Energy
National Research Programmes 70 and 71

Synthesis

Hydropower and Market

Hydropower and Market

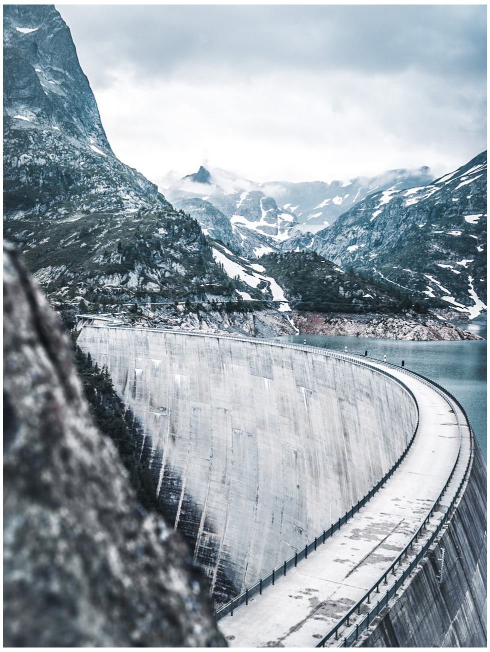
Hydropower is by far the most important source of renewable energy in Switzerland today. Questions regarding its contribution towards the transformation of the energy system and the role it is to play in the future are therefore of great importance. This thematic synthesis encompasses the findings from the various NRP 70 and NRP 71 research projects that focus on a broad range of technological and economic aspects of the future use of hydropower, and formulates recommendations for its further development in Switzerland.

1. New potential – new challenges

In future, hydropower plants will need to produce more electricity. Glacial melting is creating the conditions to establish new reservoirs while further potential is also offered by heightening dam walls. However, from an economic perspective, the sector as a whole is suffering. New economic approaches are therefore required and, at the same time, greater attention must be paid to ecological considerations.

Financing # Energy provision

1.1. Core messages



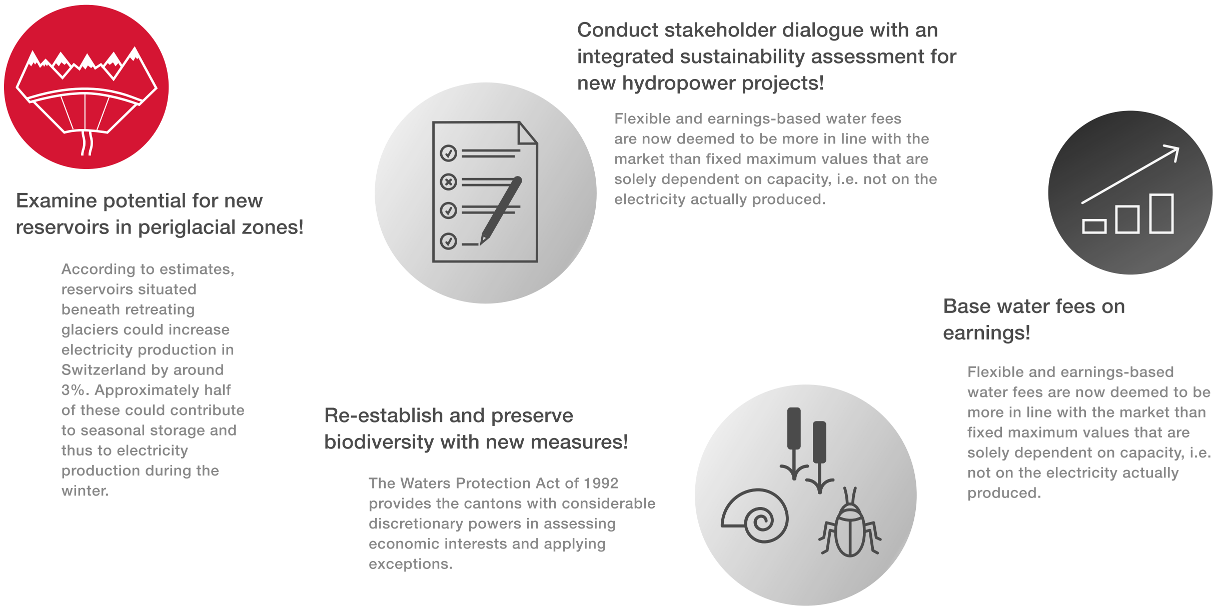
The hydropower sector should be operated in an economic manner while, at the same time, appropriately taking account of concerns relating to the protection of nature and landscapes. This requirement gives rise to the following core messages which have been derived from the research work of the NRP Energy:

1. In periglacial[1] zones, there is considerable potential for the establishment of new reservoirs. When it comes to the utilisation of this potential, however, there is, in many cases, a conflict of objectives concerning the considerations relating to the protection of nature and landscapes, on the one hand, and the production of electricity, on the other.
2. The current implementation of residual flow regulations in rivers situated beneath dams and Alpine water catchments means that the level of biodiversity in residual flow stretches cannot always be preserved and that there is very little scope for improvement.
3. As things stand, water fees are linked to the licensed production capacity and not to the generated revenues. A model is required that is adjusted in line with the changed market conditions and which also ensures transparency. The new regulations need to be flexible and based on the revenues earned from hydropower.
4. Projects conducted in the area of hydropower invariably affect a wide range of aspects: technical, economic, environmental and socio-political. Their implementation is made easier if all stakeholders are involved in the planning process from the outset.

Notes and References

1 Situated in areas with melting glaciers

1.2. Key recommendations



From the collection of recommendations that were derived from this synthesis, the programme management of the NRP Energy, with the assistance of the echo group, have selected four key recommendations that are of great relevance with a view to the successful implementation of Energy Strategy 2050.

- **Examine potential for new reservoirs in periglacial zones!**According to estimates, reservoirs situated beneath retreating glaciers could increase electricity production in Switzerland by around 3 %. Approximately half of these could contribute to seasonal storage and thus to electricity production during the winter. This was the finding of a study conducted by ETH Zurich, which identified the seven locations best suited for the establishment of new reservoirs from those sites that are generally considered for this purpose. Their theoretical storage capacity stands at 1.3 TWh, which equates to 14 % of the storage capacity offered by existing reservoirs. Compromises with respect to the protection of nature and landscapes will need to be examined.
- **Re-establish and preserve biodiversity with new measures!**The Waters Protection Act of 1992 provides the cantons with certain discretionary powers in assessing economic interests and applying exceptions. According to the research results, however, the only moderate implementation of the residual flow regulations in rivers situated beneath dams does not suffice for the re-establishment and preservation of biodiversity in regulated waters.[1] The maintenance of natural discharge dynamics as well as occasional, natural or artificially triggered floods and appropriate bedload management are prerequisites for the preservation of biodiversity. In principle, the Waters Protection Act allows the cantons and the Federal Council to enforce environmentally friendly solutions – for example, by providing zones which compensate for these changes.[2]
- **Base water fees on earnings!** Flexible and earnings-based water fees are now deemed

to be more in line with the market than fixed maximum values that are solely dependent on gross capacity, i.e. not on the electricity actually produced. Flexible, earnings-based water fees should therefore be introduced that are structured according to the principles of revenue sharing between the resource owners, i.e. the municipalities, and the power plant operators. To this end, complete transparency with respect to earnings figures is required. Regional policy and regional economic aspects should also be taken into account.

- **Conduct stakeholder dialogue with an integrated sustainability assessment for new hydropower projects!** Projects in connection with the construction or renovation of power plants as well as plans relating to new water fee regulations or the awarding of concessions are prepared together with all stakeholder groups as part of a joint planning process and the groups' respective interests are weighed up against one another. The individual criteria are assessed by experts, while the stakeholders develop the "trade-offs".

Notes and References

1 If the Rösti motion, which is supported by the Federal Council, is accepted by parliament, the condition of a body of water that is to be preserved will be deemed to be the condition that existed upon the submission of the request for the renewal of the concession in question – and not the body of water's original condition prior to the use of hydropower.
https://www.parlament.ch/de/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20133883
2 "Bundesrat genehmigt Schutz- und Nutzungsplan für Meiringen Hasliberg."
https://www.admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-76061.html

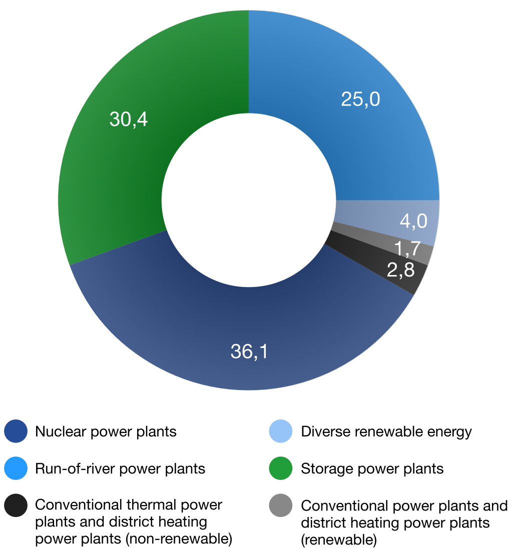
2. Hopes pinned on hydropower

As part of Energy Strategy 2050, the Federal Council wants to replace the electricity that until now has been produced by nuclear power stations with power from renewable energy sources and imports. Hydropower should also make an additional contribution – this is because it is both cost-efficient and environmentally friendly. For political, economic and environmental reasons, however, the expansion process is challenging.

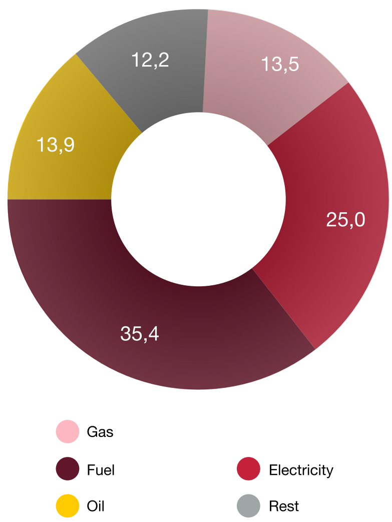
Resources

2.1. Switzerland's most important source of electricity

Electricity production (2018) by power plant category



End use according to energy source (2018)



Overall energy statistics, electricity production according to power plant category. *Source: Swiss Federal Office of Energy, Swiss Overall Energy Statistics 2018*

The generation of electricity through hydropower is cost-effective, efficient and, generally speaking, climate and environmentally friendly. It provides both base-load and peak energy, produces virtually no climate-damaging greenhouse gases, has a very good overall life cycle assessment and remains unaffected by the global market of fossil energy sources.

Thanks to its topography and considerable average precipitation, Switzerland offers ideal conditions for the utilisation of hydropower. Hydropower is also the country's most important source of electricity – and the most important domestic energy provider.[1 2 3] The forecast average production stands at 36 TWh; maximum output is around 10 GW.[4] Domestic hydropower therefore covers slightly more than one-eighth of total energy consumption, around 57 % of electricity requirements and 96 % of renewable electricity production.[5]

On 1 January 2018, 650 run-of-river and storage power plants each with an installed capacity of at least 0.3 MW were in operation in Switzerland.[6] More than 50 reservoirs in Switzerland have a volume of at least 10 million m3. They are almost all located in the Alpine region. During the construction of these power plants, there was very little or even no legislation aimed at environmental protection. However, the hydropower sector now increasingly finds itself confronted with climate protection requirements. This considerably limits their potential for expansion.

Notes and References

1 "Situation und Perspektiven der Schweizer Wasserkraft", R. Pfammatter and M. Piot, "Wasser Energie Luft", 106th volume/issue 1, 2014, CH-5401 Baden
2 "Perspektiven für die Grosswasserkraft in der Schweiz", SFOE, 12 December 2012
3 Story map "Switzerland's main hydropower plants"
4 Swiss Electricity Statistics 2017, Swiss Federal Office of Energy
5 Swiss Overall Energy Statistics 2017, Swiss Federal Office of Energy
6 admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-70623.html

Market

2.2. Also economically significant

Hydropower produces around 60 % of our electricity. Generally speaking, it is very important for the economy. Its gross added value is estimated to stand at CHF 2.5 billion a year and it provides approximately 6,000 full-time positions, including in structurally weak regions.[1] The water fees received by mountain municipalities and cantons for the use of hydropower total CHF 500 million a year. They are extremely important for the recipients and are currently the subject of political debate.

Notes and References

1 Rütter and Partner et al., “Volkswirtschaftliche Bedeutung erneuerbarer Energien in der Schweiz”, 2013

Resources

2.3. Significance of hydropower in Energy Strategy 2050

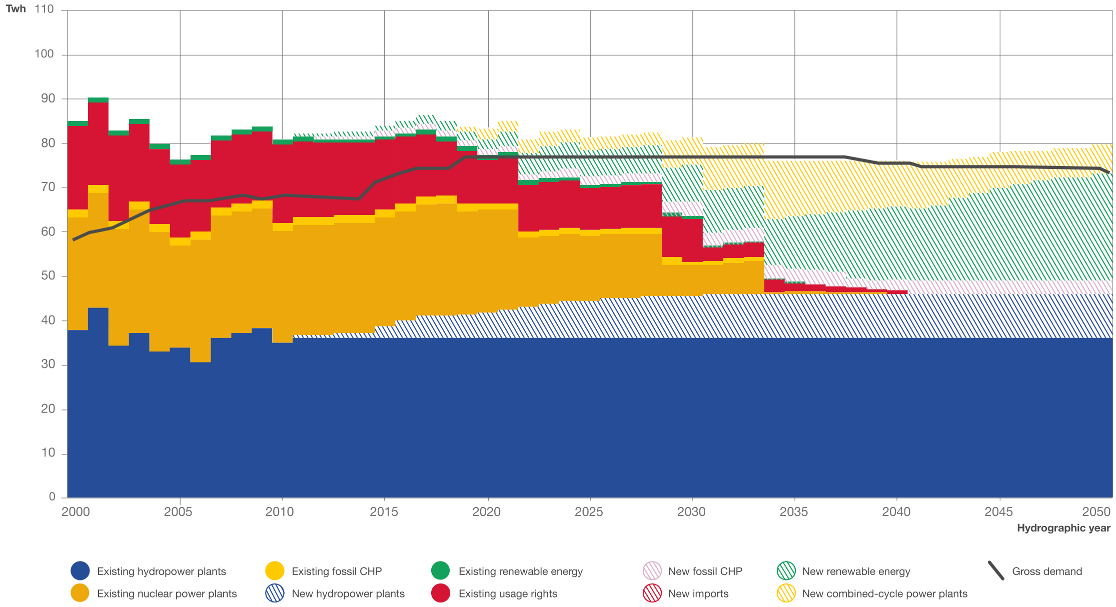


Diagram showing the vision for electricity production under Energy Strategy 2050. *Source: Swiss Federal Council, fact sheet 2 on Energy Package 2050 of 18 April 2012*

As part of Energy Strategy 2050, the Federal Council wants to replace the electricity that until now has been produced by nuclear power stations with power from renewable energy sources and imports.[1 2] It is planned to greatly expand photovoltaics and wind power, while hydropower should also make a considerable contribution.

