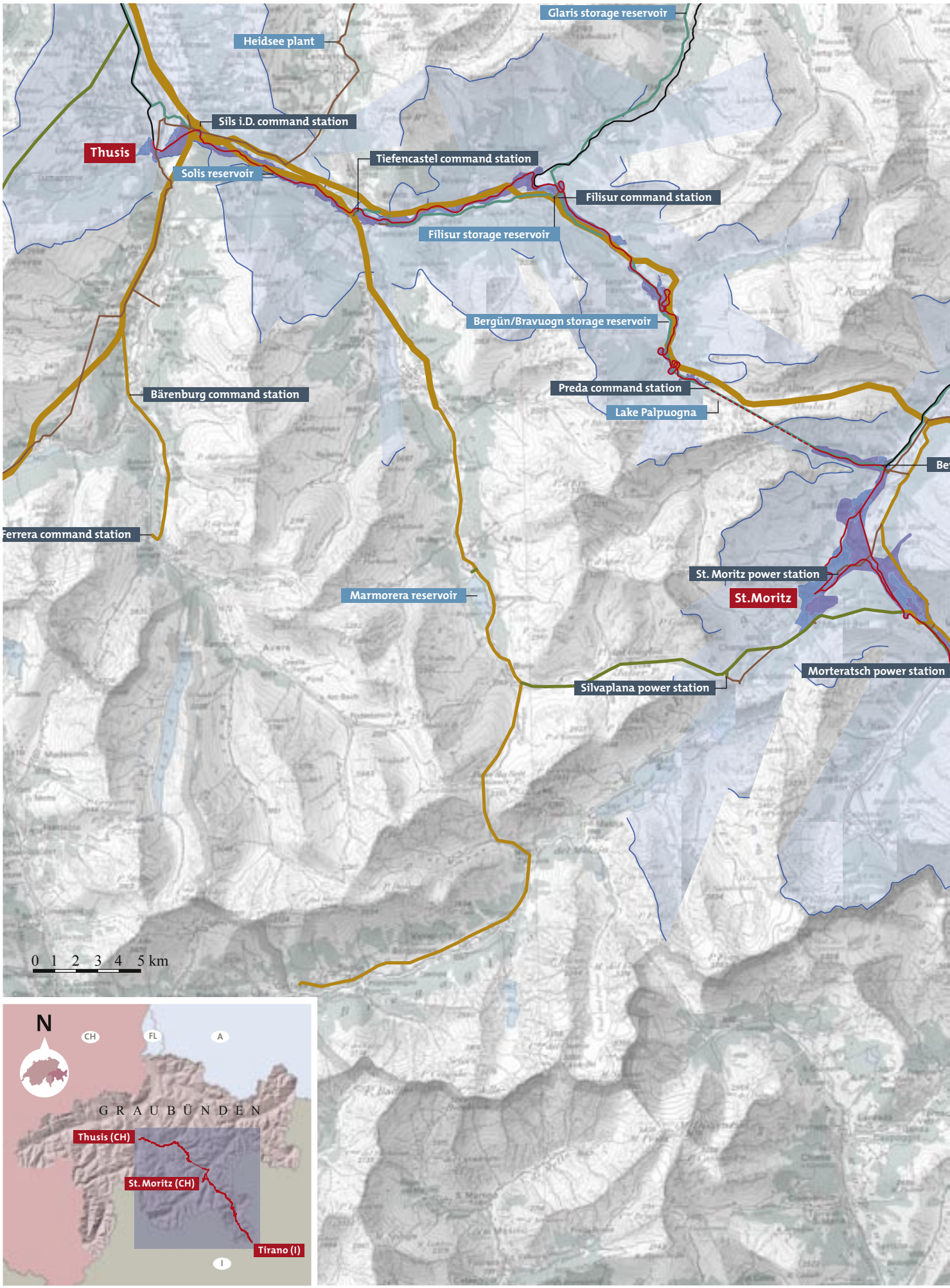
Glaris storage reservoir
Heidsee plant
Sils i.D. command station
Thusis
Tiefencastel command station
Solis reservoir
Filisur command station
Filisur storage reservoir
Bergün/Bravuogn storage reservoir
Bärenburg command station
Preda command station
Lake Palpuogna
Ferrera command station
St. Moritz power station
St.Moritz
Marmorera reservoir
Morteratsch power station
Silvaplana power station
0 1 2 3 4 5 km
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GRAUBÜNDEN
Thusis (CH)
St. Moritz (CH)
Tirano (I)
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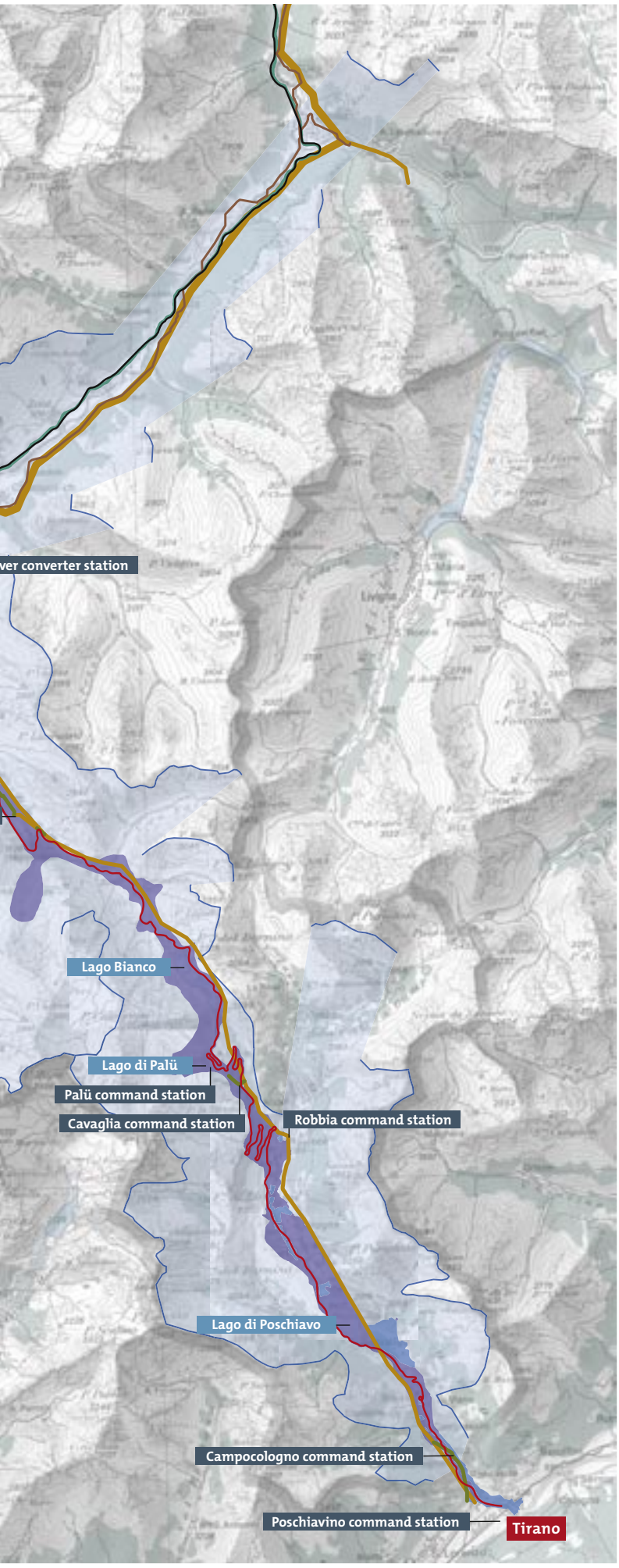

