Hydropower – striking the right balance

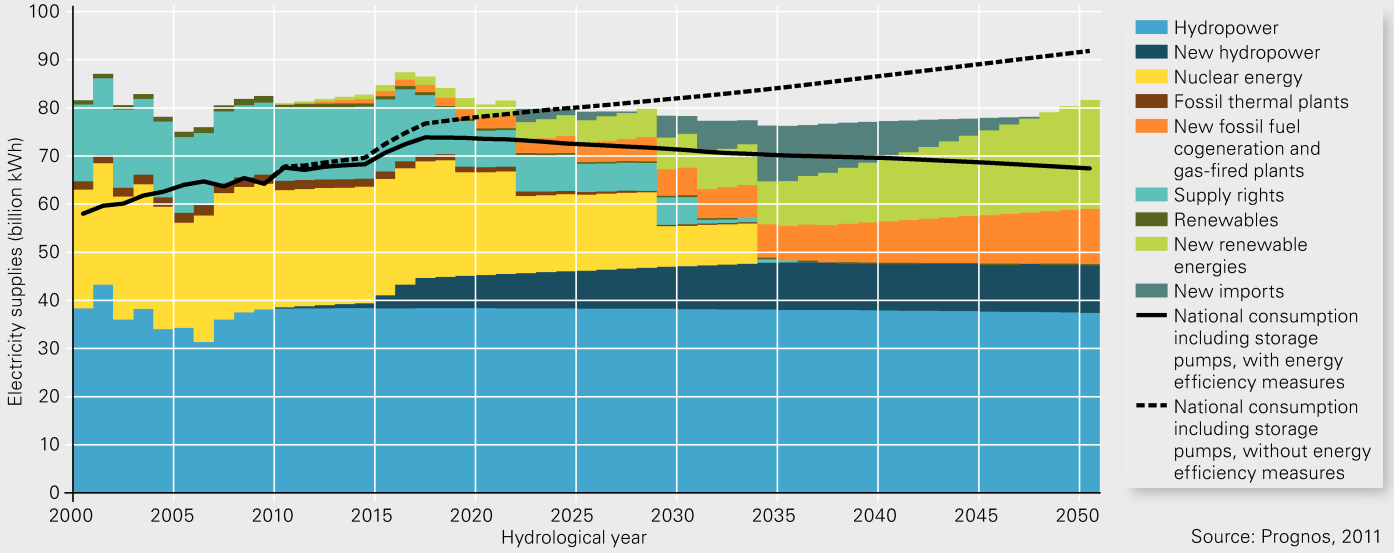
Switzerland has decided to phase out nuclear energy. As well as renewable sources, such as photovoltaics, the federal government intends to expand the use of hydropower. According to numerous experts, however, its assumptions regarding the potential for hydropower development are unrealistic. The benefits of additional small plants, they argue, are limited compared to the ecological damage; at the same time, there is a need for new pumped-storage plants. Text: Andres Jordi

By the standards of Swiss policymaking, it was a remarkably quick decision on a matter of such far-reaching importance: just a few weeks after the Fukushima nuclear disaster, the Federal Council decided that nuclear energy was to be phased out in the medium term. This decision was approved by both chambers of the Swiss Parliament. On the basis of a safe operational lifespan of 50 years, the existing plants are to be successively decommissioned – Beznau I in 2019, Beznau II and Mühleberg in 2022, Gösgen in 2029 and lastly Leibstadt in 2034.

At present, Switzerland's nuclear power plants account for roughly 40 per cent, or 25 billion kilowatt-hours (kWh), of annual electricity production [1]. In the future, this share is to be progressively replaced by other sources of energy. An outline of how this could be achieved is provided by the Swiss Federal Office of Energy's "Energy Perspectives 2050", which are based on updated models and scenarios from an earlier version ("Energy Perspectives 2035"). Assumptions concerning population growth, transport trends and energy policy instruments have been adjusted, as well as climate projections. Philipp Schwander of the SFOE explains: "The perspectives for 2050 are currently being revised by the federal authorities in preparation for the consultation procedure on the future energy strategy, so as to obtain more precise scenarios." The new version should appear in mid-2012.

Expansion of hydropower. According to the Energy Perspectives 2050, the loss of nuclear power is to be compensated for primarily by renewables (notably photovoltaics, geothermal energy and wind) and the expansion of hydropower exploitation. Any remaining shortfall is to be covered by fossil fuel (cogeneration, gas-fired) power plants and electricity imports (Fig. 1). In addition, the Federal Council is relying on energy efficiency measures, which are to limit electricity consumption to less than 70 billion kWh by 2050 (for comparison, Switzerland's consumption in 2010 was around 60 billion kWh). If current energy policy

Fig. 1: Future electricity production is to come largely from hydropower and other renewable sources. Under the federal scenario, measures to improve energy efficiency will also be needed to stabilize electricity consumption. In the chart, pumped-storage plants are included in the expansion of hydropower, although they do not lead to a net increase in the amount of power generated over a year.