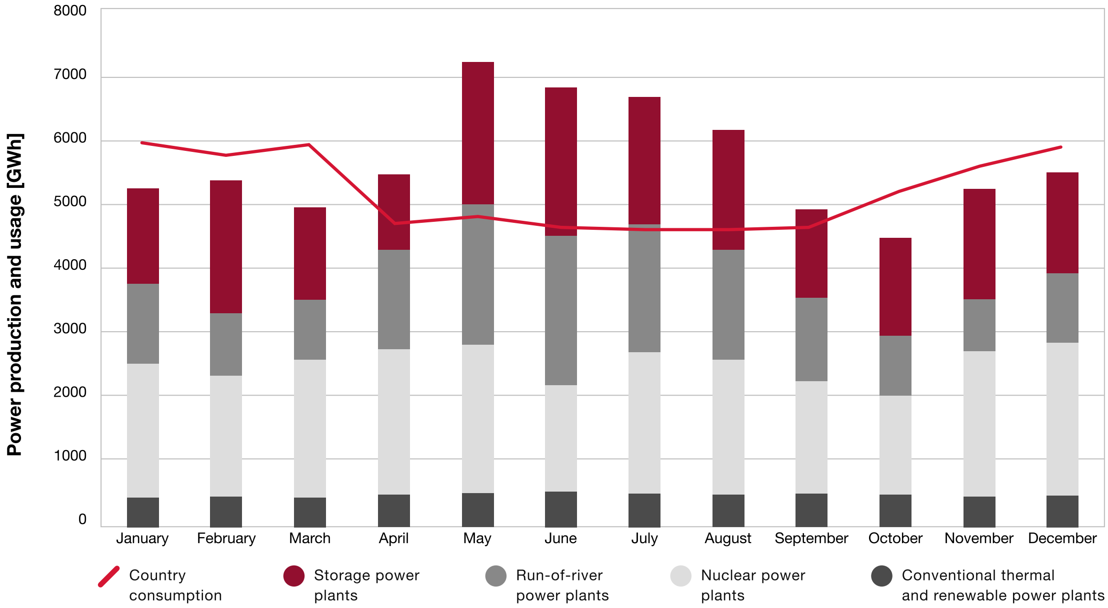
According to the SFOE, electricity generation from hydropower in Switzerland can be expanded by between 1.5 TWh and 3.1 TWh per year. This equates to around 4 % to 9 % of average production. This potential incorporates both new and converted installations as well as expansions of existing hydropower plants. 1.4 TWh per year was deducted due to new residual flow provisions. A study conducted by the Swiss Water Management Association (SWV) estimates the electricity losses up to 2050 owing to the implementation of the Waters Protection Act to be much higher at between 2.3 TWh and 6.4 TWh per year – depending on the interpretation of the legislation. This thus equates to between 6 % and 18 % of current hydropower production.[3 4]

Notes and References

1 https://www.bfe.admin.ch/bfe/en/home/policy/energy-strategy-2050/documentation/energy-perspectives-2050.html
2 “Situation und Perspektiven der Schweizer Wasserkraft”, R. Pfammatter and M. Piot, “Wasser Energie Luft”, 106th volume/issue 1, 2014, CH-5401 Baden
3 www.swv.ch/wp-content/uploads/2018/11/Kurzfassung-Studie-Energieeinbussen_lq.pdf
4 The losses to be expected due to the implementation of the residual flow provisions are currently being recalculated by the Swiss Federal Office of Energy (SFOE).

Europe / EU   # Energy provision

2.4. Electricity imports are increasing – but are not guaranteed in the long term



Electricity generation and consumption per month in 2018. *Source: Swiss Federal Office of Energy, Swiss Electricity Statistics 2018*

Until now, Switzerland's level of self-sufficiency has been characterised by an equal energy balance viewed over the year as a whole, with exports exceeding imports during the summer and vice versa in winter. With the phasing out of nuclear energy, 3.3 GW of total capacity and 20 TWh to 25 TWh of energy a year will be lost in Switzerland.[1] Power plant capacity and peak output for domestic consumption will still suffice. During the winter months, however, the situation becomes problematic.

Electricity imports during the winter months are therefore increasingly coming under the spotlight – in recent years, Switzerland has had to import so much electricity during winter that viewed on a net basis it has become an electricity importer. Due to the outages at the Beznau I and Leibstadt nuclear power plants, net imports in the winter of 2016/2017 equated to around 18 % of annual consumption. Studies[2 3] show that Switzerland will in future be increasingly dependent on imports. According to ElCom calculations[4] – and depending on the lifetime of the nuclear power stations – it could be necessary to import between 4 TWh and 7 TWh of electricity during the winter. This equates to between 7 % and 12 % of annual consumption.

For the time being, electricity imports from neighbouring countries are possible and, according to a study[5], Switzerland will in principle be able to offset gaps in electricity production up to 2030 with imports. However, the situation becomes critical, for example, if Germany not only phases out its nuclear energy facilities, but also its coal-based electricity production – which is planned by 2038.[6] In particular, this raises the question of additional seasonal storage for increased domestic electricity production during the winter.

The Federal Council wants to respond to this with a revision of the Energy Supply Act[7] for the period after 2020. The consultation process for the bill is already under way. Its key points are as follows:

- The electricity market will be fully liberalised.
- Supply security will be increased with a strategic storage reserve.
- Grid use will be optimised – e.g. with a financial incentive to avoid peaks.
- From 2025, a new and flexible water fee model will apply; the old regulations will remain in force until 2024.

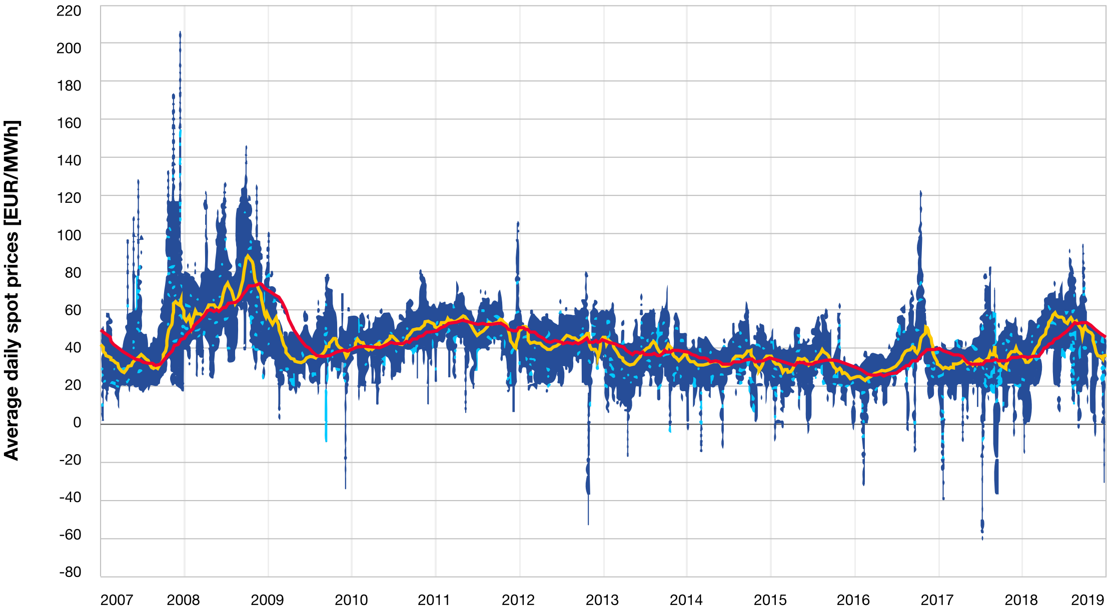
Notes and References

1 Swiss Electricity Statistics, Swiss Federal Office of Energy
2 Federal Electricity Commission ElCom, "System Adequacy 2025", 31 May 2018
3 SFOE, "CASE_REPORT", 2017.10.18D

4 ElCom, H. Bhend, Energy perspective study group presentation, March 2019, Baden
5 Modellierung der System Adequacy in der Schweiz, SFOE, 27 October 2017
6 www.wiwo.de/politik/deutschland/nach-21-stunden-sitzung-deutschland-soll-spaetestens-2038-aus-der-kohle-aussteigen/23912932.html
7 "Revision of the Electricity Supply Act (full electricity market opening, storage reserves and modernisation of grid regulation)", draft bill and consultation draft of October 2018

Market # Liberalisation / market opening

2.5. Electricity market in transition



The wholesale prices for base-load electricity on the exchange in Leipzig fell from around CHF 70/MWh to CHF 20-40 between 2009 and 2018. They have recovered slightly since this time. Gelb: 50-Tagelinie; rot: 200-Tagelinie (gleitender Durchschnitt) *Source: www.bricklebrit.com/stromboerse_leipzig.html*

The European electricity market has a considerable influence on electricity prices in Switzerland. In recent years, it has been in a state of transition.[1] [2] Wholesale prices[3] have come under massive pressure – meaning the same has also been true for Swiss hydropower prices.[4] The reasons behind the fall in prices are overcapacity in Europe as well as low CO_2 and coal prices. The overcapacity is a consequence of the greatly subsidised expansion of photovoltaics and wind power; the low CO_2 prices are linked to the oversupply of emission certificates.

The consequences of the decline in prices are varied. Electricity generated from photovoltaics and wind not only leads to low wholesale prices, but also to lower sales volumes from conventional power plants due to the "merit-order effect". Electricity prices are also changed during the course of the day. In particular, the major price differences, which in the past contributed significantly to the trading profit between peak and off-peak hours, are practically disappearing.

The lower prices have seen turnover and profit figures for Swiss hydropower shrink. This has consequences: insufficient returns mean that the investments in the construction of new hydropower plants and the renovation of existing installations that are required for the future are put at risk; and they trigger political debate about future market developments and state support. The questions of complete liberalisation, new water fee regulations and – above all – the future relationship of Switzerland with Europe, including with respect to an electricity agreement, are paramount. These issues are discussed in detail in the projects "Switzerland and EU energy policy"[5] and "Europeanisation of the Swiss energy system".[6]

Complete liberalisation as a prerequisite for an electricity agreement with the EU would also hit those electricity producers that today are still able to charge cost-covering prices to tied electricity customers. The production costs defined in the directives can be reviewed by ElCom.[7] An electricity agreement that prevents Switzerland from being excluded from cross-border trading is, however, dependent on a framework agreement with the EU.

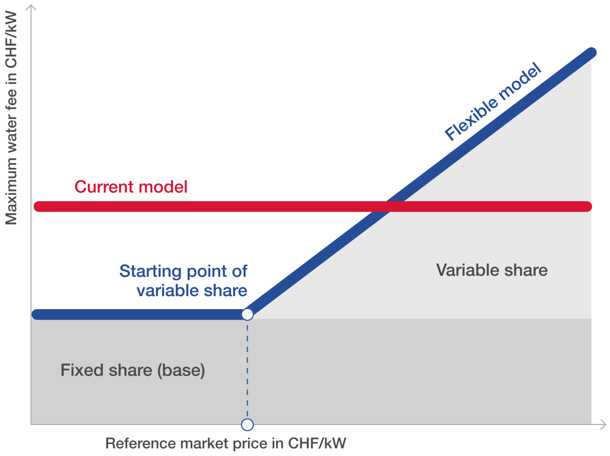
Notes and References

1 https://www.sccer-crest.ch/fileadmin/FILES/Datenbank_Personen_Projekte_Publikationen/Publications/White_Papers/White_Paper_5_Strommarktdesign_final.
2 https://www.researchgate.net/publication/321304488_Wasserkraft_Wiederherstellung_der_Wettbewerbsfahigkeit
3 P. Hettich et al., Strommarkt 2030, Schriften zum Energierecht, Dike Verlag AG, Zurich/St. Gallen, 2017
4 Between 2017 and 2019, the wholesale prices for base-load electricity have recovered slightly once more.
5 Project "Switzerland and EU energy policy"
6 Project "The European electricity market: staying away will be expensive but will also open up room for manoeuvre"

7 ElCom is the independent state regulatory authority in the electricity sector.

Market   # Price

2.6. Low electricity prices: not everyone is affected equally



Scheme of a flexible water fee model. *Source: Swiss Federal Office of Energy, Eckwerte für ein mögliches flexibles Wasserzinsmaximum – report for ESPEC-N-N, 14 December 2018*

In 2012, the price for base-load electricity on the EEX electricity exchange[1] still stood at around EUR 0.06/kWh; it hit its lowest point in 2016/2017 at EUR 0.02/kWh. The price has recovered slightly since then. However, at around CHF 0.05/kWh for Switzerland, it still finds itself in the range of average hydropower production costs of CHF 0.056/kWh.

Not all energy supply companies (ESCs) are equally affected by this development.[2] A new study by the Swiss Federal Office of Energy[3] reveals the following on the basis of contributions made to the public sector – dividends, water fees and taxes:

- The aggregate turnover of Alpiq and Axpo, the two giants of Switzerland's electricity sector, has almost halved. Value adjustments and low electricity market prices placed considerable pressure on net profit.
- For the rest of the sector, turnover and profit tended to develop positively. Electricity could be purchased cheaply, while the customers supplied – primarily small-scale customers in the area of basic supply – had to pay an electricity price that covered costs and a profit margin.
- Profit distribution to the cantons fell by almost 40 %. The biggest decline was observed for the "Mitttelland" cantons with a stake in Axpo and Alpiq of more than 10 %.

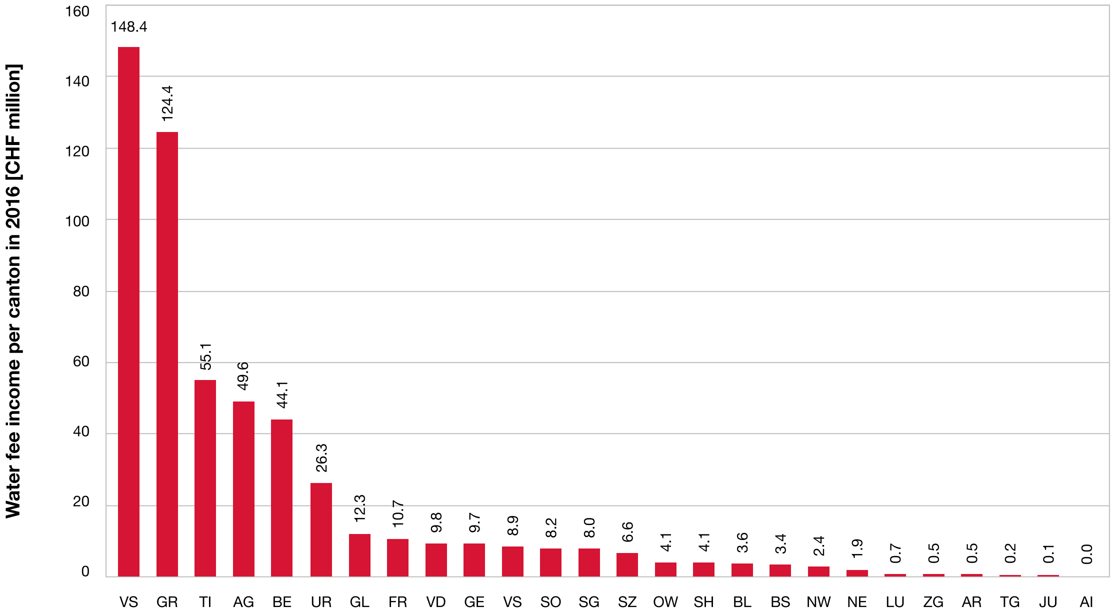
Electricity producers and politicians are wrestling for answers as to how hydropower can be made competitive again. Here, focus is being placed on the revision of the Electricity Supply Act and ensuring coordination with the EU by means of an electricity agreement. Cost savings, subsidies for large-scale hydropower plants and, in particular, new water fee regulations are under consideration.

Notes and References

1 www.bricklebrit.com/stromboerse_leipzig.html
2 nzzas.nzz.ch/wirtschaft/schweizer-kraftwerke-machen-oft-gewinn-wasserkraft-lohnt-sich-ld.1475025
3 "Wirtschaftliche Situation von EVU im Zeitverlauf", SFOE, 2017

Market # Costs / benefits

2.7. Water fees, concessions and cantonal finances



Overview of the income of the cantons from water fees in 2016. The mountain cantons of Valais and Graubünden are the biggest recipients with well in excess of CHF 100 million. Ticino, Aargau, Berne and Glarus receive between CHF 26 million and CHF 55 million a year. *Source: Project "The future of Swiss hydropower'*

Water fees are a remuneration paid by electricity producers to the mountain cantons and municipalities for the use of their water resources. In 2015, these water fees totalled around CHF 560 million. In many places, water fees made up a considerable share of income – in the canton or Uri, for example, which has the highest percentage share, they account for a quarter of cantonal income.