Infrastructure for the generation of hydroelectric power and the transport of power

	50 kV – 60 kV	Transmission cables
	66 kV	Transmission cables (Power for the railway)
	130 kV – 150 kV	Transmission cables
	220 kV – 380 kV	Transmission cables
		Control centres, power plants and converter stations
		Reservoirs

Core zone

Core zone with railway and cultural landscape

Buffer zone

Buffer zone in the near area

Buffer zone in the distant area (backdrop)

Horizon line

Other contents

Other stretches of the Rhaetian Railway

Sources:
Basic map: PK 200'000 swisstopo, Wabern
Geo-data: Amt für Raumentwicklung Graubünden
Thematic data: Adrian Collenberg
Design: Süsskind, SGD, Chur
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2.b.7 Power for the Albula and Bernina line: the power station buildings along the railway line

There are several power stations along the Albula and Bernina line documenting the surge in the use of hydroelectric power during the 20th century. When they were built 1906/07, the works in Campocologno represented the largest high-pressure power station in Europe; its construction was closely linked with that of the Bernina Railway. Other power stations along the river Albula were built later, primarily to produce electricity for the urban and industrial centres in Switzerland. The electrification – very early on an international comparison – entailed the construction of electro-technical facilities that are an important feature of the cultural landscape between Thusis and Tirano.