Source: Prognos, 2011

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Hydropower in Switzerland is already highly developed – pictured here is the Birsfelden plant on the High Rhine in Canton Baselland.

were to be continued, the SFOE projects that consumption would exceed 90 billion kWh in 2050 [2].

Conclusions similar to those of Energy Perspectives 2050 were reached by researchers at the ETH Zurich Energy Science Center. In their study, however, a more important role is assigned to biomass in electricity production [3].

In 2050, in the absence of nuclear power, a capacity shortfall of around 30 billion kWh will need to be met. Here, hydropower will continue to play a key role. At present, hydropower plants produce 56 per cent of Switzerland's electricity (an average of 36 billion kWh per year) (Fig. 2). Looking to the future, the federal energy strategy calls for capacity to be increased by 4 billion kWh, which is equivalent to about half the annual production of the Gösgen nuclear plant.

Potential for increased capacity is believed to lie in the renovation or expansion of existing facilities and in the construction of new hydropower plants (see Table). In the large hydropower sector (> 10 megawatt capacity), the federal estimates are based on projects planned but not implemented over the past 30 years. "In principle," says Alfred Wüest of the Surface Waters department at Eawag, "one additional large plant – or possibly two – would appear to me to be acceptable." But it would be important, in his view, to select sites involving minimal disruption to the environment, and to optimize construction projects as far as possible within the framework of mandatory environmental impact assessments.

Potential for expansion of hydropower, according to federal estimates.

	billion kWh
Renovation/conversion	+2.4
New large plants (>10 megawatt capacity)	+2.0
New small plants (<10 megawatt capacity)	+1.9
Use of VAEW* areas	+0.4
Gross increase in production	*+6.7*
Loss of production due to residual flow regulations	–0.7
Loss of production due to climate change	–2.0
Net increase in production	**+4.0**

* Landscape areas deserving special protection which are exempted from electricity production, in accordance with the Ordinance on Compensation for Losses relating to Hydropower Exploitation (VAEW).

Hydropower: vast potential worldwide

Hydropower accounts for around 20 per cent, or 3.4 trillion kilowatt-hours (kWh), of global electricity supplies. In a third of all countries, the share of hydropower is more than 50 per cent (56 per cent in Switzerland). Particularly in developing countries, however, the potential of hydropower remains largely unexploited. According to the World Bank, only 23 per cent of the economically feasible hydropower potential in these countries has been exploited [7]. For example, China alone has an untapped hydropower potential of about 1.4 trillion kWh, Latin America 1.2 trillion kWh, and Africa almost 1 trillion kWh.

"Capacity has been growing continuously for some years," says Anton Schleiss of the Federal Institute of Technology Lausanne (EPFL). This is reflected by increasing World Bank investments in water infrastructure projects, which rose from USD 250 million in 2002 to more than USD 1 billion in 2008. In the coming years, the institution plans to invest another USD 2 billion. "China, in particular, is investing huge sums in the expansion of hydropower," says Schleiss, "but it's also being expanded in other countries – Turkey, Iran, India, Japan, Vietnam, Laos, Myanmar, the Philippines and Brazil."

Hydropower resources need to be developed, as far as possible, in an environmentally sound and socially acceptable manner. In the Zambezi river basin, for example, Eawag researchers are investigating the biogeochemical effects of the Itezhi-Tezhi hydropower reservoir on wetlands lying downstream – and how the operation of large dams and the planning of future projects can be adapted so as to minimize environmental impacts. Other researchers are studying emissions of the greenhouse gas methane from tropical reservoirs.