The utilisation of water for the generation of electricity is approved by the cantons; the federal government can, however, define and amend rules and, for example, stipulate a maximum water fee rate. At present, water fees are tied to the gross capacity[1] of a power plant, irrespective of its income situation. The political process aimed at establishing new water fee regulations is currently under way. The burden placed on producers hit by low electricity prices should be eased. As in the past, they should be able to generate a return – only in this way can they deliver dividends to their owners, including the Mittelland cantons, and also make the investments required for Switzerland to preserve the fundamentally important generation of electricity from hydropower.

Various reform options are being discussed. They range from the abolition of the water fees, or their continuation at a reduced rate, to the introduction of a more flexible system under which water fees would be tied to a power plant's income situation.

As no solution is emerging as yet, the Federal Council and parliament have decided to leave the maximum water fee at CHF 110 per kW until the end of 2024. There is still time, therefore, to draw up the new regulations.

New regulations are important, as Swiss companies and politicians will only be able to contribute to shaping development on the European electricity market to a limited extent without an electricity agreement with the EU. Switzerland must therefore focus on those aspects where it can influence the profitability of hydropower[2]: residual flow regulations and water fees.

Notes and References

1 The gross capacity is calculated on the basis of the drop height and the usable volume of water and should not be confused with the installed capacity of the turbines and generator of a power plant.

2 "Wasserkraft: Wiederherstellung der Wettbewerbsfähigkeit", Whitepaper SCCER CREST, March/2016

Landscape

2.8. Expansion is not only a technical challenge

Source: KEYSTONE / Gian Ehrenzeller

Energy Strategy 2050 plans for hydropower to be expanded by 1.5 TWh to 3.2 TWh or by between 4 % and 9 %. This should thus offset part of the losses that will arise owing to the shutting down of the country's nuclear power plants.

However, the additional potential of hydropower is limited – for reasons of economic viability, environmental compatibility and social acceptance as well as due to climate- and weather-related uncertainties. The latter influence the melting of the glaciers as well as the form of precipitation as snow or rain and thus the flow rates of the usable water. These flow rates in turn have an impact on the amount of bedload and the sedimentation of reservoirs. Questions arise with respect to adjusted flow regulation, the reactivation of sediment dynamics, the renaturation of rivers and floodplains as well as the biodiversity of these habitats. These questions are all the more important as near-natural watercourses are among the most species-rich habitats and also among the most threatened.[1] [2]

The protection of waters in Switzerland is governed by the Waters Protection Act.[3] It states that near-natural conditions should be preserved or restored to the greatest possible extent for both watercourses and standing bodies of water. It also governs the revitalisation of waters and alluvial zones, the re-establishment of the free migration of fish, the bedload balance and the "hydropeaking" beneath power plants – the irregular daily discharge fluctuations that occur due to the temporary interruption of hydropower plant operations.

In implementing the Waters Protection Act, the cantons especially focus on the following:

- The residual flow stretches beneath reservoirs and power plants where artificial flooding should also eliminate existing impairments.[4]
- The residual flow stretches beneath Alpine water catchments where bedload flushing in some cases impairs the hydromorphology several times a day and thus also living conditions.
- The rivers beneath power plants that are affected by "hydropeaking".

Notes and References

1 https://www.wwf.ch/sites/default/files/doc-2017-07/2016-12-studie-wertvolle-gewaesser_jbr.pdf
2 https://www.bafu.admin.ch/bafu/en/home/topics/biodiversity/publications-studies/publications/biodiversity-in-Switzerland-status-and-trends.html
3 Waters Protection Act of 24 January 1991 (as at 1 January 2017)
4 "Künstliche Hochwasser – Auslegeordnung, Grundlagen und Handlungsbedarf", PROHAT, BG, 10 November 2016, on behalf of the SFOE

Landscape

2.9. Protection of alluvial landscapes and waters

Alluvial landscape between Celerina and Samedan. *Source: T. Kaiser collection 2019*

Alluvial zones are low-lying areas shaped by alternating high and low water levels along a stream or river.[1] Their locational characteristics change continuously due to the dynamics of the flowing water: floods, dry periods, erosion and sedimentation change the level of moisture, nutrient content and other factors. Alluvial zones thus offer a mosaic of different habitats that provide a home to a variety of plants and animals over a relatively small area.

While Switzerland's alluvial zones account for around 0.5 % of the country's area, approximately 1,200 to 1,500 plant species live in them, accounting for about 50 % of Swiss flora. Zoological diversity in the alluvial zones is also great: insects and amphibians as well numerous bird and mammal species live and feed in these areas.

Around 90 % of the originally existing alluvial zones have now disappeared. The primary reasons for this are water table corrections, the draining of river plains and hydropower plants. Those alluvial zones that still remain are at risk: it is now estimated that two-thirds of non-Alpine alluvial zones of national importance no longer exhibit natural flow dynamics. Embankments and dams prevent floods and the residual flow volumes beneath reservoirs are in most cases too low for the preservation of the alluvial zones. However, these diverse habitats can be re-established with appropriate flow regimes.

The fully revised Energy Act[2], which came into force on 1 January 2018, offers new potential for discussions with respect to the construction or renovation of hydropower plants. The legislation stipulates that when making decisions between interests relating to the protection of nature and landscapes, on the one hand, and those relating to electricity production from renewable energy, on the other, both will in future enjoy the status of a national interest. This means that slightly less weight will be given to the protection of nature and landscapes than was the case in the past, with greater significance being given to to the protection of biotopes.

Notes and References

1 https://www.waldwissen.net/wald/naturschutz/gewaesser/wsl_auen_schweiz/index_DE
2 http://www.newsd.admin.ch/newsd/message/attachments/50284.pdf

2.10. Six big questions for hydropower

With respect to hydropower and market, the following six questions urgently need to be addressed:

1. How can the potential of hydropower be preserved and expanded further, in particular with additional seasonal storage?
2. How can the profitability of hydropower be improved through operational measures?
3. How can the investments required for the future of hydropower be financed?
4. Which new water fee regulations are socially acceptable, economically balanced, politically feasible or advisable?
5. How can power plants, water catchments and reservoirs be operated in an environmentally sustainable manner?
6. How can all stakeholder groups be involved in hydropower projects?

The NRP Energy can neither answer these questions fully nor definitively as it only covers part of the research for Energy Strategy 2050 and certain results can also not yet be generalised. The explanations in this synthesis therefore focus on the projects that relate to the topic of hydropower and market. Further results from current energy research work can be found in the other thematic syntheses as well as in the annual reports of the Swiss Competence Centres for Energy Research (SCCER).[1]

Notes and References

1 e.g. in: Science Report SCCER-SoE 2018

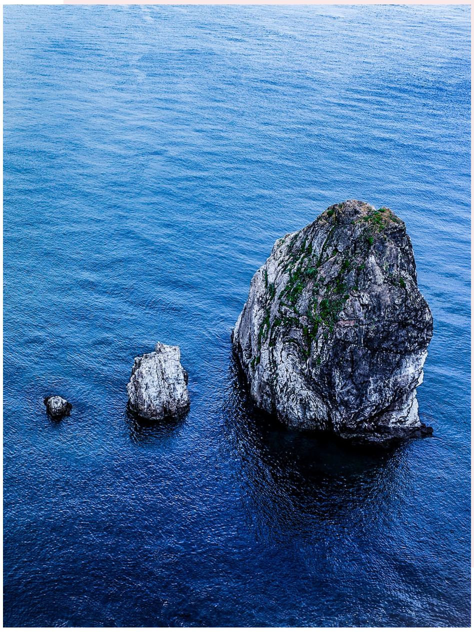
2.11. Multi-stage synthesis process

This synthesis on the main topic of “Hydropower and Market” was created as part of a multi-stage process. In October 2016, when the researchers were still in the middle of performing their project work, they exchanged information on their research questions, methods and solutions in order to identify interdependencies and potential synergies. Half a year later, the researchers met with representatives from associations, federal offices, cantons and relevant NGOs in order to find out more about the expectations placed on the research results and their dissemination.

On the basis of these findings, the Steering Committees of the NRP “Energy” developed a synthesis concept for each of the six main topics. An initial draft of the synthesis on “Hydropower and Market” was developed on the basis of this concept by Tony Kaiser, scrutinised within the Steering Committees of the NRP “Energy” and edited by a science journalist.

In June 2019, an echo group comprising nine specialists from the worlds of administration, business and NGOs came together in order to reflect on and assess the draft synthesis (see “Publication details”). They also evaluated the recommendations with a view to their impact and feasibility. Following further revisions and additions, the synthesis was approved in September 2019 by the Steering Committees of the NRP “Energy”.

3. Three focus areas



The results of a dozen research projects on the topic of “hydropower and market” were assigned to three focus areas as part of this synthesis:

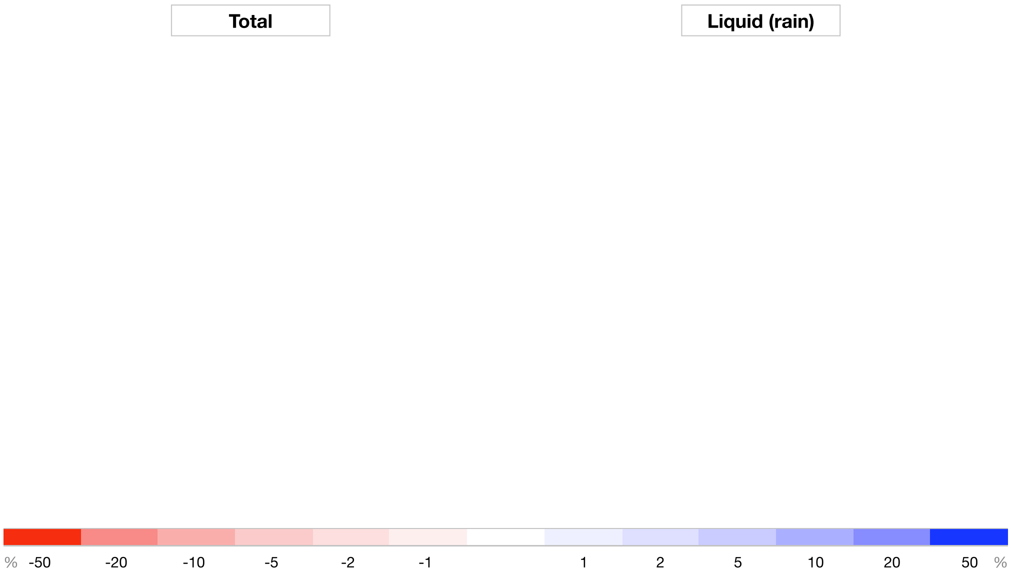
- Preservation and expansion of hydropower: technical challenges
- Costs, prices, water fees and market: economic challenges
- Alluvial landscapes, residual flows, bedload: environmental challenges

3.1. Preservation and expansion of hydropower: technical challenges

Glacial melting is reducing water reserves. In principle, however, it is also creating the conditions for new reservoirs. If the dam walls of 19 Swiss reservoirs were heightened, an additional volume of 700 km^3 would also be created. The new capacity would, in particular, enable a redistribution of production activities from summer to winter. The heightening of existing dam walls could also be realised much quicker than the establishment of new reservoirs where glacial melting is taking place.

3.1.1. Expansion potential of hydropower

Change in winter precipitation with warming of 2°C



Change in winter precipitation. *Source: Swiss Academy of Sciences, brochure "Wasserkraft und Klimawandel in der Schweiz – Vision 2030", 2003*

According to the Swiss Federal Office of Energy (SFOE), electricity generation from hydropower in Switzerland can be expanded by between 1.5 TWh and 3.2 TWh per year. This equates to around 4 % to 9 % of average production.[1] This potential incorporates both new and converted installations as well as expansions of existing hydropower plants.; 1.4 TWh per year was deducted due to new residual flow provisions.

Climate change will, however, influence this theoretical potential as rising temperatures have an impact on precipitation and extreme weather events. In the Alpine region, the expected temperature increase will be greater than the average rise. In summer, in particular, there will be less rain, while during the winter precipitation will increasingly take the form of rain rather than snow. Overall, annual precipitation on the northern side of the Alps will increase slightly, with volumes tending to decline on the southern side. [2] [3] [4]

The expected developments will also have an impact on the snow line, the thickness of the snow covering as well as glacial areas and volumes. During the summer, regions situated at up to 3,500 metres above sea level could be snow-free. The flow contribution made by melting snow will therefore decline; in return, the contribution of melting glaciers will increase for as long as the ice remains. Towards the end of the century, however, many glaciers will have disappeared completely.

As long as there are still glaciers, the annual flow rates are unlikely to change greatly either north or south of the Alps. The seasonal distribution of flow rates will, however, be markedly different; in areas with an abundance of snow and glaciers, the maximum flow rates will move from summer to late spring. Flows during the summer and autumn will decline significantly, while they will increase slightly in winter due to the higher snow line.

Notes and References

1 "Situation und Perspektiven der Schweizer Wasserkraft", R. Pfammatter and M. Piot, "Wasser Energie Luft", 106th volume/issue, 1, 2014, CH-5401 Baden

2 R. Weingartner et al. "Auswirkungen der Klimaänderung auf die schweizerische Wasserkraftnutzung", Geogr. Helv. 68, 239-248, 2013.

3 B. Schäfli et al., "The role of glacier retreat for Swiss hydropower production", Renewable Energy 132 (2019) 615-627.

4 J. Savelsberg, "The impact of Climate Change on Swiss Hydropower", Sustainability 2018, 10, 2541; doi:10.3390/su10072541

Landscape # Energy provision

3.1.2. New opportunities in areas surrounding melting glaciers

Reservoir location	V_W [hm³]	V_R [hm³]	Z_{max} [m a.s.l.]	H [m]	P [MW]	E [GWh/yr]	E_{eq} [GWh]
Aletsch Glacier	309	181	1880	355	73	218	396
Gorner Glacier	199	168	2300	594	78	235	199
Grindelwald Glacier	94	71	1520	456	28	85	64
Hüfi Glacier	44	36	1780	1204	35	105	86
Rhône Glacier	56	46	2300	790	19	57	75
Roseg Glacier	96	78	2260	1212	77	231	261
Trift Glacier*	154	85	1776	380	80	145	215
				Total	390	1076	1296

*Data provided by future operator Kraftwerke Oberhasli AG (KWO)

VW = Annual Runoff Volume
VR = Reservoir Volume
Z_{max} = Full Supply Level
H = Net Head
P = Installed Capacity
E = Annual Electricity Production
E_{eq} = Energy Equivalent of the Reservoir

If you take the seven locations situated close to glaciers that are best suited for the production of electricity through hydropower, the annual storage capacity amounts to around 1.3 TWh, while the potential annual electricity production increases to 1.0 TWh to 1.1 TWh due to the inflow amount. *Source: Project "Periglacial zones and hydropower'*

Glacial melting is reducing water reserves. In principle, however, it is also creating the conditions for new reservoirs that are either closed off by a natural rocky ridge or a dam wall.

For the project "Periglacial zones and hydropower"[1], potential locations in Switzerland with annual water discharge of more than 10 million m3 were selected and assessed according to economic, environmental and social criteria. Those locations that would be feasible in principle were classified and ranked. The storage capacity of the seven "best suited potential new reservoirs" totals 1.3 TWh – this equates to 14 % of the storage capacity of existing reservoirs. Beneath these new reservoirs, seven newly constructed hydropower plants could produce around 1.1 TWh per year of electricity. They would therefore increase domestic electricity production by 3 % and could contribute to achieving the target figure of 37.4 TWh per year[2] in 2035 – however, this does not take account of any possible decline in production due to new residual flow provisions.

Around half of the additionally produced electricity could – depending on the storage capacity – be used in winter, i.e. when Switzerland has its greatest import requirements. With the exception of the Trift Glacier, the seven best suited potential new reservoirs are, however, all registered in the Federal Inventory of Landscapes and Natural Monuments (BLN); objections and resistance would therefore have to be anticipated during planning.