In summer 1879, Johannes Badrutt surprised his guests at the St. Moritz Kulmhotel with electric arc lamps in the dining room. He had simply coupled the "light machines" first demonstrated the previous year at the Paris World Exhibition with a water-powered generator. Similar lighting systems were soon introduced in the luxury hotels in Pontresina, Maloja, Davos and Flims. Then small hydroelectric power stations started to spread throughout Switzerland to provide light in the towns and villages. Decisive for global electrification, however, was the successful high-voltage power transmission over a distance of 175 km first presented at the Frankfurt Electrotechnical Exhibition in 1891. It showed that the generation of electricity was not necessarily location-determined but that electric power could also be used, irrespective of where it was produced, for distant sales and consumer areas. As the water power could be used for industrial purposes, this technical innovation was the impetus for the first power station boom in the Alps.

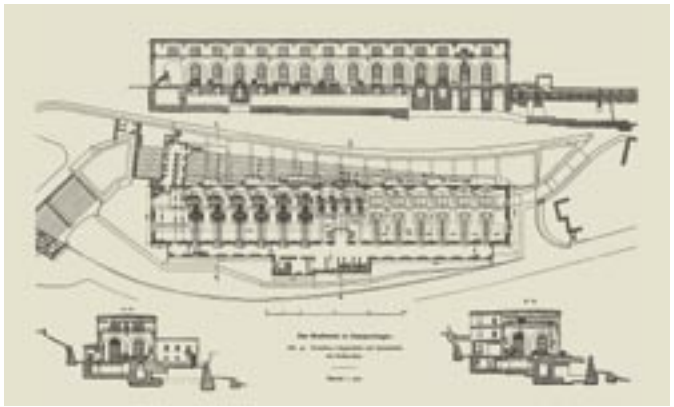
On an international comparison, Switzerland and Graubünden experienced very early electrification thanks to the power stations, as there was a plentiful supply of water to provide the energy. This boom not only had considerable repercussions on industry and the economy but also on people and the environment. Analogous to the building of the railway, the power stations in the 20th century radically changed the landscape along the Albula and Poschiavino rivers: besides rail tracks, viaducts and stations there were now reservoirs, pylons and works buildings. Naturally, the railway and power generation plants were and are closely linked.

Inter-connections on the Bernina

Initial studies on the exploitation of water power in Val Poschiavo were undertaken by the Zurich engineering office Froté & Westermann. The concessions acquired 1898/99 were sold to General Water Power Limited in London; later they went over to the Alioth electricity company in Basel. On 14th June 1904, the latter, in conjunction with the Società Lombarda per distribuzione di energia elettrica in Milan, founded the Kraftwerke Brusio AG (KWB; today Rätia Energie AG). The new company was to supply power to the industrial centres in Lombardy as well as the Bernina railway which would be electrically operated from the outset. The new line aimed to provide access to the scenic landscape between

Campocologno > Six penstocks of the largest storage power station in Europe of the time ran from the Scala gallery to the Campocologno station. Photograph before 1933.
A. Steiner/Rhaetian Railway

1929 relief of the Poschiavo Valley with the hydroelectric power plants, together with the "large Palü reservoir" and the "Asciatti" auxiliary line projects. Illustration from: *Die Kraftwerke Brusio 1904 – 1929*, published by Kraftwerke Brusio AG, Poschiavo 1929.



Ground plan and elevations of Campocologno control centre.
Rätia Energie AG, Poschiavo

Lago Bianco > The south wall of the Lago Bianco with the 1911 valve tower (left) and the new valve tower built in 1927. Photograph before 1942.
Rätia Energie AG, Poschiavo

