. Andersen	Directorat for Cultural Heritage	postmottak@ra.no	Yes
38	Digital photo	Transformer and distribution station, Rjukan	2013-05-07	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
39	Digital photo	Hydro Industrial Park in Notodden facing north west	2013-01-30	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ra.no	Yes

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
40	Digital photo	Hydro Industrial Park in Notodden facing north east	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
41	Digital photo	Hydro Industrial Park in Notodden	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
42	Digital photo	Hydro Industrial Park in Notodden	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
43	Digital photo	Furnace House A, Hydro Industrial Park in Notodden	2012-06-28	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
44	Digital photo	Furnace House A, Hydro Industrial Park in Notodden	2010-11-03	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ ra.no	Yes
45	Digital photo	Tower House A, Hydro Industrial Park in Notodden	2012-06-04	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
46	Digital photo	Furnace House C, Hydro Industrial Park in Notodden	2012-06-28	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
47	Digital photo	Packaging Factory, Hydro Industrial Park in Notodden	2012-06-13	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
48	Digital photo	Hydrogen Plant, Hydro Industrial Park in Notodden	2012-06-13	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
49	Digital photo	The Minaret, Hydro Industrial Park in Notodden	2012-10-09	Eystein M. Andersen	Directorat for Cultural Heritage	postmottak@ ra.no	Yes

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
50	Digital photo	Nitrogen Plant and Gas Cleaning Plant, Hydro Industrial Park in Notodden	2012-06-28	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
51	Digital photo	Electric Arc Furnace, Notodden	2012-09-28	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
52	Digital photo	Electric Arc Furnace, Notodden	2012-05-31	Dag Jenssen	Telemark County Council	postmottak@t-fk.no	Yes
53	Digital photo	Electric Arc Furnace, Rjukan	2013-04-21	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
54	Digital photo	Hydro Industrial Park in Rjukan	2012-06-27	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
55	Digital photo	Hydro Industrial Park in Rjukan	2013-05-07	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
56	Digital photo	Hydro Industrial Park in Rjukan facing east		Hans-Dieter Fleger	Hans-Dieter Fleger	foto@fleger.com	Yes
57	Digital photo	Part of Hydro Industrial Park in Rjukan	2013-05-07	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
58	Digital photo	Furnace House I, Hydro Industrial Park in Rjukan	2012-04-04	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
59	Digital photo	Boiler House, Hydro Industrial Park in Rjukan	2012-06-07	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
60	Digital photo	Acid Tower, Hydro Industrial Park in Rjukan	2012-06-07	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
61	Digital photo	Pump House, Laboratory and Acid Tower, Hydro Industrial Park in Rjukan		Hans-Dieter Fleger	Hans-Dieter Fleger	foto@fleger.com	Yes
62	Digital photo	AEG Pump in Pump House, Hydro Industrial Park in Rjukan	2013-05-15	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
63	Digital photo	Notodden Railway Station	2013-05-02	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
64	Digital photo	Wagon weighing hut at Notodden Railway Station	2013-05-02	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
65	Digital photo	Tinnoset Railway station	2012-09-28	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
66	Digital photo	Tinnoset Railway station, Ferry Quay and Slipway	2013-05-07	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
67	Digital photo	Tinnoset Ferry Quay and M/F Storegut	2012-09-27	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
68	Digital photo	Tinnoset lighthouse	2013-09-12	Per Berntsen	Per Berntsen	per@perberntsen.com	Yes*
69	Digital photo	Håkanes lighthouse	2009-08-08	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ra.no	Yes
70	Digital photo	M/F Storegut at the jubilee in 2009	2009-08-10	Alexander Ytteborg	Directorat for Cultural Heritage	postmottak@ra.no	Yes
71	Digital photo	M/F Storegut at the jubilee in 2009	2009-08-10	Hans-Dieter Fleger	Hans-Dieter Fleger	foto@fleger.com	Yes