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Limited potential for small plants. In addition, the federal strategy envisages an increase of 1.9 billion kWh in small hydropower capacity via "KEV" (cost-covering remuneration for feed-in to the grid). This scheme, introduced in 2009, is designed to promote renewable energy sources, including hydropower plants with a capacity of less than 10 megawatts. According to Hans-Heiri Frei of Swissgrid, which manages the KEV programme on behalf of the federal authorities, applications have already been received

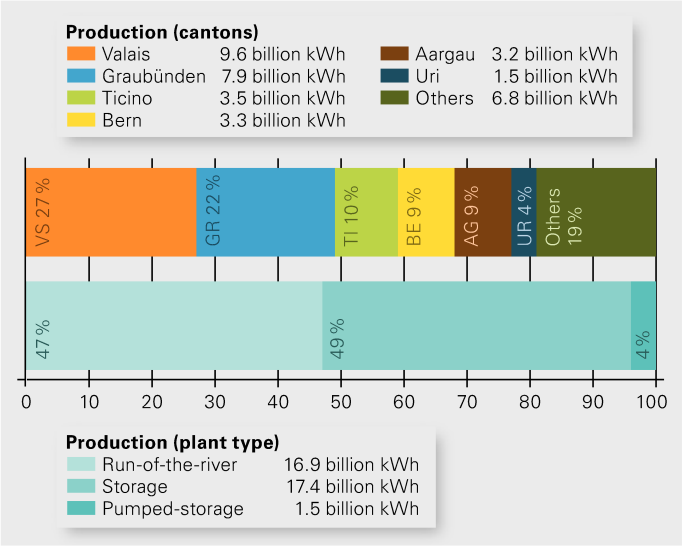

Fig. 2: Swiss hydropower statistics. Switzerland has around 1,300 hydropower plants, with 185 large plants (> 10 megawatt capacity) accounting for 90 per cent of the total electricity produced. Run-of-the-river plants supply continuous, base-load energy, while storage and pumped-storage plants are mainly used to meet peak-load requirements.

for hydropower plants which would produce a total of more than 2 billion kWh.

However, since ecological criteria are not used in the assessment of projects for KEV approval, many of these plants – especially those in previously unexploited waters – would seem to be unsuitable from the viewpoint of biodiversity and water protection. This deficiency has been recognized by the federal authorities, and (non-binding) guidelines have been developed which should enable cantons to determine which watercourses deserve special protection and where moderate exploitation would be appropriate [4]. But, as Schwander of the SFOE points out, "Approval of KEV projects remains a cantonal responsibility."

If, in the interests of a sustainable energy policy, ecological constraints are taken into account in selecting appropriate sites for small hydropower plants, the potential is substantially reduced. Thus, a WWF Switzerland study concludes that an increase in capacity of no more than about 1 billion kWh would be acceptable [5]. For his part, Wüest believes that investments in the expansion of small hydropower would be misguided: "In terms of filling the energy gap, it contributes virtually nothing, and the impacts on aquatic ecosystems and landscape are disproportionately large."

The ecological costs of hydropower. The effects of hydropower operations on the aquatic environment are numerous, as has been shown by various Eawag research projects. Weirs and dams lead to habitat fragmentation, posing major obstacles to migratory fish, such as salmon or nase. In addition, as Armin Peter of the Fish Ecology and Evolution department explains, "Artificial barriers alter the sediment dynamics – gravel and sand are prevented from moving downstream. If there is a lack of sediment, then gravel-bed spawning grounds are not replenished, and they are no longer functional." In rivers, flow regulation and water withdrawals can affect the composition of biotic communities – from algae to fish – and thus have an impact on the entire food web.

The operation of storage hydropower plants leads to unnatural fluctuations in flow rates ("hydropeaking"). Animals and plants are washed away by the artificial surges produced at times of peak demand. Conversely, their habitats frequently dry up during the daily low-flow periods when little or no water passes through the turbines. Peter says: "Sudden reductions in flow rates often lead to the death of juvenile fish, as they are stranded. So hydropeaking operations on the Alpine Rhine adversely affect the natural reproduction of brown trout or grayling."

Inadequate residual flows in river stretches below reservoirs or at diversion hydropower plants lead, for example, to poor connectivity, temperature changes and insufficient water levels or flow rates. As fine sediment accumulates in the riverbed, clogging may also occur.

Water protection efforts under threat? To mitigate the impacts of hydropower operations, Switzerland's water protection legislation has been revised several times. Under the 1991 Water Protection Act, the cantons are required to ensure adequate residual flows by 2012. But as Peter observes, "Implementation of these regulations has been unsatisfactory, and some cantons are seriously behind schedule." Under the latest revision of the Act (2010), the federal government is making additional resources available to reduce the adverse effects of hydropeaking and river fragmentation. For example, the longitudinal continuity of rivers is

Energy efficiency in the water sector

Alongside the development of renewable energy sources, improving energy efficiency is a key component of the federal government's future strategy. There is substantial potential for savings in the water sector – water supplies and wastewater treatment plants currently account for more than 30 per cent of municipal electricity consumption for public infrastructure in Switzerland.

