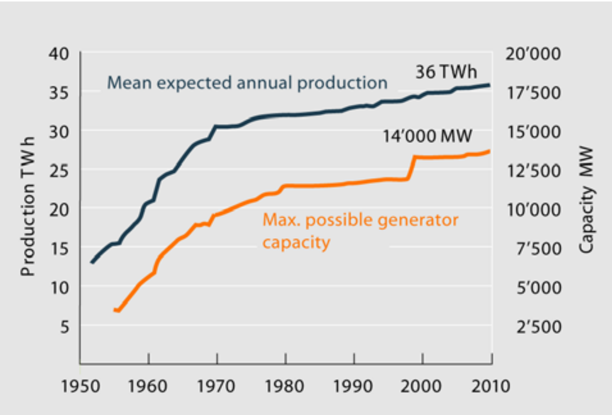
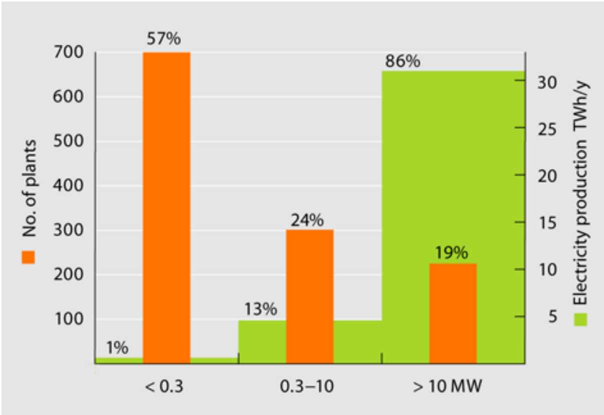
Factsheet: Hydropower and ecology

Accounting for 20% (around 3,400 TWh) of global electricity production – even though its contribution to gross final energy consumption is only about 2% – hydropower plays a vital role. This is largely due to the fact that it can be readily regulated to meet fluctuations in demand and substantial reserves can be stored in reservoirs. Hydropower supplies around 56% of Switzerland's electricity needs. Worldwide, there are at least 47,655 large dams and an estimated 800,000 smaller ones.[1,2] Since 2000, investments in hydropower projects have risen once again. The World Bank and the World Commission on Dams expect to see further strong growth in this sector[3]. The key figures for Switzerland are as follows:

- 576 large plants (>300 kW capacity), plus around 700 microhydropower plants (<300 kW).
- About 1,400 withdrawal sites[4] and 102 reservoirs >0.1 km[2 5]
- Total electricity production (2010): 66.3 TWh/year; hydropower 37.5 TWh/year (56% share)[6]
- A notable feature of hydropower in Switzerland is the high proportion (57%) of production to meet peak demand from Alpine reservoirs; 43% comes from run-of-the-river plants.
- Storage pump consumption (2010): 2.5 TWh/year



Expansion of hydropower 1950–2010 (only plants >300 kW)[7]



Production in relation to number of plants[8]

In many areas, the use of hydropower provides benefits in terms of water supplies and agricultural irrigation, but it also has impacts on aquatic ecosystems. Here, it should be borne in mind that biodiversity in aquatic ecosystems is disproportionately affected by chemical pollution, eutrophication and structural modifications (loss of wetlands, deforestation, water withdrawals, river engineering/damming).[9] Extinction rates for freshwater fauna are five times higher than for terrestrial biota.[10] 91% of Switzerland's former alluvial zones have disappeared.[11] Of the country's total river network of 65,000 km, 22% is in a poor ecological condition (40% of watercourses in the Central Plateau, 80% in urban areas); 4000 km is culverted.

Disruption of river continuity

Dams and weirs disrupt the longitudinal continuity of rivers. Habitat fragmentation threatens, in particular, species whose life cycle includes long-distance migrations (e.g. salmon, nase, eel). Rheophilic species (those dependent on flowing water) are deprived of their habitat in storage areas. The extent to which artificial barriers impede the passage of fish was shown by Eawag biologists on the lower reaches of the Töss river (Canton Zurich): they counted 23 fish species below a 6-m-high weir, but only 12 above it. On the Sitter (Cantons St Gallen/Appenzell Outer Rhodes/Appenzell Inner Rhodes), 46 of 54 tributaries were found to be inaccessible for the bullhead. Conversely, the number of fish species in the Lichtensteiner Binnenkanal rose from 6 to 16 within only 4 years after a steep drop where the artificial channel entered the alpine Rhine was reshaped to make it passable for fish. Upstream fish migration is facilitated at power plants with fish ladders. However, not all fishways are of a good standard, and existing fishways are not suitable for certain species. For downstream migration, no fish bypasses are available at hydropower plants in Switzerland. Many fish are injured or killed as they pass through turbines.