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
72	Digital photo	D/F Ammonia	2009-08-08	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ ra.no	Yes
73	Digital photo	D/F Ammonia	2009-08-09	Alexander Ytteborg	Directorat for Cultural Heritage	postmottak@ ra.no	Yes
74	Digital photo	D/F Ammonia	20013-09-12	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
75	Digital photo	D/F Ammonia	2013-09-12	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
76	Digital photo	D/F Ammonia	2013-09-12	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
77	Digital photo	Mæl Ferry Quay	2013-06-20	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ ra.no	Yes
78	Digital photo	Mæl Railway Station and Ferry Quay	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
79	Digital photo	Mæl Railway Station Building and D/F Ammonia	2010-10-21	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ ra.no	Yes
80	Digital photo	TSFO 76 with a synthesis furnace	2013-09-08	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
81	Digital photo	Miland bridge, The Rjukan Line	2013-09-10	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
82	Digital photo	Wind wall, The Rjukan Line, with Gaustatoppen	2012-06-06	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
83	Digital photo	Rjukan Railway Station Building with signal board	2011-06-17	Eystein M. Andersen	Directorat for Cultural Heritage	postmottak@ ra.no	Yes
84	Digital photo	Vemork railway track	2012-09-21	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
85	Digital photo	Grønnebyen and Admini, Notodden Hydro Town	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
86	Digital photo	Villamoen and Admini, Notodden Hydro Town	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
87	Digital photo	Grønnebyen, Notodden Hydro Town	2011-08-23	Trond Taugbøl	Directorat for Cultural Heritage	postmottak@ ra.no	Yes
88	Digital photo	Grønnebyen, Notodden Hydro Town	2012-04-12	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
89	Digital photo	Grønnebyen, Notodden Hydro Town	2012-05-30	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
90	Digital photo	Admini, Notodden Hydro Town	2012-05-23	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
91	Digital photo	Admini, Notodden Hydro Town	2013-02-25	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
92	Digital photo	Rjukan seen from top of Krosso Aerial Cableway	2005-12-10	Hans-Dieter Fleger	Hans-Dieter Fleger	foto@fleger.com	Yes
93	Digital photo	Krosso Aerial Cableway, Rjukan Hydro Town		Hans-Dieter Fleger	Hans-Dieter Fleger	foto@fleger.com	Yes
94	Digital photo	Krosso and Villaveien-Flekkebyen housing areas, Rjukan Hydro Town	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
95	Digital photo	Fjellveien, Rjukan Hydro Town	2012-03-28	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
96	Digital photo	Fjøset farm building, Rjukan Hydro Town	2012-05-22	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
97	Digital photo	Villaveien-Flekkebyen housing area with the industry area on the south bank, Rjukan Hydro Town	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
98	Digital photo	Admini, Rjukan Hydro Town	2012-05-22	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
99	Digital photo	Gatehouse and fire station, Rjukan Hydro Town	2012-06-14	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
100	Digital photo	Rødbyen and Tyskerbyen housing areas, Rjukan Hydro Town	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
101	Digital photo	Rødbyen housing area, Rjukan Hydro Town	2013-05-06	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
102	Digital photo	Tyskerbyen housing area, Rjukan Hydro Town	2013-04-25	Trond Taugbøl	Directorat for Cultural Heritage	trond.taugbol@ ra.no	Yes
103	Digital photo	The Rjukan House, Rjukan Hydro Town	2012-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
104	Digital photo	Tyskerbyen housing area and Market Square, Rjukan Hydro Town	2012-04-17	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
105	Digital photo	New Town (house type O), Rjukan Hydro Town	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
106	Digital photo	New Town (house type O), Rjukan Hydro Town	2013-04-13	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
107	Digital photo	Baptist Church, Rjukan Hydro Town	2012-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
108	Digital photo	Rjukan Church and Rjukan Hospital, Rjukan Hydro Town	2012-04-17	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
109	Digital photo	Rjukan Church, Rjukan Hydro Town	2013-03-27	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
110	Digital photo	New Town (house type O), Market Square and Tyskerbyen housing area facing west, Rjukan Hydro Town	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
111	Digital photo	Mannheimen single men’s home and Paradiset housing complex, Rjukan Hydro Town	2012-04-16	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
112	Digital photo	Sing Sing housing quadrant, Rjukan Hydro Town	2012-04-29	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
113	Digital photo	Sing Sing housing quadrant, Rjukan Hydro Town	2012-06-06	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
114	Digital photo	Tveito Park and Tveito Avenue, Rjukan Hydro Town	2013-05-07	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*

Fig. no	Format	Caption	Date of photograph	Photographer	Copyright owner	Contact details of copyright owner	Non-exclusive cession of rights
115	Digital photo	Tveito School, Rjukan Hydro Town	2012-07-30	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*
116	Digital photo	Tveito Avenue, Rjukan Hydro Town	2012-06-06	Per Berntsen	Per Berntsen	per@ perberntsen.com	Yes*

*According to the agreement between photographer Per Berntsen and Directorate for Cultural Heritage, Berntsen has granted a limited right for Directorate for Cultural Heritage to the following use of the photographs:

Directorate for Cultural Heritage grants permission for UNESCO and the Municipalities of Vinje, Tinn and Notodden to reproduce all the photographs in the copyright areas regarding the world heritage nomination.