The Federal Office for the Environment therefore only views the Trift Glacier as representing a realistic legal opportunity for a new reservoir.[3] The Gorner Glacier also offers certain potential as it only has national protection. As part of the UNESCO World Heritage Site, the Grindelwald Glacier would not be a realistic option, while the other glaciers enjoy precautionary protection under Art. 12(2) of the Alluvial Zones Ordinance.[4]

Notes and References

1 Project "Periglacial zones and hydropower"
2 Energy Act (EA) Art. 2(1)
3 R. Estoppey and S. Lussi, Federal Office for the Environment in a personal note from 11 June 2019 to the author.
4
https://www.bafu.admin.ch/bafu/de/home/themen/biodiversitaet/fachinformationen/massnahmen-zur-erhaltung-und-foerderung-der-biodiversitaet/oekologische-infrastruktur/biotope-von-nationaler-bedeutung/auen.html

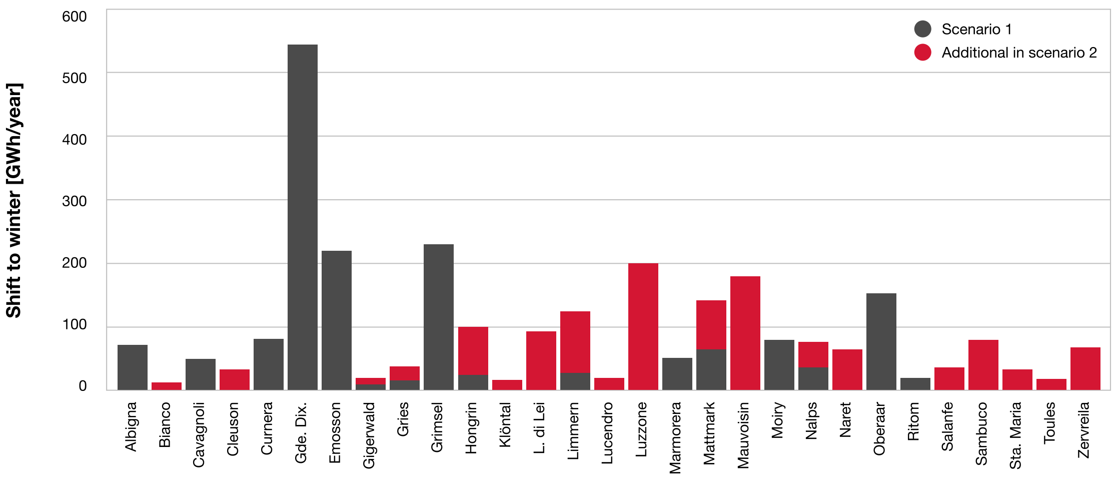
Landscape # Energy provision

3.1.3. Possible proglacial reservoir at the Trift Glacier

The Trift Glacier in the central Alps of the Bernese Oberland is an impressive example of the development of a proglacial lake. In 1948, there was still glacial ice at 2,500 metres above sea level. In 2008, a lake had already formed at this site. And in 2014, the glacier ended clearly above the lake. The lake is located on terrain where a dam wall could be built with relatively little effort – the site is therefore considered to be very suitable for a new reservoir. In a participatory process that has been running since 2012, interests with respect to the protection of nature and landscapes have been confronted with those of the electricity sector. Kraftwerke Oberhasli (KWO), an operator of hydropower plants, submitted an application for the construction of a dam wall to the Bernese authorities in 2017.

Landscape   # Energy provision

3.1.4. More electricity thanks to the heightening of dams



Shift to winter		Number of storage solutions		Increase by:	5%	10%	20%
Scenario 1	1.7 TWh/a	Total:	16		3	6	7
Scenario 2	2.8 TWh/a	Total:	29		2	8	19

The heightening of the dams of existing reservoirs by 5 %, 10 % or 20 % would provide additional storage potential of up to 30 % during the winter months; this is greater than the storage potential of future glacial lakes of around 15 % of the current total storage potential of 8.8 TWh. *Source: R. Boes, "Schweizer Wasserkraft in der Energiestrategie 2050", Energy Day. ETH Zurich 2018*

If the dam walls of 19 Swiss reservoirs were heightened, an additional volume of 700 km3 would be created. The new capacities would, in particular, allow for a redistribution of production activities from summer to winter. The heightening of existing dam walls could also be realised much quicker than the establishment of new reservoirs where glacial melting is taking place.

The project "Periglacial zones and hydropower"[1] examined various scenarios with the heightening of dam walls. Depending on the scenario, a redistribution of production from the summer months to the winter months in the amount of 1.7 TWh to 2.8 TWh per year would be possible. Together with the seven new reservoirs in areas located close to former glaciers, winter production could thus be increased by between around 2 TWh and 3.5 TWh a year. This would not offset the electricity imports required in winter, which on average totalled 4.2 TWh between 2003 and 2007, but would considerably improve the situation during the critical half of the year.

Notes and References

1 Project "Periglacial zones and hydropower"

Europe / EU # Energy provision

3.1.5. New storage potential for the reduction of imports during the winter months

in [TWh/a]	Objective according to Energy Perspectives: 38.6 TWh/year								
	Worst Case			**Likely Case**			**Best Case**		
Potential study	BFE	SWV	ETHZ	BFE	SWV	ETHZ	BFE	SWV	ETHZ
Potential through efficiency increases, expansions and new constructions 0.5 TWh/a already realised between 2012 and 2018 (SFOE Monitoring Report 2018)	2.43	1.50	1.50	3.25 *	4.00 *	5.50	4.06	6.50	8.00
Losses due to residual flows (Pfam. & Semad. 2018)	-6.41	-6.41	-6.41	-3.65	-3.65	-3.65	-2.28	-2.28	-2.28
Total hydropower potential (rounded)	-4.00	-4.90	-4.90	-0.40	0.40	1.90	1.80	4.70	5.70
Hydropower production 2050 Based on average production expectation of 35.9 TWh (as at 1 January 2018) (SFOE Monitoring Report 2018)	**31.90**	**31.00**	**31.00**	**35.40**	**36.30**	**37.80**	**37.70**	**40.60**	**41.60**

* Mean value between the scenarios “Current usage conditions” and “Optimised usage conditions”

Hydropower potential. *Source: R. Boes, “Schweizer Wasserkraft in der Energiestrategie 2050”, Energy Day. ETH Zurich 2018*

The potential offered by lakes situated at the end of glaciers and the heightening of dam walls demonstrated in the project “Periglacial zones and hydropower”[1] was examined in the context of various estimates[2] [3] that arise from the implementation of the new residual flow provisions. These new provisions must be implemented over the coming decades during the concession renewal process for hydropower. Relative to today and depending on the scenario, they require increased residual flow volumes, greater water depths to facilitate fish migration and the protection of alluvial zones or “simultaneous-dynamic allocation”, meaning that a certain percentage of the natural flow must remain in the body of water at all times.

The summary[4] shows the published estimates and figures of the Swiss Federal Office of Energy (SFOE), the Swiss Water Management Association (SWV) and ETH Zurich in accordance with the following scenarios: “worst case”, “likely case” and “best case”. The spread of these figures indicates how difficult it is to gauge the expansion potential and the impact of the Waters Protection Act. The figures are currently being revised by the Swiss Federal Office of Energy and are scheduled to be published before the end of 2019. It is to be expected that the expansion potential is likely to be slightly lower due to the planned increase in residual flow volumes and less electricity from small hydropower plants.

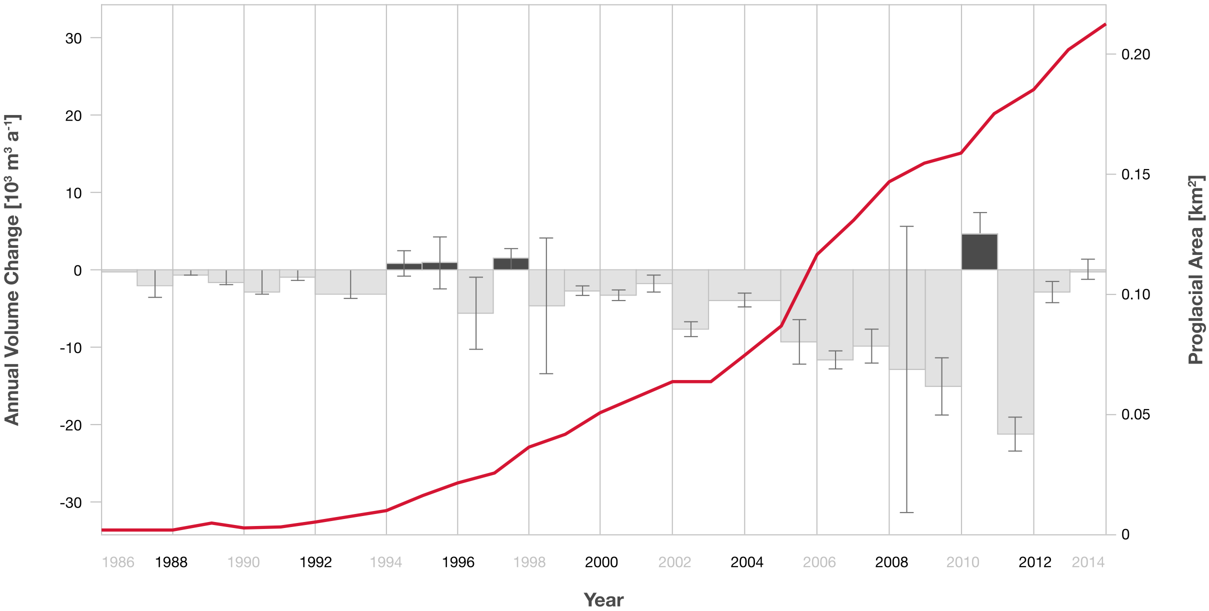
Notes and References

1 Project “Periglacial zones and hydropower”

2 Energy Strategy 2050
3 R. Pfammatter and N.S. Wicki, “Energieeinbussen aus Restwasserbestimmungen – Stand und Ausblick”, Wasser Energie Luft, volume 110, 2018, issue 4, p. 233
4 H. Boes, “Schweizer Wasserkraft in der Energiestrategie 2050 – quo vadis”, Energy Day ETHZ, December 2018

Landscape

3.1.6. Bedload rates increase where glaciers melt



Increase in the non-glaciated, proglacial area around the Gries Glacier in the canton of Valais and the annual change in sediment transportation between 1986 and 2014.
Source: Project "Periglacial zones and hydropower'

If reservoirs are to be constructed beneath melting glaciers, one aspect, in particular, needs to be taken into account: melting glaciers increase the transportation of bedload into the reservoirs situated beneath them – this reduces their storage volume over the long term. Until now, however, very few studies have been conducted on how great the sediment load actually is. Details in this regard are provided by a comparison of bedload transport from the following areas:

- Proglacial areas: recently exposed zones due to glacial retreat.
- Subglacial areas: zones that are still situated beneath a glacier and from which melt water escapes.

As part of the project "Periglacial zones and hydropower"[1], new measurement methods and a new simulation technique were developed in order to compare bedload transport from proglacial and subglacial areas. Field measurements of sediment concentrations in the melt water beneath the Gorner Glacier and the Aletsch Glacier provided a differentiated picture. Considerable bedload volumes were recorded for both glaciers. In the case of the Gorner Glacier, there are significant seasonal fluctuations in bedload transportation; the highest figures are observed at the start of the summer season. For the Aletsch Glacier, on the other hand, bedload transportation is more balanced over time and correlates closely with the volume of water flowing out.

Sediment deposition in reservoirs increases when the share of non-glaciated sections within the respective catchment area increases due to glacial melting. However, the discharge of sediment from the exposed glacial surface falls again over time and stabilises.

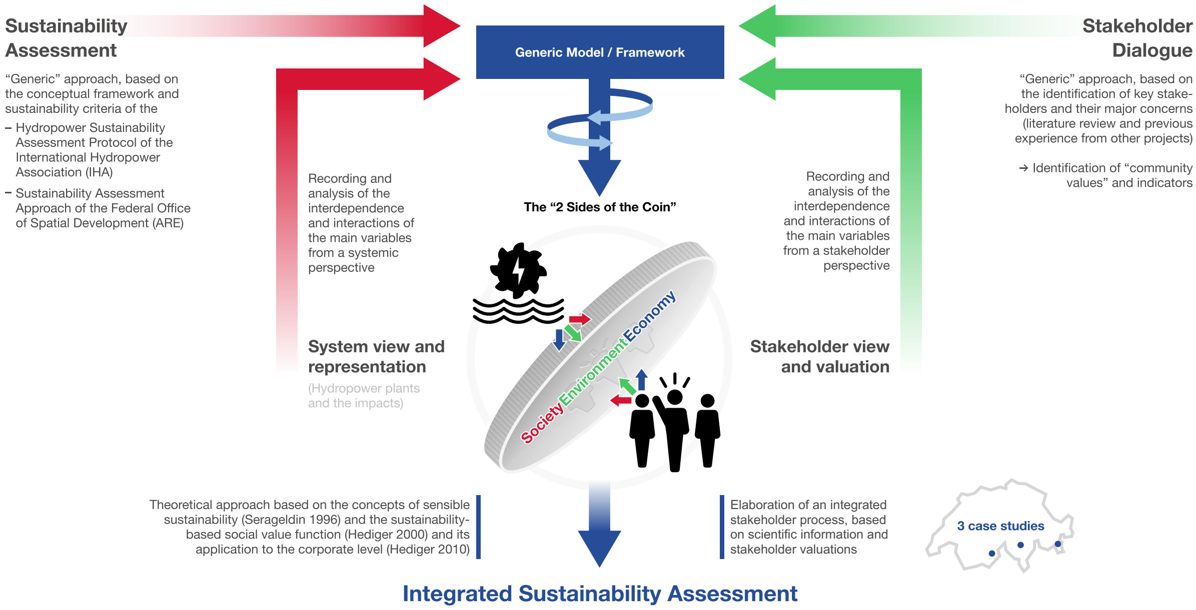
Field measurements and analyses also currently serve as an input parameter for a long-term simulation of the sedimentation in a reservoir. They are of great importance in the planning process for periglacial reservoirs: they make it possible to understand the location-specific requirements – the impact of sedimentation and the hydraulic conditions – and, where necessary, to take measures aimed at delaying the sedimentation of reservoirs.

Notes and References

1 Project "Periglacial zones and hydropower"

Participation

3.1.7. Integral sustainability assessment and stakeholder dialogue



Proposed and tested scheme for the process of gaining a comprehensive sustainability assessment of projects in the area of hydropower use by means of stakeholder dialogue. *Source: Project "The future of Swiss hydropower'*

For hydropower projects, there are always many aspects that need to be taken into account: technical, economic, environmental and socio-political. Projects also need to coordinate the interests of very different stakeholder groups.

The project "Hydropower sustainability"[1] looked in detail at the question of which processes should in future underpin projects in the area of hydropower – during the planning of new plants as well as with respect to new water fee regulations or the revision of the Waters Protection Act.

It is proposed there should be a comprehensive integral stakeholder dialogue together with a scientifically- based sustainability assessment. The model is based on an approach that is applied in the canton of Berne in a simpler form.[2] It has been developed further and tested during two projects: for the planned Lagobianco pumped-storage plant and the Piottino project of Azienda Elettrica Ticinese (AET).

In addition to economic viability, the new and expanded process also incorporates criteria from the areas of society and the environment and already involves all stakeholder groups affected by the project at the planning stage. In addition to the "net present value" of the project from the perspective of the hydropower company, the 150 indicators include environmental and socio-political criteria. The criteria are assessed by experts and conclusions (trade-offs) are drawn as part of stakeholder dialogue. This allows for a comprehensive assessment of the entire project – the so-called "social net present value" – to be gained from the purely economic value.