St. Moritz and Tirano for a broad public.
The first hydroelectric power station used the water from the lake at Poschiavo; this was led via a surge tank in Monte Scala through five (later six) above-ground penstocks down to the turbine chamber in Campocologno. This covered a surface of 104 x 17 m. The works were upgraded in 1906/07 to a turbine power of over 26,000 kW. In winter 1908/09 the number of generator sets was increased from ten to twelve, raising the output to over 30,000 kW. For a short time, with respect to building, the Campocologno power station was the largest plant of the kind in Europe. The spectacular works were praised at length in engineering publications and viewed by visitors from all over the world.
A second power station with its command station in Robbia, opposite San Carlo, utilised the hydropower from the Bernina lakes and the Palü glacier, collected by two dams. The works came into operation in November 1910 with three generator sets. Shortly afterwards the power output was raised to 11,000 kW.
Four converting stations were set up in Campocologno, Poschiavo, Ospizio Bernina and Pontresina to supply power to the Bernina Railway, which transformed the three phase high-voltage current into 750 volt direct current. After the successful start of the Bernina railway, a power supply contract was concluded with the Rhaetian Railway and the KWB built a converter station in Bever, which supplied the Engadin railways with power from 1913. The KWB contracted further supply agreements with the local electricity works in St. Moritz and Madulain, while the local distributor networks in Poschiavo and Brusio were established and operating earlier. Two power lines were taken over the Bernina Pass and one to Italy to distribute the current. At first, most of the hydropower was exported to Italy. It was only with the political disputes at the beginning of the 1920s that the KWB began to orient its supplies to the north.
The complex roles played by the leading personalities were a striking feature of the founder years. Between the years 1904 und 1914, for example, Alfred von Planta (1857 – 1922) was at the same time president of the KWB, the Bernina Bahn AG and the Rhaetian Railway. His successor, Alfred Sarasin was President of the Board of Directors of the KWB 1914 – 1953 and responsible for the Bernina Railway until 1935. Further his bank in Basel played a major financing role for other Swiss mountain railway projects.
After the end of the First World War the utilisation of hydropower spread throughout the Alpine region. To meet the rising demand for power, the KWB expanded its plants and built the Palü and Cavaglia power stations in the upper Poschiavo valley. Water from the Bernina lake is run through a subterranean pressure tunnel to the Palü command station where there was a 10,000 kW machine set. The penstocks and connecting tunnels led down to Cavaglia from the additional reservoir which stored the water in Lago Palü. The output of the Pelton turbine installed there was over 7,000 kW. This upgrade entailed renewal work on the plants in Robbia and Campocologno. The increased production volume was still exported to Italy, but the electricity could now be taken via the Albula power line to Thusis and Sils i.D.
Besides generating tax and duties income and preferential electricity for the Val Poschiavo, the KWB created jobs and earning opportunities in a remote Alpine region. In the mid 20th century, the power company had a total staff

Transporting the pole wheel (rotating part of a generator) for a machine aggregate at Campocologno power station by horse and cart between Tirano and Campocologno. Photograph about 1906.
Rätia Energie AG, Poschiavo

The Rhätische Werke Thusis built a power line over the Albula Pass in 1921. This created a link with the south; with the Brusio power stations. The photograph shows the erection of the iron masts in the Engadin.
Rätia Energie AG, Poschiavo

Electrification of the Albula line > The trial-run train in Bergün/Bravuogn station. Photograph about 1919.
Collection G. Brüngger

of 117 while the continuous expansion and maintenance work created more earning possibilities. The KWB also supported social and cultural projects in the valley. In contrast to the Bernina Railway, which experienced serious economic crises and was taken over by the Rhaetian Railway in 1944, the use of hydroelectric power proved to be a relatively safe investment even in difficult times.