7b. Texts relating to protective designation

The content of the texts relating to protective designation, management and maintenance can be found described in relevant depth in Section 5b and 5d. The World Heritage Management Plan mentioned in Section 5e, including Declaration of intent mentioned in Section 5c, can be found as Annex no. 3.

7c. Form and date of most recent databases/ inventory of the site

Background material and reports

In connection with the preparation of this nomination dossier the following background material and reports have been prepared especially:

- Aasland, Trond *Lysbueovnen – et industrielt svar på et globalt landbruksproblem* 2012, 11 p.
- Andersen, Eystein M. *Rjukanbanen. Beskrivelse og dokumentasjon*, 2012, 79 p.
- Andersen, Eystein M. *Forslag til fredning etter kulturminneloven §§ 15 og 19 av Hydroparken Notodden – Notodden kommune*, 2012, 16 p.
- Andersen, Eystein M. *Arkitektur generelt i Hydroparken*, 2012, 10 p.
- Andersen, Eystein M. *Forslag til fredning etter kulturminneloven §§ 15 og 19 av Rjukan Næringspark – Tinn kommune*, 2012, 14 p.
- Andersen, Eystein M. *Hydros eldste kalksteinsbrudd i Telemark*, 2013, 1 p.
- Andersen, Ketil Gjølme *Den andre industrielle revolusjon og etableringen av den vannkraftbaserte storindustrien i Norge* (8 p., 2007)
- Bjørsvik, Elisabeth *Odda Smelteverk – en oversikt* 2009, 12 p.
- Brennsund, Jan Petter *Tilstandsrapport lysbueovner*, 2011, 5 p.
- Dugstad, Andreas *Konsesjonslovene – de politiske konsekvensene av den andre industrielle revolusjon i Norge* 2011, 17 p.
- Dugstad, Andreas *Pionerbyen Notodden og nitratindustrien* 2011, 18 p.
- Dugstad, Andreas *Tinfos og nitratproduksjonen på Notodden* 2011, 5 p.
- Dugstad, Andreas *Notodden. Stedet ved elva* 2012, 19 p.
- Föhl, Axel and Rolf Höhmann *Taming the waterfalls* 2011, 24 p.
- Gundersen, Edgar *Hydro industrial site at Notodden and som more*, 2010, 41 p.
- Gundersen, Edgar *Jugendbebyggelse* på Notodden 2011, 20 p.
- Gundersen Edgar *Svælgfos II – bevarte fysiske spor med litt forklaring* 2012, 3 p.
- Gundersen, Edgar *Boligbyggingen på Svelgfoss 1906 – 1913* 2012, 7 p.
- Gundersen, Edgar *Notoddens reguleringsplaner* 2013, 6 p.
- Henriksen, Norolf *NH3-anleggene*, 2012, 3 p.
- Hydro Energi, *Rjukananleggene. Tipper. Oversikt over anleggenes tipper*, 2012, 5 p.
- Iversen, Bjørn *Rapport om eksisterende/gjenværende historiske gjenstander av betydning* 2012, 98 p.
- NIKU *Rapport DIVE-analyse Notodden* 2012, 64 p.

- NIKU *Rapport DIVE-analyse Rjukan* 2012, 78 p.
- Telemark fylkeskommune *Rjukananlegget. Hvordan var det mulig?* 2011, 18 p.

Digital records

All objects legally protected through the Cultural Heritage Act are registered in the database Askeladden run by the Norwegian Directorate for Cultural Heritage. Askeladden has restricted access. A public version can be seen on the website www.kulturminnesok.no. The most recent results of the environmental monitoring programs are presented on the website www.miljostatus.no.

Archives

The Norwegian Industrial Workers' Museum made sure in 2012 that Rjukan's industrial history became a part of Norway's Document Heritage. Two objects were chosen. These were Rjukan's revolutionary banner and a minutes record from 1911-12. The latter contained a list of locked-out workers from Rjukan Saltpetre Factory. This means that these objects are part of the Norwegian contribution to the UNESCO Memory of the World.

A large archival material concerning Norsk Hydro's activities in Rjukan and Notodden is preserved. There are significant differences in the level of registration of the archives and documentation. In http://www.arkivportalen.no there is a simple description of theme, time period and type of document within each file. In http://digitaltmuseum.no/ there is information about objects and photographs from Norsk Hydro's activity where each registered item is represented with a small photograph.