Notes and References

1 Project "Hydropower sustainability"
2 Hediger, W. (2017). Nachhaltigkeitsbeurteilung (NHB) von Wasserkraftprojekte, working document, May 2017, Centre for Economic Policy Research, HTW Chur

3.1.8. Lagobianco pumped-storage plant and Piottino hydropower centre

The Lagobianco on the Bernina Pass.

Using an integrated sustainability assessment, both the construction phase and the later operational activities of the Lagobianco power plant were checked with respect to positive and negative effects.[1] The stakeholders discussed the advantages and disadvantages and together determined the “trade-offs” – i.e. the overall assessment. Participating stakeholders included the Head of the Lagobianco project from Repower, a representative from both the electricity sector and WWF Graubünden, the consulting firm that drew up the project sustainability assessment and representatives from the worlds of science and politics.

For the six-year construction phase, earth movements, habitat restrictions and atmospheric emissions were identified as negative aspects. The positive aspects – investments in infrastructure and higher local consumption due to additional temporary residents – could not offset these.

The impact of the expected 80-year operating phase on the regional economy, on the other hand, was assessed very positively. Environmental concerns were also overcome. Overall, this gave rise to a slightly positive “social net present value”.

As part of the upgrading of hydropower plants in the Leventina district, a sustainability assessment for the renovation of the Piottino hydropower plant of Azienda Elettrica Ticinese (AET) was conducted in Lavorgo, also taking account of the relevant stakeholders. Here, it was shown once more that if a project is selected in a well-considered and optimised manner, the positive aspects with respect to biodiversity, habitat, energy and prosperity during the later operating stage can outweigh the negative aspects during the construction phase.

Notes and References

1 Project "Hydropower sustainability"

3.1.9. Preservation and expansion of hydropower: conclusion

- Energy Strategy 2050 aims to increase average electricity production from the current figure of 35.9 TWh per year to 38.6 TWh per year by 2050. The new construction of power plants as well as the expansion of existing power plants together with efficiency-boosting measures will, however, only result in a limited increase in production. Estimates of the potential lie between a pessimistic 1.5 TWh a year and an optimistic 8 TWh per year.
- The optimistic estimates include the theoretically exploitable technical potential offered by proglacial reservoirs of around 1.3 TWh a year as well as the potential provided by heightening dam walls by 5 % to 20 % of between 1.7 TWh and 2.8 TWh each year. In principle, the heightening of dam walls can be implemented quicker than proglacial reservoirs. Provisions with respect to the protection of nature and landscapes as well as residual flows greatly limit the exploitable potential, however.
- The ecological redevelopment of hydropower can significantly hit production. Depending on the scenario, the reduction stands at between 2.3 TWh and 6.4 TWh per year. The decline could therefore be even greater than the expansion planned under Energy Strategy 2050. There is a conflict of objectives between environmental and economic aspects.
- Overall, values of 31.0 TWh to 41.6 TWh per year result for average expected hydropower production in 2050. The Federal Office for the Environment urges caution with respect to these figures as the impact of the residual flow provisions and the potential for expansion is greatly dependent on their implementation; the cantons can make use of exceptions.
- During the winter months, it will in future be necessary to import more electricity; with the phasing out of nuclear power, this trend will intensify further and is likely to account for between 7 % and 12 % of annual consumption depending on which estimate is applied. During the outages of the Beznau I and Leibstadt nuclear power plants in the winter of 2016/2017, net imports during the winter totalled 18 % of annual consumption.
- For this reason, all options to increase electricity production from hydropower must be utilised,

including the expansion of storage. New technical storage potential that could support domestic electricity production during the winter months is being opened up by glacial retreat and the lakes forming at the end of the affected glaciers as well as by the heightening of existing dam walls.

3.2. Costs, prices, water fees and market: economic challenges

Over recent years, electricity producers have suffered from falling income and smaller profits, with some even experiencing significant losses. There is therefore a lack of funds for the renovation of infrastructure. Two challenges are key for hydropower in Switzerland: firstly, the European market, which will determine the future profitability of hydropower and thus also investment opportunities, and, secondly, the growing significance of political, social and legal considerations.

Water fee # Market # Financing # Europe / EU

3.2.1. Low electricity prices, high taxes?

With respect to supply security, Energy Strategy 2050 places great emphasis on electricity from hydropower. Over recent years, however, electricity producers have suffered from falling income and smaller profits, with some even experiencing significant losses. There is therefore a lack of funds for the renovation of infrastructure.[1]

The economic situation is related to the development of the European market and the fall in prices observed in recent years. Reasons for the slump in prices include the liberalisation of the electricity market in Europe, the growing share of electricity from renewable energy as well as the low coal and CO_2 prices. The low CO_2 prices are in turn a consequence of the oversupply of emission certificates.[2]

With low wholesale prices, hydropower investment and operating costs can only just be covered or no longer covered at all. Income must therefore be increased in the short term; over the long term, new investment strategies, alternative trade strategies, a good understanding of future markets and the optimal use of decentralised production and storage technologies are required.

The likely most-discussed political issue at present is the water fee – the remuneration that electricity producers pay to cantons and municipalities as compensation for the use of water. For mountain regions, water fees are an important source of income. A recently published study of the Association of Swiss Electricity Companies (VSE)[3] indicates that Swiss electricity companies pay excessive duties relative to their international counterparts due to water fees and are thus at a competitive disadvantage relative to foreign hydropower plants as well as with respect to electricity produced from other sources. The mountain cantons disagree with this. They state that water fees do not represent a tax, but rather the price for a raw material and thus income. Furthermore, they are of the opinion that the VSE analysis is incomplete as it neither takes account of value-added tax nor subsidies relative to neighbouring countries.[4]

The restructuring of water fees requires a political process.[5] Parliament and the Federal

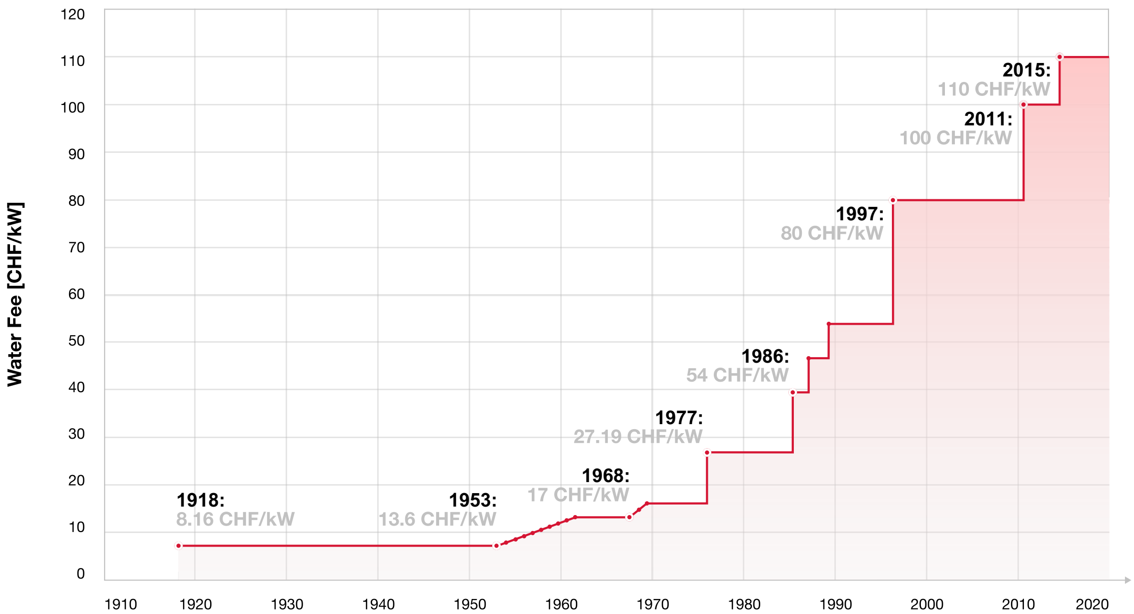
Council have decided to extend the rigid system until 2024 – there is thus time to develop a new solution.

Notes and References

1 Between 2017 and 2019, the wholesale prices for base-load electricity have recovered slightly once more.
2 "Wasserkraft: Wiederherstellung der Wettbewerbsfähigkeit", Whitepaper SCCER CREST, March/2016
3 "Schweizer Wasserkraft bis neunmal stärker besteuert als die europäische Konkurrenz", VSE, 18 February 2019
4 J. Meier, NZZ am Sonntag, 24 February 2019, p.33
5 "Wasserkraft: Wiederherstellung der Wettbewerbsfähigkeit", Whitepaper SCCER CREST, March/2016

Market # Financing

3.2.2. Water fees – a fixed system for 100 years



The historical development of the maximum water fee from the early 20th century to today. *Source: Project "The future of Swiss hydropower'*

Water fees are not dependent on the energy produced by a power plant, but rather its gross capacity. The system therefore does not respond to the current economic value of the resource of hydropower. The maximum level of the fees is defined by parliament.

The Swiss system is governed in the Water Rights Act and has existed for 100 years. It is applicable to power plants with a gross capacity of at least 1 megawatt (MW). The maximum amount for these fees is increased periodically. When introduced in 1918, the water fee totalled CHF 8 per kilowatt; more recently, it was increased to CHF 100 per kilowatt in 2011 and to CHF 110 per kilowatt in 2015.[1]

Countering the accusation that the maximum water fee has increased more than inflation, the General Secretary of the Government Conference of the Mountain Cantons explains that this is politically desired – because public interest in the value of water for the protection of landscapes and renewable electricity production has increased significantly as part of Energy Strategy 2050.[2]

With respect to the revision of the Water Rights Act, which is currently the subject of parliamentary debate, focus is being placed on a flexible maximum water fee as part of the new water fee regulations. A report of the Swiss Federal Office of Energy (SFOE)[3] looks at the key figures in this regard.

Notes and References

1 “Wasser Energie Luft”, 108th volume, 2016, issue 3, CH-5401 Bade
2 Personal message from the General Secretary of the Government Conference of the Mountain Cantons to the author.
3 “Eckwerte für ein mögliches flexibles Wasserzinsmaximum” – report for ESPEC-N-N, SFOE, 14 December 2018

Market # Financing

3.2.3. An instrument of regional policy?

How should the water fee be designed in future? In its message on the amendment of the Water Rights Act, the Federal Council wrote the following: “For the selection of a future solution, it will be decisive that the water fee does not too greatly inhibit market forces and make investments impossible. It should not negatively affect incentives for cost reductions and increases in productivity and at the same time provide appropriate remuneration for the use of the resource of water”.

The discussion is currently focussing on ways of making the water fee more flexible. The Swiss Federal Office of Energy (SFOE) described this process in great detail in December 2018 in a report to the Environment and Energy Commission of the National Council.[1]

In its study “Konzessionen bei den Konzessionen”[2], Avenir Suisse suggests several variants that it believes need to be taken into account in connection with national fiscal equalisation (NFE). Avenir Suisse argues that over the decades water fees have increasingly degenerated into “an instrument of regional policy”. It therefore proposes that water fees be incorporated in NFE calculations as “regional policy objectives should explicitly be pursued by means of burden sharing”.

The Federal Council has in the meantime presented parliament with different variants for the new water fee regulations which will apply from 2024, while remaining frozen until this time:[3]

- The water fee is to be made more flexible; this takes better account of the current value of the resource of water than a rigid solution.

- The water fee is to be based on the profit of the electricity producers.
- The concession system is to be fundamentally changed: consumers pay a duty via the grid surcharge.
- The resource potential of water is to be considered in NFE.

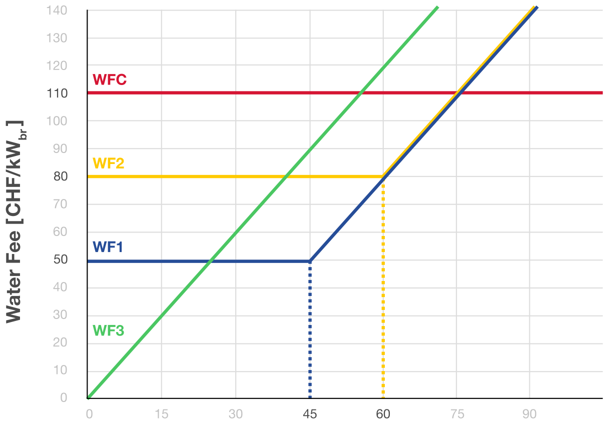
The Federal Council points out, however, that the variant which sees the resource potential of water taken into account in NFE has always been rejected until now as it would place water-abundant cantons in a worse position with respect to NFE. The federal government and mountain cantons continue to reject this variant at a national level.[4]

Notes and References

1 "Eckwerte für ein mögliches flexibles Wasserzinsmaximum" – report for ESPEC-N-N, Swiss Federal Office of Energy, 14 December 2018.
2 P. Dümmler and L. Rühli, "Konzessionen bei den Konzessionen – Varianten einer Reform des Wasserzinses", Avenir Suisse, March 2018
3 "Botschaft zur Änderung des Wasserrechtsgesetzes vom 23. Mai 2018"
4 Various cantons, including the canton of Graubünden, take account of the water fee in their resource equalisation systems – because the water fee is of great significance for individual municipalities in the mountain cantons. At the level of the 26 cantons, however, income from concessions only plays a minor role.

Market # Financing

3.2.4. Simulation model for a flexible water fee



WF1, WF2 and WF3 are three different implementations of a flexible water fee model. WF1 and WF2 have a different basic amount and a different reference market price at which the variable component starts to take effect. WF3 is a scenario without a basic amount. WFC is the current, rigid model with a constant maximum water fee. *Source: Project "The future of Swiss hydropower"*

The Association of Swiss Electricity Companies (VSE) claims that the rigid water fee is hindering investments in hydropower.[1] Can this claim be backed up? What impact would making the water fee more flexible have on the profitability of electricity producers with different market prices for electricity? And what consequences would this have for the water-fee income of the mountain cantons and municipalities? The project "The future of Swiss hydropower"[2] investigated these questions with simulation calculations.

The researchers based the simulations on market prices in the following range:

- Low-price scenario: prices fall from the current figure of around CHF 40 per MWh to CHF 30 per MWh.
- High-price scenario: prices increase to more than CHF 100 per MWh by 2030.

CHF 0, 50 and 80 per kW were selected as basic amounts; CHF 0, 45 and 60 per MWh were set as the reference prices at which the water fee starts to rise linearly.

The currently applicable fixed water fee of CHF 100 per kW was used for comparative purposes.

With these parameters, the researchers calculated the level of profitability for 62 hydropower operators – 36 run-of-river as well as 26 storage and pumped-storage operators – for the years 2015, 2020, 2025 and 2030.