Electricity for the Albula Railway

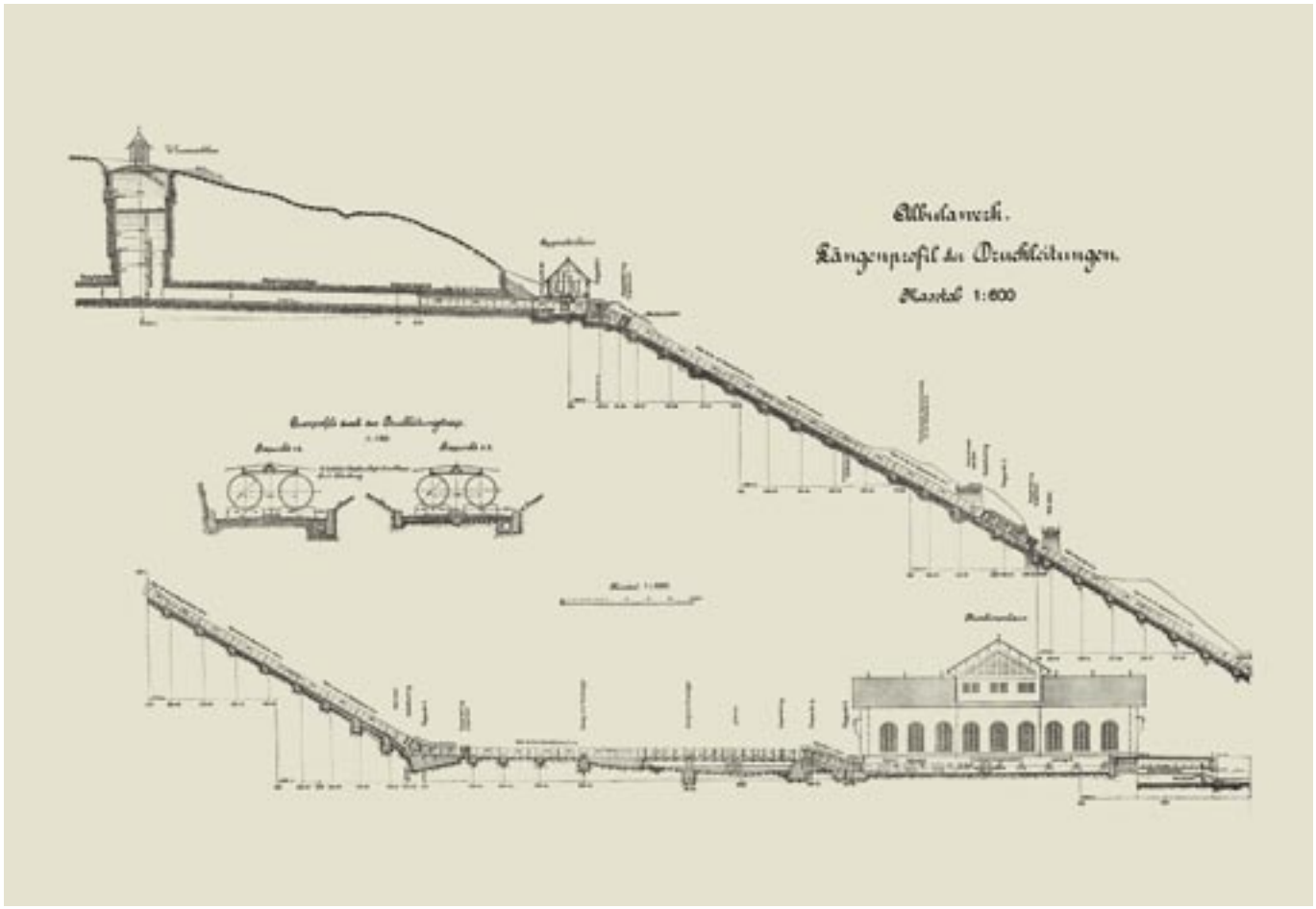
A small electricity works was set up in Preda as early as 1898, during the construction of the Albula tunnel; after the railway line was opened this went over to the community of Bergün/Bravuogn. The water was tapped from the lake at Palpuogna and run to the machine house in Preda to a Pelton turbine with an output of 88 kW. Besides Preda and Bergün/Bravuogn, it also supplied power to Latsch, Filisur and the spa hotel in Alvaneu. Particularly for the latter, having electricity was an important publicity argument – to be able to keep up with other wellness resorts.

The Albula Railway from Thusis to St. Moritz was not yet electrified when it was opened in 1904; steam locomotives were used. At that time the voltage was still insufficient for transporting power over considerable distances. In view of the positive experience with the Bernina Railway, the Rhaetian Railway resolved, in 1910, to power the new Lower Engadin line from Bever to Scuol with 11,000 volt single-phase alternating current. At the same time the existing Bever – St. Moritz as well as Samedan-Pontresina lines were converted to electricity. Electric operation started 1st July 1913; as already mentioned, the power was supplied by the KWB.

The scarcity of coal during the First World War accelerated the electrification of the entire rail network of the Rhaetian Railway. On 20th April 1919, the Rhaetian Railway "after completely satisfactory trials" opened the electrically powered scenic stretch from Bever to Filisur and, 15th October 1919 from Filisur to Thusis.