The archive material encompasses drawings, photographs, documents, maps and newspaper cuttings associated with the planning and development of the town structures at Notodden and Rjukan with buildings, power stations and factories. In addition there are technical drawings of machines, as well as descriptions of production processes in the factories. It cannot be denied that life in the industrial towns of Rjukan and Notodden is an important part of the labour movement's history in Norway, and archive material about this is also to be found in the Norwegian Labour Movement Archives. In addition there are parts of archives from Sam Eyde's activities registered in the databases of the National Library and the National Archives of Norway. The Norwegian Technical Museum preserves artifacts used by Kristian Birkeland.

The Norwegian Industrial Workers' Museum

The Museum manages historical buildings and artifacts. It has the largest stake in the preservation of documents, drawings and photographs from ASA Norsk Hydro at Notodden and Rjukan. The Museum informs about the industrial history thematically through its website. In addition it publishes historical photographs and photographs concerned with Hydro's activities in the database http://digitaltmuseum.no/. The Museum also has more than 10 photographic collections of which Norsk Hydro's photograph collection is the largest.

The Norwegian Industrial Workers Museum administers the historical material related to the activities registered in the catalogue **A-1108** in the national base www.arkivportalen.no. The catalogue covers the period 1902-1998. The archive series are mainly the originals. Two different archive keys are in use. The total archive consists of more than 450 shelf metres of documents and the archive catalogue covers 912 pages.

The following is a small, edited selection from the catalogue which is relevant for the nomination.

Hydro-electricity

D. 20 Kraftverkene 1904 – 1973. Situated in the archive deposit at Vemork and consisting of the administrative archive for the planning of the power station in Vestfjorddalen. It also contains documents relating to the rebuilding of Vemork and construction of Saaheim, Rjukan II and Morkfossen-Frøystul, as well as the regulation of the watercourse.

Industry

A-1120: Hydro Notoddens arkiver – Bedriftshistorisk samling. Reference material, archive lists, instructions, newspaper cuttings. Newspaper cuttings from daily newspapers which concerned Hydro 1906-1954.

Map and drawing collection: ca. 500 sheets from the period 1905-1930 are registered manually. Contains drawings of buildings, factory buildings, machines and technical drawings. Contains amongst other objects drawings of the Ammonium-Nitrate Factory, Notodden Saltpetre Factory, Workers' Housing and the Packaging Factory.

D02 og D03: Saksarkiv (1902 – 1996) Situated in the archive deposit at Vemork. The factories' administration and leadership's archive for ca. nine decades. The archive is vital for tracing changes and restructurings on and in the factory buildings and production processes. The material covers 167 shelf metres.

D-16 Såheim og Rjukan fabrikker (1910-1928) Consists of the administrative archive relating to the planning, construction and running of several production plants, including the Rjukan-II plants. In addition documents from planning work and correspondence concerning furnace buildings and synthesis furnaces. Covers ca. 1.5 shelf metres.

A-1119: Professor Kristian Birkeland's archive 1898 - 1920 is kept by the The Norwegian Industrial Workers Museum. The archive consists of letters, drawings and notes composed in connection with Birkeland's work within aurora research and the development of the electro-magnetic canon.

Transport

B/Brjb: Rjukanbanens (NTA kopibøker) (1918 – 1923) All outgoing correspondence from the Rjukan railway administration during a five-year running phase, including the period with electrification, while the organisation was led from Notodden. Bound copies of outgoing letters. Covers 3.2 shelf metres.

D2: Rjukanbanen (1905 -1993) This archive for the Rjukan Line was established in connection with the running and upgrading of the Vestfjorddal railway, the ferries on Tinnsjøen and partly the Tinnos/Bratsberg railways. It also contains the administrative archives of the Rjukan railway administration which cover most aspects of the railway's installations and transport equipment, including documents from the construction works before the running phase. It covers 42 shelf metres.

Ba: Tinnos- og Rjukanbanen, dokumentsamling (1905 – 1971) Documents from the construction phase of the two railway lines. It also covers changes to the ferries. Covers 1.6 shelf metres.

Town structures

D 14: Rjukan Byanlæg (1909-1934) The administrative archive concerning the planning and construction of infrastructure, housing and other necessary buildings in the Hydro town of Rjukan. Also documents from the planning work and correspondence concerning the construction of several areas of Rjukan. Covers 1.6 shelf metres.

Ta: Tegningsarkivet (1905 - 1940) Original drawing and map material from Hydro Rjukan's own drawings archive. The archive contains many original documents, particularly from the construction of the Rjukan railway's installations and transport equipment, the factories and the town. The material consists of ca. 1500 drawings in very varied formats, including some large.