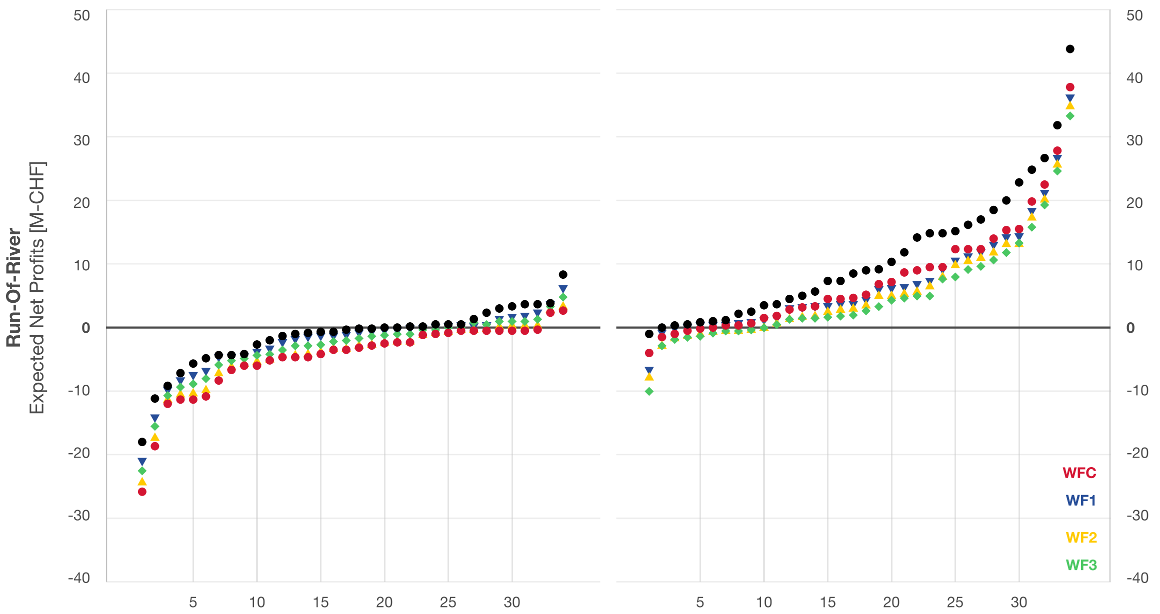
Notes and References

1 “Schweizer Wasserkraft bis neunmal stärker besteuert als die europäische Konkurrenz”, VSE, 18 February 2019

2 Project “The future of Swiss hydropower”

Market # Financing

3.2.5. Income shaped by the market price – not by the water fee



Left: Profitability of 35 run-of-river power plants (in ascending profit order) for a low electricity price of around CHF 30 per MWh in 2025. The difference in the profitability of the power plant with the biggest loss (left on the diagram) relative to the power plant with the greatest profit (right on the diagram) is much bigger than the differences of the different water fee models (coloured spots for the water fee models WF1 to WF3 as well as WFC). Right: Profitability of 35 run-of-river power plants (in ascending profit order) with a high future electricity price of around CHF 80 per MWh in 2025. *Source: Project "The future of Swiss hydropower"*

The simulation of the project "The future of Swiss hydropower"[1] shows the following: whichever variant of the water fee is selected, the results for a selected company are close together. The profitability of the individual operators differs greatly, however. The profit margin is significantly greater than that which results for the individual company due to the different variants of the water fees.

This gives rise to the following findings:

- The impact of the water fee – whether flexible or rigid – is much smaller than the effect of the market price.
- The current fixed water fee has little impact on earnings development with high market prices and does not lead to the majority of operators which were investigated suffering a loss.
- Conversely, the complete eradication of the water fee would make only a few operators profitable under poor market conditions.

- However, the flexible water fee has a clear effect on operators who find themselves at break-even point.
- A flexible income-dependent solution requires full transparency with respect to revenues.

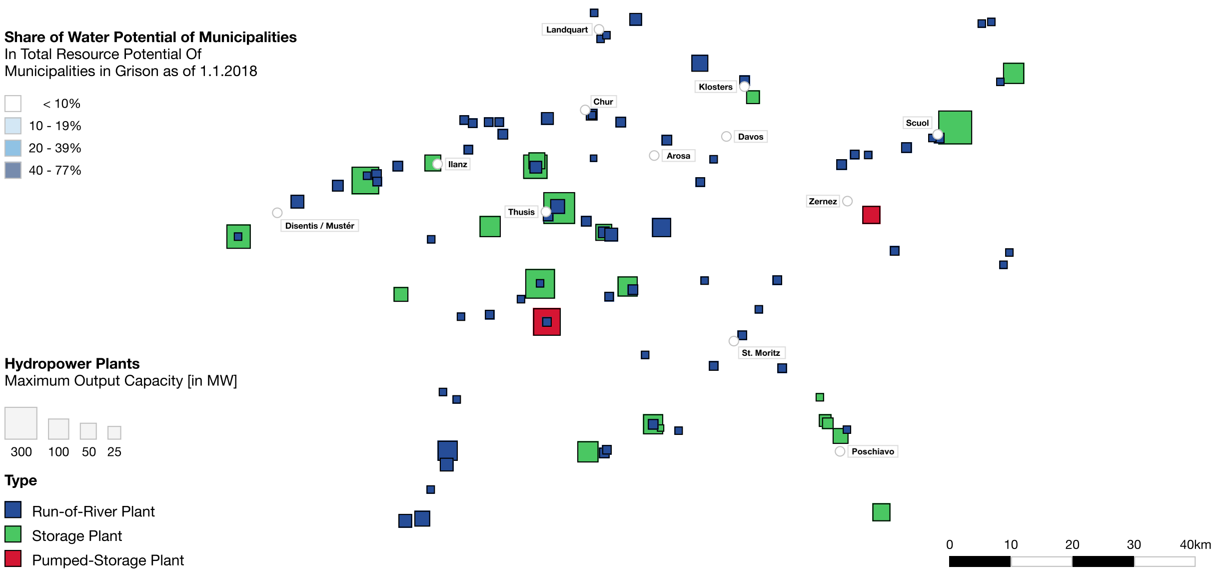
Viewed overall, a water fee of CHF 0.012 to CHF 0.015 per kWh appears to be a substantial cost block at electricity prices of CHF 0.04 to CHF 0.06 per kWh; market dynamics can, however, easily lead to prices above or below this range. The higher the market price, the less of a factor the water fee is with respect to profitability – and vice versa: the lower the market price, the greater the impact of the water fee. In a poor market environment, however, the elimination of the water fee would also be of little help. And, generally speaking, the battle for the distribution of resource income intensifies during periods of falling market prices.

Notes and References

1 Project “The future of Swiss hydropower”

Market # Financing # Politics (federal government, canton, municipality)

3.2.6. The significance of water fees for the public sector



In the canton of Graubünden, water fees can account for up to 77 % of communal income and exceed regular tax proceeds. *Source: Barry et al. "The Future of Swiss Hydropower: Realities, Options and Open Questions", Final Project Report, March 2019*

For many cantons, municipalities and corporations, the water fee represents a substantial source of income. The six cantons of Valais, Graubünden, Aargau, Ticino, Berne and Uri together receive more than 80 % of the income; the cantons of Valais and Graubünden are the main recipients and receive around 50 % of all water fee payments.

The project "The future of Swiss hydropower"[1 2] investigated the importance of the water fee for the public sector using the example of Graubünden.

The researchers view the water fee as part of the economic value of the natural resource of water.

- Internal value: the retained and distributed earnings of the electricity producers.
- External value: taxes, water fees, wages and other contributions to the economy and society.

In the canton of Graubünden, water fee proceeds equate to 15 % of tax revenues and 5 % of cantonal income overall. They are split roughly 50/50 between the canton and the municipalities and are incorporated in intercantonal financial equalisation so that their impact can be smoothed out. In some municipalities, water fee proceeds account for a share of between 40 % and 77 % of resource potential. In terms of tax revenues, this means that some municipalities receive more money through water fees than they do through regular taxation.

For example, if we compare the importance of water fees for the municipalities and the canton of Graubünden, it becomes apparent that changes to the water fee have a greater impact on the holders of water rights than on the profitability of the power plant operators for whom the market price plays a decisive role.

Notes and References

1 Project "The future of Swiss hydropower"
2 fonew.unibas.ch/fileadmin/user_upload/fonew/Paper/HP_Future_2019_WaterFees.pdf

Market # Financing # Politics (federal government, canton, municipality)

3.2.7. Distribution effects with a flexible water fee

Results of model calculations for 2018

Implied maximum water fee		230.0	110.0	80.0	50.0	0.0
Water fee income and equalisation payments	Graubünden municipalities	119.7	57.3	41.6	26.0	0.0
	Canton of Graubünden	131.7	63.0	45.8	28.3	0.0
Total resource potential [CHF million]		820.9	758.4	742.8	727.2	701.2
Cantonal contribution to resource equalisation [CHF million]		10.9	8.3	8.0	8.0	9.2
Number of municipalities	Strong in terms of resources	44.0	38.0	38.0	35.0	26.0
	Weak in terms of resources	62.0	68.0	68.0	71.0	80.0
Electricity reference price [CHF/MWh]		135.0	75.0	60.0	45.0	not relevant

Results for 2018 from the modelled scenarios for water fee levels from zero – in the event of the elimination of the water fee – and maximum water fees with a value of up to CHF 230 per MW. The modelling also considered the effects on cantonal financial equalisation. *Source: Hediger et al., "Wasserzins: Erfolgsmodell oder Hemmschuh?", Energy Research Talks Disentis 2019, 24 January 2019*

The project "The future of Swiss hydropower"[1] investigated the distribution effects upon changing the rigid water fee to a flexible model with a different basic amount and different reference prices in the canton of Graubünden.[2] This also looked at the effect on intercantonal equalisation payments and the shifts that result in the resource strength of the individual municipalities.

In Graubünden, the revenues from water fees are split roughly 50/50 between the canton and the municipalities. If the maximum water fee is increased, revenues of course also increase for both the canton and the municipalities – and they fall if the maximum is reduced. The contribution of the canton to resource equalisation, however, reveals a slightly different picture: it is at its lowest with a maximum water fee of CHF 80 per kW and CHF 50 per KW; it is higher with a higher maximum water fee but also in a scenario which sees the complete elimination of water fees as the canton would have to pay certain compensation.

The water fee also influences the number of municipalities classified as having a high and low level of resources. The higher the revenues from the water fee, the more municipalities there are that are deemed to have a high level of resources and thus that also pay into the cantonal pot for resource equalisation.

Between 2016 and 2018, the financially weaker municipalities received between CHF 26 and

CHF 27 million. The financially stronger municipalities provided the canton with around CHF 18 million, while the canton itself bore the remaining CHF 8 million.

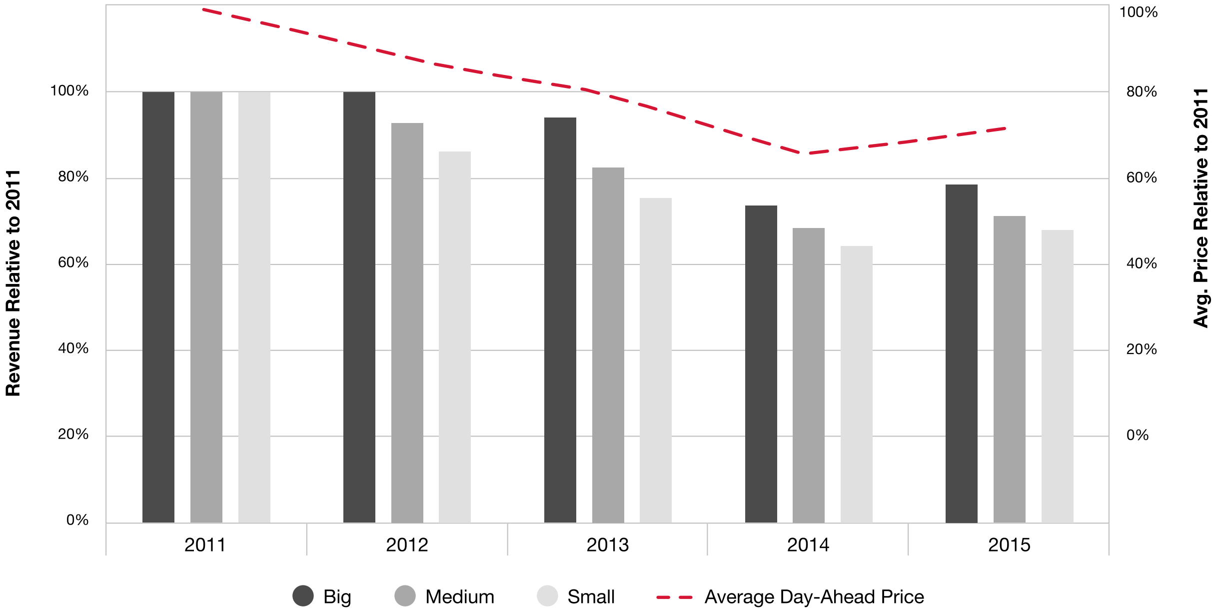
Cantonal resource equalisation therefore ensures that all municipalities also benefit from the revenues in the case of a flexible water fee – and that the burden is spread between all communities should lower revenues be generated.

Notes and References

1 Project “The future of Swiss hydropower”
2 Hediger et al. “Water Fee-induced Financial Flow in Switzerland”, Final Report, April 2019

Market   # Europe / EU

3.2.8. European market and politics as the biggest challenges



Due to the growing share of electricity from photovoltaics and wind energy and due to low prices for CO_2 and fossil fuels, spot market prices for electricity fell significantly between 2011 and 2014. As a consequence, the revenues of hydropower plants also declined, with the impact being felt more by small plants relative to large plants. With their reservoirs, the large plants have greater opportunities to curb production during periods of low prices and ramp it up again in periods of higher prices. *Source: Project "Market environment of hydropower"*

How can money still be made with electricity under the current market conditions? As part of the project "Sustainability of hydropower"[1], a survey relating to this question was conducted with stakeholders from the world of business as well as from research institutions, NGOs and administrative bodies.[2] It shows that two challenges are key for hydropower in Switzerland: first, the European market, which will determine the future profitability of hydropower and therefore investment opportunities and, secondly, the growing significance of political, social and legal aspects. Only after these two considerations, in third place, natural factors were stated as a challenge. And at the bottom of the list, technical issues were mentioned.

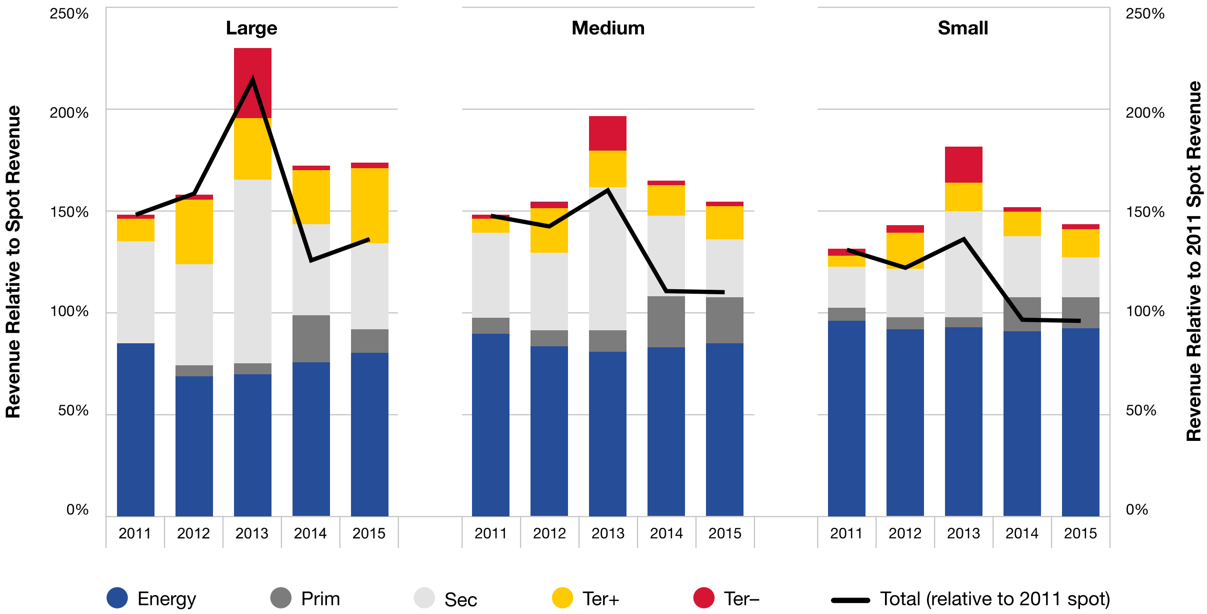
As the investigations show, the day-ahead electricity price – i.e. the price for electricity delivered on the following day – fell considerably between 2011 and 2015.[3] This gave rise to a significant fall in revenues and profits. However, the decline in prices did not have an impact on all producers equally, as the breakdown according to the size of the plants shows. Small and medium-sized hydropower plants tended to suffer more from the decline in prices than large plants. The researchers attribute this difference to the fact that – thanks to their reservoirs – larger storage plants have the flexibility to curb their electricity production during low-price periods and to then sell the electricity during high-price periods.