The conversion in Bever was not sufficient to power the extended electrified network. However, the Rhaetian Railway – in contrast to the Swiss Federal Railways (SBB-SFR) – did not opt to build its own power stations. Instead it obtained its electricity from the AG Rhätische Werke für Elektrizität (RhW), founded 1920 in Thusis. The KWB also held a share in the RhW, which transferred its power supply contracts with the Rhaetian Railway together with the Bever converter station to the new company. The RhW took over the Thusis electricity works, at the end of the Viamala gorge, which were used for industrial purposes. Various extensions raised the turbine output to 10,000 kW by 1921 and the plant was converted to produce single-phase current. After the first 60 kV power line across the ridge of the Alps was built, the Albula line from Thusis to Bever could also be supplied with electric power. Later the Rhaetian Railway also concluded agreements with the AG Bündner Kraftwerke (BK) that operated hydroelectric power stations in the Prättigau for the supply of power throughout the region.

The reciprocal relationship between clean rail power and the promotion of tourism was underlined in a publication by the Graubünden tourist association with the title "Recalling the completion of the electrification of all narrow gauge railways (400 km) and the expansion of the greatest electricity works in Graubünden" that was addressed primarily to English-speaking tourists. Despite economic fluctuations, hotel bookings



Sils i.D. > Penstocks, gallery, pressure pipe and control centre of the Albula works, owned by the city of Zurich. Plan (reduced in size) from the report on how the works were built: *Bericht zur Erstellung des Albulawerkes*, Zurich 1910.
Elektrizitätswerk der Stadt Zürich

Nisellas > Running off floodwater at the Nisellas wier gate. Photograph from before 1980.
Elektrizitätswerk der Stadt Zürich

Sils i.D. > The enormous control plant along the Albula river is a very important intersection in the Swiss power network. The EWZ machine house bottom right.
E. Süsskind

in the Upper Engadin, which is served by the Albula line, continued to rise and the railway proved its worth in making it possible for tourists to travel in comfort. The connection between the electrified Albula railway and the tourist industry in the Engadin was as evident as that between the building of power stations and promoting economic development in Val Poschiavo.

Hydroelectric power stations along the River Albula

The city of Zurich electricity works (EWZ) had a hydroelectric plant built in the years between 1907 and 1910 to cover the rising need for electricity in Zurich. The engineering office already mentioned, Froté & Westermann, was responsible for this costly building project. The Albula river was dammed at Nisellas, below Tiefencastel, and the river led off to the machine room in Sils im Domleschg via a gallery and hydro dam. The turbines installed there initially had an output of 18,000 kW; the capacity was raised continuously. The renowned Zurich architect Gustav Gull (1858 – 1942) was responsible for building the 65 x 22 m machine house; the settlement around it was built by Nicolaus Hartmann the younger (1880 – 1956) from St. Moritz. Today there is a switching station built on to the great hall – the first 380 kV plant in Switzerland with an open transformer field next to it.

The EWZ built the Heidsee plant on the Lenzerheide as a "supplementary plant for winter power" in the years 1917 – 1920. To cover the continually rising need for energy in winter, the EWZ had the Juliawerk built between 1949 and 1954, with an artificial lake in Marmorera as the main reservoir and with the command station in Tiefencastel. The EWZ also built enormous plants between 1954 and 1959 in Bergell and a 220 kV line over the Julier Pass to Zurich. At the beginning of the 1980s, the old Albula river dam at Nisellas was demolished and replaced by a 61 m arch dam. This raised the content of the regulating reservoir considerably. Further, a new penstock was built from the Solis storage reservoir to the command station at Rothenbrunnen. All the EWZ plants were now remotely controlled from the new operational buildings in Sils i.D.

At the beginning of the 1960s, the Kraftwerke Hinterrhein (KHR) had storage reservoirs built in Valle di Lei and on the Hinterrhein (Upper Rhine) with its principal command stations Ferrera, Andeer-Bärenburg und Sils i.D. tapping the water used by the RhW power station at Thusis and jeopardising the power supply for the Rhaetian Railway. Consequently, two single-phase machine sets with a total capacity of 5 MW were installed as a "special case plant". From 1961 these have been producing exclusively single-phase current with 16 $^{2}/_{3}$ Hz for the Rhaetian Railway catenary network. This KHR command station in Sils i.D. – in the immediate vicinity of the EWZ command station – was completed under the direction of the architect Konrad Metzger, who subsequently also modernised the smaller pioneer electricity works in Morteratsch (1968) and Silvaplana (1973). The enormous switchboard plant along the Albula river in Sils i.D. is a very important intersection in the Swiss power network. Today shareholders of the KHR include Rätia Energie AG, Canton Graubünden and the city of Zurich.