Alteration of sediment and solids dynamics

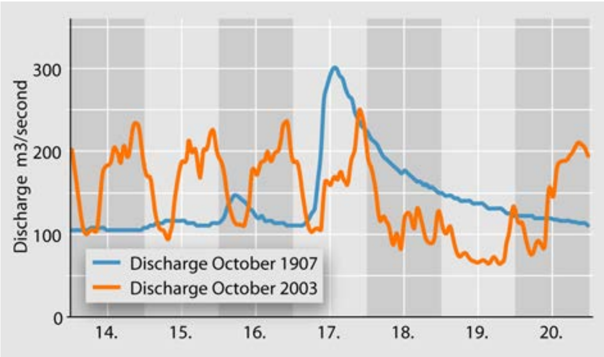
Hydropower plants frequently alter solids and sediment dynamics in the storage area and downstream. Gravel and sand trapped by dams are not available further downstream. This leads to a loss of gravel-bed spawning grounds and, more generally, to a loss of structured habitats for rheophilic species (also invertebrates such as fly larvae, etc.). In the storage area, gravel becomes clogged with fine sediment, as the current is not strong enough to wash out interstitial spaces in the riverbed. A lack of sediment below dams or reservoirs can also lead to channel deepening, necessitating bank reinforcement or artificial stabilization of the bed – often involving new transverse structures (sills). In some cases, as an enhancement measure, riverbeds are lined with gravel dredged elsewhere.

Residual water flows

Water withdrawals for reservoirs and diversion hydropower plants on rivers and streams lead to residual flow stretches, and in some cases to the drying-up of watercourse sections. By law (constitutional basis 1975, Water Protection Act 1991), these are required to be remediated by 2012, insofar as this is permitted by the relevant concessions. However, according to an Eawag study,[12] progress on implementing the residual flow regulations is limited. For 40% of the withdrawal sites, a remediation report had not yet been prepared. Remedial measures had only been adopted for 24%. In the case of newly granted concessions and renewals, the residual flows stipulated are mostly barely adequate, in view of the values specified in Art. 31 para. 1 of the Water Protection Act. Only rarely has an increase been ordered in accordance with the multi-step procedure specified in the Act; the same applies to seasonally variable residual flows. With the revision of the Act in 2011, additional exemptions have been approved for minimum residual flows, e.g. for streams over 1500 m a.s.l.. Inadequate residual flows are associated with poor connectivity and insufficient water levels and flow rates; they can also lead to altered water temperatures.

Hydropeaking

30% of Swiss watercourses below hydropower plants are adversely affected by artificial fluctuations in flow rates (hydropeaking).[13] Ratios of up to 30:1 (in extreme cases up to 150:1) are measured for maximum/minimum flows.[14] Animals and plants are displaced by these unnatural surges and stranded when flows decline. According to Eawag studies, fry and juveniles are particularly affected by hydropeaking. Individual density and biomass are reduced – also for benthic food sources. Riparian zones are abandoned, as they no longer provide a suitable habitat for aquatic or terrestrial organisms. Hydropeaking operations can shorten the winter clear-water period and lead to clogging of the riverbed with fine material. By 2014, the cantons are required to determine which plants have significant adverse impacts on watercourse sections with a high ecological potential.



Discharge of the Rhône at Vouvry before and after the construction of large dams.

Storage area management

Flushing of reservoirs, desanders and river impoundments can have adverse impacts on fish and macroinvertebrates as a result of surge and deposition effects, as well as unnatural water level fluctuations in the storage area. Flushing management – as developed by Eawag e.g. on the Spöl (National Park, Canton Graubünden) – can mitigate adverse impacts or even have positive effects, if carefully timed flushings simulate flooding events with sediment transport.

Removal of debris

To prevent damage to turbines, debris is removed with the aid of gratings at hydropower plants. In addition, riparian trees are often felled as a precautionary measure, so that they are not washed away by floodwaters. However, woody debris and leaves offer a habitat and food source for many species, and provide structural elements in watercourses. This problem can be partly addressed by weir engineering measures, the preservation of individual trees and appropriate debris management. One positive aspect of debris removal from watercourses is the fact that rubbish (plastic, etc.) is also extracted.

Greenhouse gas emissions

In river impoundments, biomass is converted into greenhouse gases. In shallow reservoirs, in particular, the greenhouse gases methane and CO_2 are emitted from bubbles rising to the surface and when water passes through turbines. Eawag scientists calculated that Lake Wohlen (a reservoir on the Aare) produces 150 tonnes of methane emissions per year.[15] Renewable hydropower, especially in tropical regions, is thus not completely climate-neutral. This problem could be alleviated by deeper reservoirs and appropriate arrangement of turbine inlets.

Other infrastructure

Hydropower infrastructure comprises more than withdrawal facilities, dams/weirs and plants. Access roads, pressurized pipelines and transmission lines may be associated with adverse environmental impacts. In river impoundment projects, banks have generally been engineered in connection with plant construction so as to facilitate maintenance or to exploit a greater vertical difference created by damming.

FOEN analysis of KEV hydropower planning applications[16]

- Drinking water power plants (infrastructure plants) generally have negligible effects on watercourses. The 255 infrastructure plants submitted for KEV (cost-covering remuneration for feed-in to the grid) can produce around 0.2 TWh.
- The 365 river-based plants submitted are expected to produce 1.7 TWh.
- Plants with a capacity >300 kW (45% of the total) represent 94% of the energy potential.
- Of the 365 river-based plants submitted, 68 are located in areas meriting protection or already protected – these would produce approx. 0.2 TWh.

September 2011

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