Notes and References

1 Project "Hydropower sustainability"
2 www.sccer-crest.ch/fileadmin/user_upload/2015_Barry_Future_of_Swiss_Hydropower.pdf
3 In the meantime, the market has recovered again slightly.

Market # Europe / EU

3.2.9. Higher income through participation in the balancing market



Theoretical maximum income from simulation calculations for large, medium-sized and small hydropower plants through participation in the “multi-energy” market, i.e. the energy and balancing market, for 2011 to 2015. The additional income varies from 40 % to 130 %; it would not be possible to reach this level in practice, however. *Source: Project “Market environment of hydropower”*

As part of the project “Market environment of hydropower”[1], an analysis was undertaken of the extent to which higher revenues and thus greater profits would have been possible between 2011 and 2015 despite the difficult market situation. To this end, it was calculated how earnings in the past would have looked if the power plant operators had also sold their electricity in the balancing market instead of exclusively in the energy-only market. The balancing market aims to keep the frequency and voltage in the grid constant by curbing or quickly increasing production.

The study reveals that if the power plants had not exclusively participated in the energy-only market, but rather participated on a mixed basis in both the energy-only and balancing market, revenues would potentially have been higher. The additional income would theoretically have equated to a 130 % increase for large power plants and a 40 % rise for small power plants, with secondary reserve exhibiting greater potential than primary and tertiary reserve. For the large electricity producers, the calculated additional income due to their greater operational flexibility is higher than for medium-sized and small companies.

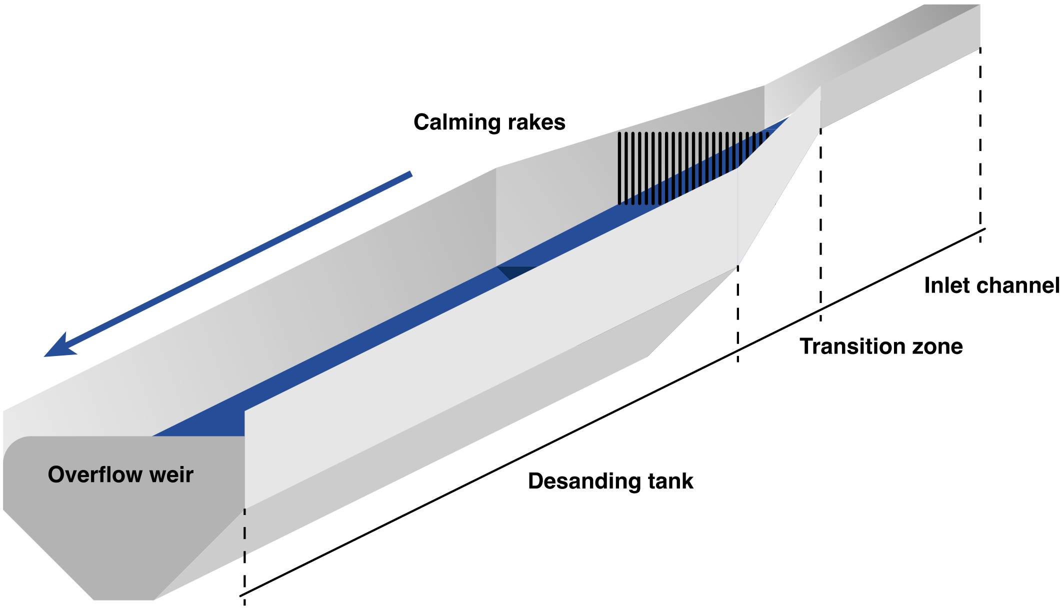
There are several reasons why it would not have been possible for the additional income to reach this level in practice: the uncertainty involved in predicting balancing energy prices, the limited balancing market, the competitive situation owing to many providers and the limited storage capacity of small electricity producers. These factors limit the realisable additional revenues to less than 13 % relative to a pure energy market. New earnings opportunities could, however, open up if Switzerland concludes an electricity agreement with the EU and thus gains access to the intra-day market.

Smaller electricity producers will in future also remain disadvantaged on the free market relative to large producers. The researchers anticipate that an electricity market characterised by low prices is likely to remain for a number of years.

Notes and References

1 Project “Market environment of hydropower”

3.2.10. Lower costs due to less abrasion in the turbines



Schematic illustration of a desanding system with the following zones: inlet channel, transition zone, desanding tank, overflow weir and calming rakes. *Source: Project "Sediments in high-head hydropower plants"*

Water from reservoirs always carries sand and other sediments with it. These loose materials block pressure pipes, turbines and guide apparatus if they make their way into the intake water channel. This increases maintenance costs and reduces the economic viability of hydropower. With a desanding system – a special sedimentation tank – the sediments can be removed before the water shoots into the pressure pipe and then the high-pressure turbines. The removed sediments must be flushed out of the desanding system on a regular basis.

However, many operational systems do not remove the sediment efficiently enough. The cause is often an inappropriate design of the desanding system whose geometry does not meet the requirements posed by the dynamics of the water flow. And the stilling basins are often too short. A good desanding system requires a correctly dimensioned, widening transitional zone with constructive elements to calm the flow as well as a sufficiently long sedimentation tank.

As part of the project "Sediments in high-head hydropower plants"[1], the geometry of desanding systems was optimised in terms of flow mechanics using numerical 3D simulation. In particular, the flow was calmed in the transition zone between the water inlet and the sedimentation tank using vertical and horizontal construction elements and the length of the sedimentation tank was optimised. It was shown that sedimentation tanks constructed according to the design rules commonly applied today are much too short for efficient desanding. The findings from the calculations and measurements conducted on a prototype desanding system were transferred to a new design process. It takes account of the geometry and hydrodynamics of the entire system, from the inflow of the water and the transition zone with the elements to the calming of the flow and the end of the sedimentation tank.

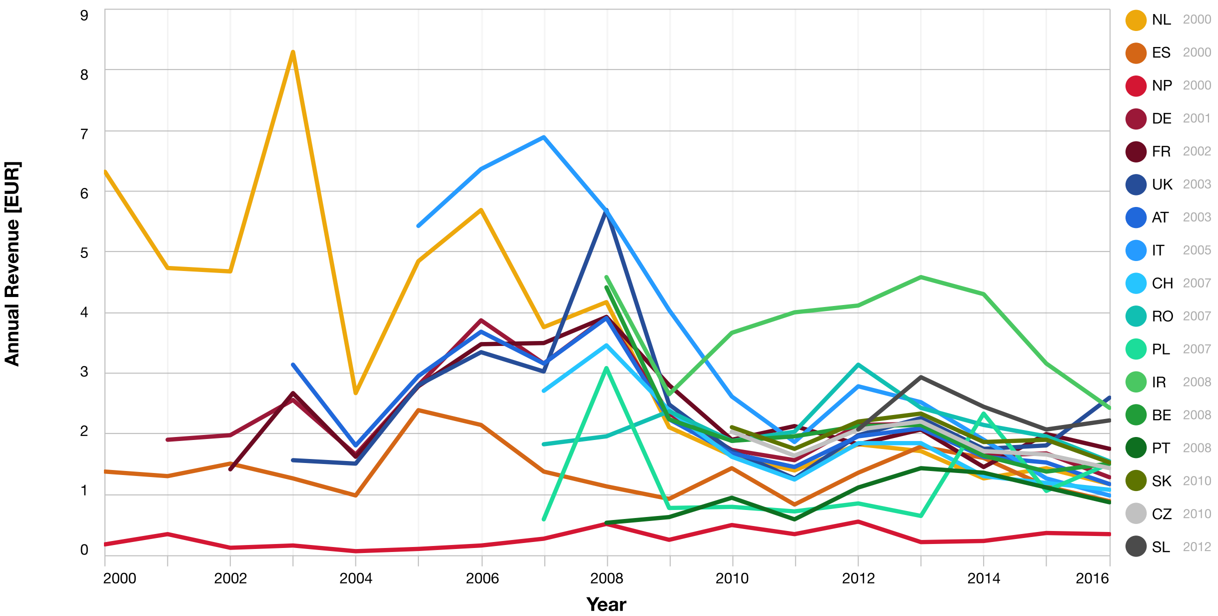
Inadequate desanding systems lead to higher maintenance costs and downtime – and annual production losses of an estimated 160 GWh for medium- and high-pressure power plants in Switzerland. As part of the project, the economic potential offered by optimised desanding systems was also assessed: the savings potential stands at CHF 6 million a year.

Notes and References

1 Project “Sediments in high-head hydropower plants”

Market # Investment # Financing

3.2.11. “Think big, act small”



Income of pumped-storage power plants in different countries. Revenues have generally fallen – and have moved closer together. *Source: Project “Investments in hydropower”*

If the funds for investment in hydropower become scarcer, new strategies will be required. A better knowledge of important long-term factors and areas of uncertainty will help to ensure the right decisions are taken. The uncertainties include climate change and its impact on the management of reservoirs, the future importance of electricity storage devices, the significance of new renewable energy for electricity production and market developments over the coming decades. All of these uncertainties relate to periods of time that may be significantly smaller than the service life of the hydropower infrastructure. It is therefore especially challenging to make decisions for capital-intensive, long-lasting infrastructure.

The project “Investment in hydropower”[1] developed new instruments that make it possible for robust investment decisions to be taken despite uncertainties. This reduces the difficulty posed by the fact that investment in hydropower can be used over decades but the markets only allow a short-term assessment.

An analysis of the revenues from the pumped-storage plants in Europe shows, for example, that income since 2000 has firstly become very volatile and secondly decreased significantly. In general, the differences from country to country have reduced greatly in size, with the normalised values having levelled off at around EUR 2 per kWh of storage capacity. With these values from the energy-only market, most pumped-storage plants are no longer able to generate a positive net present value (NPV) – there is no longer an incentive to invest in long-term energy storage.

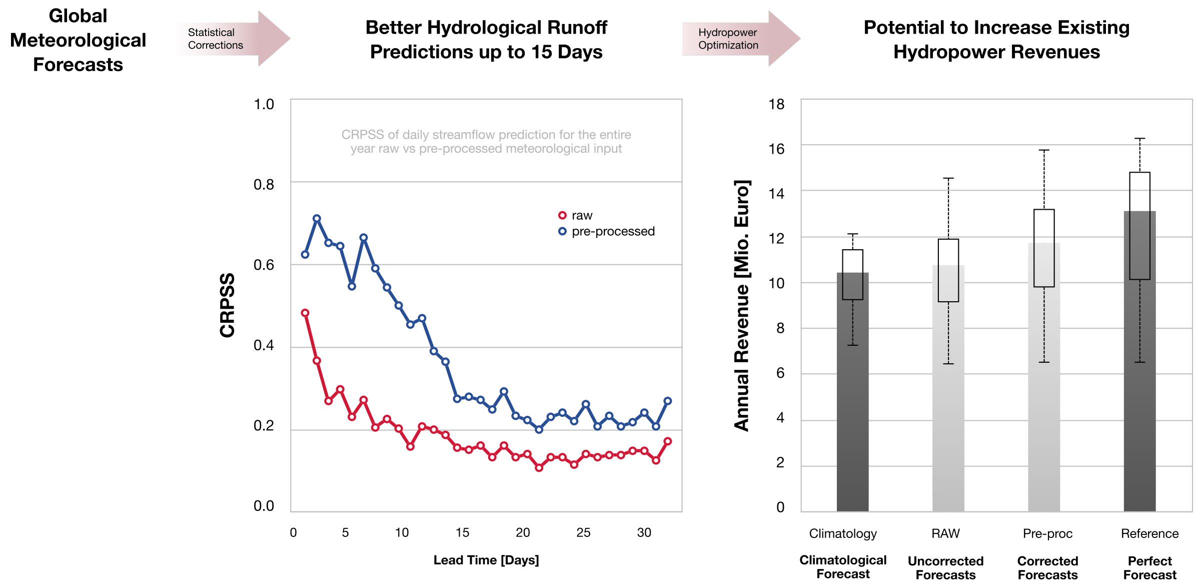
To make investments profitable once more, researchers recommend the so-called real option method. This is based on a time-staggered and flexible investment process. Alongside short-term investments, it also earmarks future options that are not yet profitable and incorporates these in the planning. The optional investments are deferred.

Notes and References

1 Project "Investments in hydropower"

Market

3.2.12. Make better use of long-term forecasts for dry periods



With improved long-term hydrological inflow forecasts, the income from electricity production could be improved for the test region of Verzasca. CRPSS is a statistical measure for improving the meteorological forecast of water inflow. This value indicates how well the forecast corresponds to the actual weather (in this case for precipitation and thus water inflow). A CRPSS of 1 means perfect agreement, while a CRPSS of 0 means no improvement with respect to today's forecast accuracy. *Source: Project "Hydrometeorological predictions"*

Weather forecasts can also strengthen hydropower: long-term, regionally detailed forecasts help to improve the planning of water reserves and allow the power plants to be operated more profitably, i.e. by producing electricity, where possible, when prices are high. Corresponding forecasts can now be made for a period of two to three weeks.

The project "Hydrometeorological predictions"[1] looked intensively at the complexity of these long-term forecasts. Forecasts for the inflow and outflow of water can be combined with the expected price developments on the energy market. This combination allows for the operation and economic viability of storage power plants to be further optimised.

Notes and References

1 Project "Hydrometeorological predictions"

Market # Investment # Financing

3.2.13. Costs, prices, water fees and market: conclusion

- Power plant operators must also anticipate volatile electricity markets and low prices during the coming years – as well as the corresponding consequences for the investment required in hydropower infrastructure over the long term.
- Flexible use, for example through greater participation in the balancing market, only generates little additional income due to the additional costs involved and the numerous market participants. There is also the fact that – in the absence of an electricity agreement with the EU – the extent to which Switzerland can participate in the European electricity market is becoming ever smaller.
- Measures need to be taken in order to get the hydropower sector through this lean period – until higher prices for CO_2 and coal also lead to a renewed spike in electricity prices and the power plants can once more generate the required investment funds through their operational business.
- An environment where energy producers are facing a squeeze on income, demands new investment strategies. Decision-makers should find robust, scalable solutions for their investments – in keeping with the motto “start small, think big!”
- The “real option” method, which foresees the gradual execution of a project with options for additions, can bring investments above break-event point.[1]
- Water fees, irrespective of whether they are governed by rigid or flexible regulations, prove to

be far less decisive for the profitability of a power plant than the market price.

- New water fee regulations should be underpinned by a comprehensive view of the value of the resource of water – taking account of social, regional economic, regional policy, environmental and economic factors.

- Each new regulation in the area of water fees leads to changes in the cash flows into the financial budgets of the canton and its municipalities. A revision of the water fee regulations therefore still requires a great deal of analysis and a lot of political work in keeping with the stakeholder dialogue model. It also requires a more transparent number base. As part of an integral sustainability assessment, a socially acceptable system of profit and loss distribution that enjoys political, economic and social acceptance must be found.

Notes and References

1 National water concession legislation does not yet support this gradual investment strategy, however.

3.3. Alluvial landscapes, residual flows, bedload: environmental challenges

Water catchments, diversions and damming significantly alter the water flow in our waters. In the case of watercourses, the law requires continuous residual flows in order to reduce or even eliminate the negative impact of changed flow volumes in the rivers beneath reservoirs. Constant residual flows without certain dynamics are not sufficient to create a good balance between ecology and electricity production. Other measures are required.