The Albula – Landwasser Kraftwerke AG (ALK) was formed in Filisur in 1961 with the objective of exploiting the river Albula between Naz/Preda und Bergün/Bravuogn and the river Landwasser between Davos and

Current power stations in the Albula / Bernina region:

Company	Power station	Turbine capacity	Annual production
Rätia Energie AG	Campocologno I	49.60 MW	195.00 GWh
	Campocologno II	1.62 MW	6.00 GWh
	Robbia	27.00 MW	105.60 GWh
	Cavaglia	8.30 MW	20.00 GWh
	Palü	10.40 MW	14.00 GWh
Rätia Energie Klosters AG	Morteratsch	0.57 MW	3.70 GWh
	Silvaplana	1.47 MW	4.80 GWh
EW St. Moritz	Islas	3.60 MW	12.80 GWh
EW Bergün	Preda	0.90 MW	3.60 GWh
ALK	Filisur	60.00 MW	266.20 GWh
	Tiefencastel	24.00 MW	100.00 GWh
EWZ	Tiefencastel East	56.00 MW	145.30 GWh
	Tiefencastel West	26.00 MW	76.80 GWh
	Solis	7.30 MW	26.40 GWh
	Sils i.D.	26.00 MW	92.60 GWh
KHR	Sils i.D.	255.40 MW	645.00 GWh

Source: Graubünden Energy Office from the 1.1.2005 Federal Statistics

Lago Bianco > The northern dam wall built 1910 – 1911.
A. Badrutt

Filisur. Due to rising building costs and competition from nuclear energy the original project had to be downsized. From two shallow storage reservoirs in Bergün/Bravuogn and Glaris, pressure pipes lead to a joint hydro dam above Filisur. The subterranean Francis turbines in the command station, opened 1965/66, achieve a capacity of 60,000 kW. The Filisur – Tiefencastel gradient was first used in 1988; a regulating reservoir was built below Filisur for this purpose and a head-race tunnel was laid from there to Tiefencastel. A capacity of 24,000 kW is generated in this inconspicuous building.

Important electro-technical historic structures alongside the railway

The Albula and Poschiavino rivers had already been used to generate power. Both the Rhaetian Railway contact wires and the hydroelectric companies' high-voltage lines follow the course of these rivers. Further several storage reservoirs, walls, pressure pipes and industrial buildings stand out in the landscape from the Schin gorge to Tirano. The engineers, architects and many workmen played a significant role in forming the landscape as we see it today.

The landscape on the Bernina Pass is sharply defined by the Lago Bianco (White Lake) that was created when the power station and the two dams were built; before then there were two small lakes with silted banks of alluvial deposits. The dam to the north at 2,200 m is on the watershed; water flows to the north with the Inn and the Danube towards the Black Sea, the Adda and the Po flow south to the Adriatic. It was built in 1910 – 1911 as a three-element, arched gravity dam. The wall to the south, facing down the valley, the Diga Scala with the maintenance tower standing proud is clad with local stone so that it looks like a natural dam. In the mid 1920s there were plans to dam Lago Palü with a 40 m wall, which would have been a serious intrusion in the sensitive glacier environment. The project encountered too many problems and was abandoned. Instead the Diga Scala was raised by 4 m in the 1940s; entailing a massive increase in the volume of the Bernina lakes. Today the crown of the dam is 190 m long.

Nicolaus Hartmann takes pride of place with respect to architectural influence in the building of the power plants: Hartmann, who also realised projects for the Rhaetian Railway (cf. 2.a.5), built the high-altitude command stations in Palü and Cavaglia. The Palü command station, with its vantage position at 1,923 m, perched in the midst of a wild mountainscape, is a fascinating sight even from the train window. All the technical elements are so well hidden in this massive rough-stone masonry structure that the first glimpse is reminiscent of a fort from the Middle Ages; the impression is accentuated by the irregular arrangement of the windows. The tower-like machine hall rears above the connected cube-shaped auxiliary buildings with the switching stations, the workshop, the shop and an apartment. Inside, the hall is almost baronial; the sole technical installation is the generator that is driven over a 28 m long vertical cam by Pelton and Francis turbines.

