Acknowledgement

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Overview of Switzerland's electricity market

Thanks to its topography and high levels of annual precipitation, Switzerland has ideal conditions for the utilisation of hydropower. In the nineteenth century, hydropower underwent an initial period of expansion because coal was largely unavailable. Large-scale hydropower was developed after WWI with the electrification of railways. Between 1945 and 1970 it experienced a genuine boom with both run-of-river and large-scale storage plants.

Today (end of 2020) there are 677 hydropower plants in Switzerland with a capacity of at least 300 kilowatts. These produce an average of around 37 TWh per annum, 48.7% of which is produced in run-of-river power plants, 47% in storage power plants and approximately 4.3% in pumped storage hydropower (PSH) plants (10 years average, numbers not yet fully reflecting the Linth-Limmern 1,000 MW PSH, which was commissioned in 2016/17). The hydropower market is worth around 1.8 billion Swiss francs (basis = delivery from power plant at 5 cents per KWh) and is therefore an important segment of Switzerland's energy industry.

Alongside hydropower, four nuclear power plants are currently in operation, which produced around 23 TWh in 2020. New (variable) renewable energies (mostly photovoltaic) produced 3.5 TWh in 2020 (a mere 5% of total). Thermal plants (mostly waste incineration) for district heating produced non-renewable 1.6 TWh, renewable 1.2 TWh.

It should be noted that there is a ban on new nuclear power plants in Switzerland. The existing ones may continue to operate as long as they comply with all safety standards. In the long term, nuclear power plants are to be mainly replaced by photovoltaic (PV) expansion.

Total domestic generation in Switzerland amounted to almost 69.9 TWh in 2020. Taking into account the consumption of storage pumps of 4.4 TWh, this results in a net generation of 65.5 TWh. Consumption amounted to 59.9 TWh. After deducting transmission and distribution losses, the electricity consumption is 55.7 TWh.

The graph below gives an overview of the development of the individual generation categories since 1950.

Figure 1 Development Electricity production Switzerland 1950-2020

Because of the small size of the Swiss market, and Switzerland’s high interconnection with its neighbours, Swiss pumped storage has always been designed for the European market. Cross-border trade amounts to about 90% of domestic generation. Historically, Swiss PSH served to import cheap French nuclear power at night and export power during daytime. This business model disappeared with the onset of solar development in Europe and diminishing price spreads. Final investment decision for recently commissioned or about-to-be-commissioned PSHs were taken before the renewable boom in Europe. These PSH plants face difficult market
conditions but remain confident that they will play an important role for the integration of growing shares of variable renewables in Europe. Currently, there are very few hydropower projects in Switzerland (capacity increases at existing plants, very few new sites), but not a single PSH as permitting is challenging.

The Swiss Federal Government wants to promote hydropower. Current legislation calls for stabilizing average annual hydropower production at 37.4 TWh (about 2% more than current yearly average production). Investment aid is available (0.1 Swiss cent/kWh of a grid surcharge) for new capacity, including capacity upgrades, totalling some 50 million CHF annually.

Planned legislation calls for increasing average yearly production by 5% over current levels to reach climate neutrality by 2050, including 2 TWh of dispatchable winter production by 2040 (much of which would be hydropower). This could be incentivized by doubling funds available from the grid surcharge to 0.2 Swiss cent/kWh, resulting in an additional 55 million CHF/year for large and 30 million CHF/year for small hydro, especially if by 2030 the 2040 target is considered at risk. The planned legislation also would extend the investment aid from 2030 to 2035. PSH currently does not qualify for investment aid. The proposed legislation calls for keeping an option for PSH investment aid if market development requires so.

**Current status of pumped storage & development potential**

In Switzerland, 15 pumped storage plants are currently in operation with a total capacity of 2,695 MW. The production expectation per year is around 1.6 TWh without pumping operation.

![Figure 2 Pumped Storage Hydropower Plants (End of 2020)](image)

In 2017, the Linth-Limmern Pumped Storage Powerplant was commissioned. Using the 630m gross head between the existing Limmern Lake and the heightened Muttsee reservoir. The four variable speed pumps-turbines have a 250 MW capacity each.

A large pumped storage plant called Nant de Drance is to be commissioned in 2022. It is designed with six turbines of 150 MW each for 900 MW turbine and pumping capacity and is expected to produce around 2.5 TWh per year with a cycle efficiency of more than 80% (i.e., around 3.1 TWh of pumping consumption). Both PSH-Plants (Linth-Limmern and Nant de Drance) were constructed within existing hydropower complexes, where only the upper lake was enlarged. For both projects the high voltage grid capacity had to be regionally
increased, which was an unexpectedly lengthy permitting process as compared to the rather quick authorization process for the plants itself.

Further projects within existing schemes (Grimsel 3, Lago Bianco) have been authorized but are awaiting improved market conditions to launch the construction phase.

The economic developments for pumped storage hydropower plants are difficult to estimate in the long term. They also depend on how much transmission line capacity is available and how well Switzerland can be integrated into the European electricity market.

Challenges, barriers and emerging opportunities for pumped storage development

For the Swiss energy system itself, the pumped storage hydropower plants offer a very high level of flexibility that can more than cover the present demand. In the long term, however, with higher penetration of renewables, there will likely be increased demand. The Energy Perspectives 2050+ (i.e., models to achieve Net Zero Emissions) published by the Swiss Federal Office of Energy at the end of 2020 also indicate this. By 2050, 6,000 MW of installed PSP capacity is assumed. Today's installed capacity and Nant de Drance in 2022 add up to approximately 3,600 MW. Grimsel 3 and Lago Bianco would add another 1700 MW. Accordingly, additional projects of 700 MW would be needed.

To exploit the flexibility, efficient integration into the European electricity market, including for balancing power, is necessary. Efficient integration would also involve shortening the lead times for cross-border trading in order to better utilise short-term price fluctuations.

With pumped storage hydropower plants, Switzerland can play a role in the integration of variable power generation in Europe. With an increasing share of variable renewable energies, the demand for peak energy and control capacity is increasing throughout the interconnected European grid. For this reason, the importance of pumped storage hydropower plants is likely to endure in the long term. Therefore, it is important that the EU allow Switzerland's pumped storage hydropower plants to participate in the EU energy market without regulatory disadvantages.

Recommendations

- Cross-border trade should be improved by integrating Switzerland into the European internal energy market, including balancing. This is a prerequisite for exploiting the full potential of pumped storage hydropower plants.
- Future evolution of Swiss power system (less nuclear, more solar and other RES) will require higher flexibility and hence new PSH play an important role (assumed capacity in 2050 of 6,000MW).
- However, while the necessary role of PSH for the integration of RES in Switzerland and Europe is generally recognised, market conditions are not adequate to promote building of new PSH or even the existing ones. Bespoke public support mechanisms or adequate compensation for flexibility could help to ensure adequate remuneration for PSH projects.