For both wastewater management and drinking water treatment, Eawag scientists are working on optimized, energy-efficient methods. For example, process engineers have helped to develop the so-called anammox method for removing nitrogen from sludge digester liquid. With this method, compared to the conventional nitrification/denitrification process, significantly less aeration is required and no external carbon source is needed. This saves energy – and considerably reduces operating costs. Another Eawag project is studying the use of energy-efficient gravity-driven membrane systems to produce drinking water from polluted lake or river water.

www.eawag.ch/forschung/eng/schwerpunkte/abwasser/nitrations_anammoxprozess/index_EN

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to be improved by rehabilitation projects. Some experts are highly optimistic about these efforts, going so far as to speak of the reconciliation of river engineering and ecology.

Does the impending expansion of hydropower not run completely counter to the advances made in water protection? Armin Peter says: "If hydropower is to be expanded in line with the federal proposals, then a reversal of ecological progress is to be expected, especially in connection with small hydropower." In his view, aquatic habitats are already so severely fragmented that no further fragmentation can be contemplated. With new small hydropower plants, the progress achieved through rehabilitation measures at one site would be immediately cancelled out at another.

To date, landscape areas deserving special protection have been exempted from electricity production under the Ordinance on Compensation for Losses relating to Hydropower Exploitation (VAEW). The SFOE sees some potential for hydropower in these areas, too. But Schwander, of the SFOE, puts the proposals into perspective: "This is merely an initial assessment. We are currently – together with the cantons – analysing the realistic potential for expansion." For most experts, at any rate, development of this kind is not an option. Anton Schleiss of the Laboratoire de Construction Hydraulique at the EPF Lausanne concurs: "In my view, protected areas such as the Greina high plateau are ruled out."

Unrealistic assumptions. Commenting on the federal proposals for an overall increase in capacity of 4 billion kWh, Schleiss says: "That's just the net increase – in practice, hydropower would have to be expanded by a total of 6.7 billion kWh." Moreover, according to Schleiss, the energy losses due to residual flow regulations are underestimated: if the legal requirements were met, a decrease in production of 1.4 billion kWh would be expected. On the other hand, the losses of production due to climate change appear to him to be overestimated. This assessment is in agreement with a study recently published by the Swiss Society for Hydrology and Limnology and the Commission for Hydrology, which concludes that only limited changes are to be expected in the period up to 2035 [6].

In any case, many experts consider the federal scenario to be impracticable. The Association of Swiss Electricity Companies (VSE), for example, has stated that there is practically no remaining scope for expansion of hydropower in this country. While the Swiss Association for Water Resources Management (SWV) essentially welcomes the proposals for expansion, it says that they are unrealistic within the existing legal framework. It therefore calls for greater weight to be given to resource-use concerns when they are weighed against protection interests.

Schleiss also finds the figures unrealistic: he regards a net increase in capacity of around 2 billion kWh as feasible –"and even that is very optimistic." This would mean, he adds, that Switzerland would have to build at least one new large reservoir.

Wüest, of Eawag, says: "Rather than squeezing every last drop of energy out of our rivers, we need to resolutely expand photovoltaics – a sector with a far greater potential." Where hydropower could make a contribution, he believes, is in the area of energy storage with pumped-storage plants. In future, because energy will increasingly be obtained from renewable sources such as solar and wind power, which are not continuously available, there will be a need for greater storage capacity. However, pumped-storage plants do not, in net terms, produce any additional electricity.

Switzerland: a battery in the European grid. "Switzerland has a very substantial potential for pumped-storage plants," says Schleiss – and he believes this should be exploited for the European electricity market. Switzerland could increasingly assume the function of a battery within the European grid, also supplying neighbouring countries with pumped-storage electricity. "Conversely," he says, "we will be increasingly dependent on European wind and solar power."

In the coming years, the SFOE expects pumped-storage capacity to increase by around 5 billion kWh. Some facilities – e. g. Nant de Drance in Canton Valais or Linth-Limmern in Canton Glarus – are already under construction.

Naturally, pumped-storage plants also inevitably involve disruption to the environment. In an environmental impact assessment for the Lagobianco project in Poschiavo, for example, Eawag scientists demonstrated that the operation of a pumped-storage plant would have significant impacts on the temperature and turbidity of the two connected lakes. At the same time, they found that the project would also lead to ecological improvements, such as the elimination of hydropeaking, higher and more dynamic residual flows, and various rehabilitation measures.

Schleiss is convinced that moderate expansion of hydropower in Switzerland would not necessitate major sacrifices on the environmental front. In his view, it is very important that all stakeholders should be involved in the planning process, so that solutions can be sought jointly; this, he stresses, will require certain compromises on all sides. ○ ○ ○

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