In contrast, the Cavaglia command station (1,706 m) at the northern edge of the forest on the plain of the same name looks like an oversized traditional "Engadin farmhouse" (cf. 2.a.6). The building complex is in roughcast stonework, the wooden roof frame is covered with large shingles of local stone. As in Palü, the auxiliary facilities are arranged around the machine house, but the power line exits here

Diga Scala > The Lago Bianco south dam wall and service tower, clad in local stone, looks rather like a natural dam.
L. Dosch

Palü power station > The tower-shaped machine house, designed by the architect Nicolaus Hartmann the Younger is reminiscent of the weirs built in the Middle Ages.
L. Dosch

Cavaglia power station > The building complex, reflecting the lines of a house in 'Engadin style' was also designed by Nicolaus Hartmann the Younger.
L. Dosch

and the transformers are clearly visible. The architect brilliantly realised the building concept "form as simple as possible rationally adapted to the interior arrangement". In winter, the water stored in Lago Bianco is used to produce power via the Palü and Cavaglia stations. The two power stations are linked by a gallery track along the penstock. This is still used today for personnel and material transport.

The converter station in Bever is another important architectural object; Nicolaus Hartmann was again the architect.

The four-storey main building together with the distributor substations is right next to the rail track and has the same form and design as the neighbouring traditional Engadin houses. Stylistically, the complex is described as "Heimatstil" (cf. 2.a.4 and 2.a.5).

The other power station buildings were renewed and converted over the years to keep pace with technical progress. For example a second command station was added to the gigantic Campocologno station in 1950 to exploit the remaining gradient of the Poschiavino river as far as the border. The principal command station from the pioneer days had to give way to a new building in 1968/69. At the same time the original, striking six-lane head-race tunnel was replaced by a single penstock. At the time it was built opinions were divided on the aesthetics of this open head-race tunnel; rejection on romantic grounds met technical pragmatism head on. The principal argument in favour of the open version was the danger of rust, to be countered by painting. National heritage and tourism circles, however, complained that the complex was "unnatural". After all, an intact and unspoiled natural environment was a central element of tourism marketing.

The critics were taken seriously in Brusio: "In the interest of the landscape, from Pontresina to Punt Muraigl [sic] and from Samaden to Bevers the Engadin power station 8 kV and 23 kV three-phase power lines shall run parallel on the same masts." Wooden masts were used for the transmission lines to the north with lengths of 46.4 and 28.6 km – whereas only the cheaper iron masts were used for the "C" line from Robbia to the Veltlin valley. Already by 1945 the KWB were claiming "despite considerable extra cost" to have taken national heritage issues into account "to a very great extent". In particular in the renewal of the power lines over the Bernina Pass, the building companies and engineers took the impact on the landscape into consideration by replacing the wooden masts with more transparent lattice masts. The Engadin architect Ulrich Könz (1899 – 1980), himself a member of the Engadin National Heritage Association, praised his work: "We managed to render the entire line from Morteratsch opposite Pontresina up to and including the pass into Val Roseg virtually invisible."

Also in the extensions and changes to the power lines, switching stations and power stations of more recent times "consensus solutions" are aimed at and cooperation sought with the regional and national landscape conservation organisations and the Cantonal authorities.

Recent developments

The KWB command stations were automated from 1970 and remotely controlled from Robbia. With the 220 kV Albula line, the KWB connected up with the west European combined network. In 1978 the Italian shareholders gave up their KWB holdings, which they had held since the earliest days. In 2000 the KWB, BK und RhW electricity companies merged as the Rätia Energie AG domiciled in Poschiavo. The principal shareholders are the Canton Graubünden, the Aare-Tessin AG and the Elektrizitätsgesell-

The eco-power trail from Ospizio Bernina to Cavaglia, opened in 2002, gives details on the production of eco-power on twelve information boards.
Photos: Rätia Energie AG, Poschiavo

schaft Laufenburg. In 2004, the Rätia Energie's own power stations produced 598 GWh energy while the EWZ, with all its plants in central Graubünden, produced 732 GWh. This gives both companies a significant position on the Swiss electricity market. In summer 2002, Rätia Energie and the Rhaetian Railway collaborated on laying out an eco-energy teaching trail from the Ospizio Bernina along the Bernina lake down to the glacier moulins at Cavaglia. This demonstrates yet again the intimate link between the railway and its power producer. The close meshed network of catenaries and power lines represents an essential economic artery, symbolic of the parallelism of the most important economic factors in Graubünden, namely tourism and power. A network that is vital for so many.