Tb: Rjukan Byanlægs tegningsarkiv (ca 1910 - 1940) Consists of work drawings used by officials and leaders of the town entity. The drawings are kept in their original document folders and the series is arranged in its original order. The documents are central for the preservation of the architectural and long-term principles both for construction and running of the Hydro town Rjukan. In addition the series is an irreplaceable supplement to the Rjukan town archive *Rjukan byanlægs saksarkiv (D14)*. Covers 9 shelf metres.

10. Tegningssamlingen (1905 -) Collection of drawings kept in the drawings deposit at Vemork. Consists of drawings of housing, public buildings, shelters, fences, garages, dovecotes, etc. Includes drawings of the factory plant. Detail drawings are down to 1:1. Includes regulation plans and zone maps for the whole town area. Factory drawings have previously been cut or censored to prevent industrial espionage. It has been ascertained that the drawings originally had a volume of 2-3 cubic metres. Altogether 3996 drawings are preserved.

The Herøya archives

Hydro itself currently manages the archives for Herøya in Porsgrunn. These contain a photograph archive for the period 1920-2007 and a correspondence archive covering several hundred shelf metres. There are also 300 shelf metres with research and development archives from 1938 and later, as well as the archives from the company health service.

The Lysbuen Museum and Gallery at Notodden

This Museum manages art from Norsk Hydro's and the Norwegian Industrial Workers' Museum's art collections. The collections contain pictures from the golden age of power development and industry in Telemark. The museum also manages Norsk Hydro's former museum collection with sereval different historical objects and documents.

Photographs and film – institutional depositories and websites

Photographer Anders B. Wilse (1865-1949) took innumerable photographs of nature, folk life, hydro power and industrial history at Rjukan and Notodden. The photographs are mainly owned by the Norwegian Folk Museum and cover the period from ca. 1900-1940. They are published in the database www.nb.no.gallerinor which is run by the National Library.

Photographer Auguste Léon took photographs in Rjukan, Notodden and Tinfoss during a journey he made together with the French investor Albert Kahn in 1910. The originals are kept in Les Collections des Albert Kahn, in Boulogne-Billancourt in Paris.

Film by Stig Andersen for the Norwegian Broadcasting Company (NRK) ca. 1980. Reference: Rjukan en industriby blir til – Hefte nummer 5. S. Andersen og D. Hvoslef-Eide 2012.

Film from Notodden 1917
http://www.telen.no/nyheter/notodden/fra-notodden-by-1.7674574

Film from Rjukan 1917
http://www.telen.no/nyheter/notodden/fra-rjukan-og-mel-1.7674569

Film from Rjukanbanen 1952
http://tinn.videoarkivet.no/index.php?vid=135
http://tinn.videoarkivet.no/index.php?vid=118
http://tinn.videoarkivet.no/index.php?vid=91
http://tinn.videoarkivet.no/index.php?vid=92
http://tinn.videoarkivet.no/index.php?vid=95

Demolition of the old Møsvannsdammen
http://videoarkivet.no/company.php?cid=1004&vid=106

Hvor mye vann er nok? (How much water is enough, about water in regulated lakes)
http://videoarkivet.no/company.php?cid=1004&vid=208

Rjukanbanen 100 år (The Rjukan Line 100 years)
http://videoarkivet.no/company.php?cid=1023&vid=191

Arkitektene Astrup og Hellern AS
This architect company, which is a direct successor to Thorvald Astrup, owns a considerable number of drawings from the development of Notodden and Rjukan. They cover all types of buildings from doctor's surgery, power station, paper factory, iron works, to agronomist housing and more. (The drawing list is registered in P360 13-5001).

7d. Address where inventory, records, and archives are held

Riksantikvaren (Norwegian Directorate for Cultural Heritage)
Pb 8196 Dep
N-0034 Oslo
NORWAY

Telemark fylkeskommune (Telemark County Council)
Postbox 2844
N-3702 Skien
NORWAY

Norsk Industriarbeidermuseum (Norwegian Industrial Workers Museum)
Vemork
N- 3660 Rjukan
NORWAY

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8d. Official websites for the World Heritage Site

http://www.riksantikvaren.no/?module=Articles;action=Article.publicShow;ID=134730

9 SIGNATURE

Rjukan – Notodden Industrial Heritage Site

Signed on behalf of the State Party of Norway

Place and date

Tine Sundtoft
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NORWEGIAN MINISTRY OF
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