Landscape

3.3.1. Constant residual flows are not enough to preserve biodiversity

Water catchments, diversions and damming significantly alter the water flow in our waters. The current Waters Protection Act (WPA)[1] requires continuously flowing residual water quantities for watercourses. These should reduce or even eliminate the negative impact of the changed flow rates in the rivers situated beneath dam walls. It is known, however, that constant residual flows without certain dynamics are not sufficient to create a good balance between ecology and electricity production.[2]

Among other things, residual water changes the composition of the community of macroinvertebrates. Macroinvertebrates are organisms that lack a spine and live in fresh water and which have a size from around 1 mm: they include insects and their larvae, amphipods, mites, snails and mussels, leeches and worms. It is widely documented that the use of hydropower can greatly impair the natural flow and bedload regime. This is primarily due to the interruption of river networks by dams and weirs, the removal of water and the resultant unnatural flow and level fluctuations. This can lead to a range of environmental and morphological deficits in river and alluvial landscapes, especially with respect to habitat availability. However, electricity producers currently focus primarily on ensuring residual flow volumes. Only few show an interest in the impact of artificial floods on the biodiversity and hydromorphology encountered beneath the reservoirs.

Questions relating to biodiversity and the preservation of morphological diversity also arise, however, in Alpine areas at around 2,000 metres above sea level, where many water catchments for reservoirs and power plants are located. Finding a balance between energy and ecology over the long term is also important here; the relationships have, however, not yet been sufficiently researched. In the Alpine region too, where around 50 % of the water's catchment area is situated, the research results reveal that the current guidelines will not ensure the preservation of the biodiversity.[3]

Notes and References

1 Waters Protection Act of 1991, as at 2017
2 Project "Aquatic ecosystem"
3 M. Doering et al., "Künstliche Hochwasser an der Saane" "Wasser, Energie, Luft" – 110th volume, 2018, issue 2, CH-5401 Baden

Landscape

3.3.2. Measures against the negative impact of residual water

Pebbles and rocks ensure hydromorphological diversity in watercourses. *Source: L. Hunziger, U. Schälchli: publication “Die erforderliche Geschiebefracht”, Flussbau AG, on behalf of the Federal Office for the Environment (FOEN)*

The projects “Sustainable floodplain management and hydropower”[1] and “Aquatic ecosystem”[2] investigated which factors need to be taken into account for residual flow management if we want to preserve the biodiversity and variety of the habitats situated in waters used for hydropower.

Both projects looked at the following questions:

- How can the impact of hydropower plants on alluvial zones and floodplains, on the areas surrounding Alpine water catchments and on residual flow stretches be assessed from a qualitative and quantitative perspective?
- How can the diversity of plants and animals be preserved in the alluvial zones of residual flow rivers?
- What is the significance of artificial flooding and bedload management?
- What do field studies reveal with respect to the consequences of water use on the river Saane, river Borgne d‘Arolla and river Maggia?
- How can the requirements of electricity production be combined with the need to preserve and maintain alluvial landscapes?
- Can alluvial zones that are no longer active be reactivated and can the original diverse fauna and flora be re-established – either in part or in full?

The research results show that the regular repetition of artificial floods – possibly with bedload replenishment – is necessary in order to keep the bedload and habitat dynamics that are important for rivers and alluvial zones going. Generally speaking, the scale, frequency, duration and timing of artificial floods should be geared towards the natural flow regime. Furthermore, artificial floods should generally be triggered during the natural flooding period.

Notes and References

1 Project "Sustainable floodplain management and hydropower"
2 Project "Aquatic ecosystem"

Landscape

3.3.3. The alluvial landscapes beneath the lake of Gruyère

Macroinvertebrates are organisms that lack a spine and live in fresh water and which have a size from around 1 mm.: they include insects and their larvae, amphipods, mites, snails and mussels, leeches and worms. *Source: image.slidesharecdn.com*

The environmental and morphological habitat characteristics of the river Saane have been extensively affected due to the residual flow management caused by the dam wall of the lake of Gruyère, the lack of natural flooding and the retention of bedload. The composition of the biological communities living there has also changed.

To quantify the habitat composition and dynamics in the residual flow stretch of the Saane, historical aerial images from between 1938 and 2013 were analysed and compared with the condition of the Sense, a natural tributary of the Saane.[1] In contrast to the Sense, the habitats typical of alluvial zones – such as open gravel flats – situated in the section of the Saane managed via residual flows, declined by 95 % between 1943 and 2013 following the construction of the Rossens dam wall. They have been replaced primarily by overgrown gravel banks and forest. At the same time, the forest conquered significantly more space (+24 %), which reduced the active alluvial zone. On top of this, the dynamics have also been greatly diminished. With respect to habitat type, around 60 % of the habitat area of the residual flow stretch has not changed in the past 70 years, while the Sense has experienced a marked habitat change.

The flood triggered on the Saane in September 2016 redynamised the system. As is usual for natural alluvial landscapes, habitats were relocated, while bedload was transported and deposited further downstream, fine sediment was discharged and the compacted riverbed was removed. The very high population density of microorganisms on the riverbed was reduced in the short term. In the area of the partially eroded additional bedload, there was an increase in hydromorphological diversity.

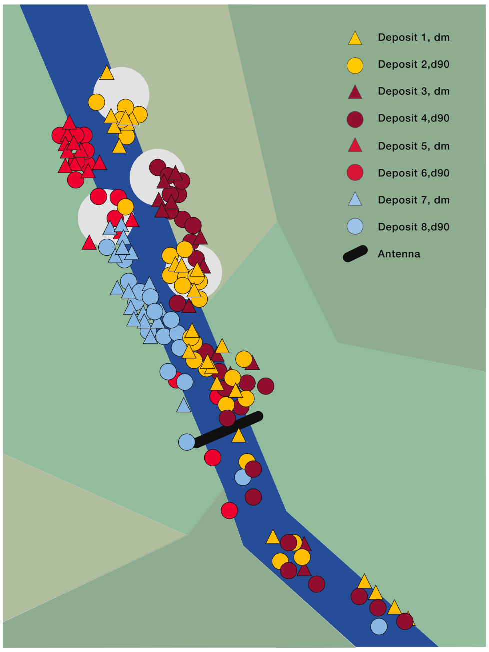
However, the artificial flood on the Saane was a one-off; the long-term and sustainable effects need to be scrutinised. This is made clear, in particular, by observing the communities of macrozoobenthos. The flood had a short-term impact, as shown by the reduction in the very high overall population density. However, the massive dominance of amphipods could not be reduced: just two months after the flood, the overall population density had increased greatly once more.

Notes and References

1 Project "Sustainable floodplain management and hydropower"

Landscape

3.3.4. Bedload balance is key for diverse habitats



The distribution of the bedload from the four replenished gravel deposits following the flood. The deposits marked in yellow and blue were eroded to an extent of around 50 %, while the red-marked deposit was hardly shifted and the purple-marked deposit was virtually completely displaced (schematic illustration). *Source: Project "Sustainable floodplain management and hydropower"*

Bedload is the building material of rivers with which the water forms characteristic structures and thus diverse habitats. Gravel deposited on the riverbed is used by certain fish as a spawning substrate, the fringes of gravel banks provide habitats for young fish, while the gravel banks themselves provide habitats for birds, spiders and other small organisms. In rivers with inadequate bedload dynamics, the riverbed becomes compressed and is no long suitable as a spawning substrate; floods can no longer sufficiently flush out the pore space blocked with fine sediment and the supply of oxygen declines; gravel banks that are periodically relocated by water silt up and lose their typical morphology.

Artificial floods and measures aimed at managing bedload transport in a manner that should reproduce the natural conditions to the greatest extent possible are therefore increasingly coming under the spotlight, including at the Federal Office for the Environment (FOEN).[1 2 3]

An example of a possible restoration was the Saane flood in September 2016.[4 5] The gravel deposits created at various points in the river prior to the flood were swept along and led to erosion and the transportation of artificially introduced bedload. The configuration with the four areas of bedload replenishment as alternating banks led to an increase in the habitat diversity in a section of around 400 metres. The material eroded from the additional bedload was deposited in clusters and was not dispersed across the entire river. This leads to a greater increase in habitat diversity than is the case when the material is added to the river in the form of a single bedload replenishment site on the riverbank or as an island. The transport of the bedload and its positive impact on habitat diversity were, however, limited to a local level due to the one-time flood that was somewhat too small in scale.

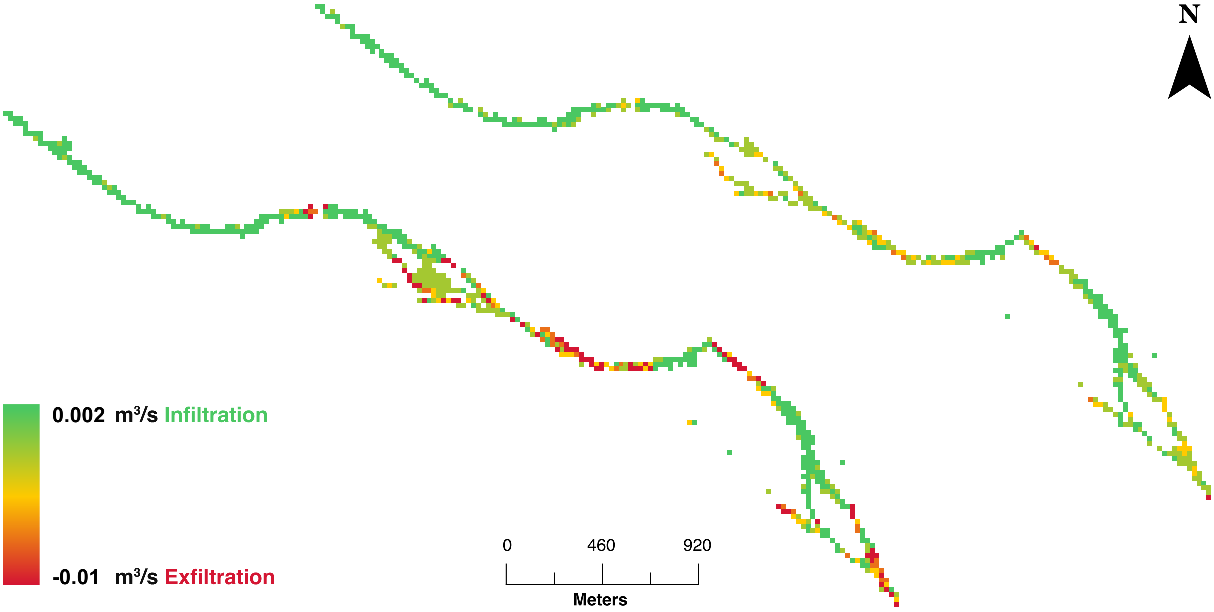
The results underline the fact that the regular repetition of such floods with bedload replenishment is necessary in order to keep the bedload and habitat dynamics that are important for rivers and alluvial zones going.

Notes and References

1 “Geschiebehaushalt – Massnahmen”, version for the consultation, 8 November 2018, Federal Office for the Environment (FOEN)
2 “Künstliche Hochwasser – Auslegeordnung, Grundlagen und Handlungsbedarf”, PRONAT Umweltingenieure AG and BG Ingenieure und Berater AG, 10 November 2016, on behalf of the SFOE
3 “Die erforderliche Geschiebefracht”, Flussbau AG, 5 November 2018, on behalf of the SFOE
4 Project “Sustainable floodplain management and hydropower”
5 M. Doering et al., “Künstliche Hochwasser an der Saane” “Wasser, Energie, Luft” – 110th volume, 2018, issue 2, CH-5401 Baden

Landscape

3.3.5. The interaction of rivers and groundwater using the example of the Maggia



Simulation of the interaction between groundwater and flowing water along the Maggia before (left) and after the construction of dams. Prior to the regulation of the Maggia and its tributaries, the modelling of a section of the river, based on historical flow rate data, shows significantly more locations at which groundwater seeps out into the riverbed (exfiltration) than is the case afterwards (right). The groundwater level has fallen and thus also hinders the take-up of water by riverbank vegetation. *Source: Project "Aquatic ecosystem"*

In order to better understand the mutual influence of flowing water and groundwater, the dynamics between the river and the groundwater on the Maggia floodplain as well as their impact on the variety of morphology and habitat dynamics was investigated.[1] The aim was to understand how the water and groundwater systems respond to different residual water strategies. The Maggia is a typical example of a river for which the majority of the water is diverted into reservoirs at various points. It is thus well suited for investigating the impact on the flow and the ecology.

To this end, the researchers further developed a simulation model for the interaction between surface water and groundwater in a manner that made it applicable to complex gravelly floodplains. Here, they investigated the exchanges between the flowing water and the groundwater – doing so for both the years prior to the construction of the dams and the years that have followed.

The investigations showed that constant residual flows cannot restore the diversity of habitats and creatures to their previous natural state before the expansion of hydropower owing to average flow volumes and occasional flooding. One reason for this is the much lower groundwater level. The earlier natural water flow, which was very varied, with occasional dry periods had led to an interplay with the groundwater. River water seeped into the ground, while groundwater was drawn out during dry periods – all of these processes created biological and morphological diversity that cannot be replicated by a constant residual flow.

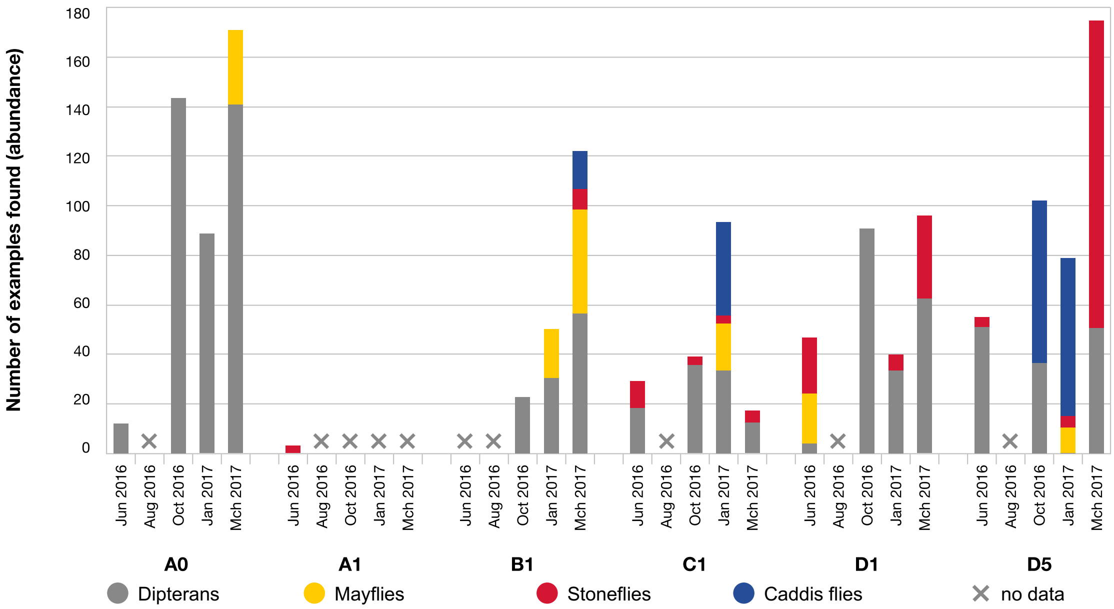
Simulations of an increased, constant residual flow volume revealed that the biological and morphological diversity no longer reaches its past, natural level. While the groundwater level would rise again, a natural situation can only be achieved through bigger floods and greater temporal and spatial variability in the water flow.

Notes and References

1 Project "Aquatic ecosystem"

Landscape

3.3.6. Bedload control above Alpine water catchments more important than residual water?



Due to daily bedload flushing in Alpine water catchments, microorganisms – illustrated here in various colours – are swept along, meaning that in the Borgne d'Arolla there is a "summer in winter". As the amount of flushing falls in autumn, macroinvertebrates immigrate from tributaries and revitalise the Borgne d'Arolla. A0, A1 etc. are different measurement points. *Source: C. Gabbud, Bull. Murichienne 135/2017 (2018): 39–53*

The project "Aquatic ecosystem"[1] investigated the river Borgne d'Arolla in the canton of Valais to discover how the removal of water and bedload management have an impact on the biodiversity and morphology of the streams situated below the water catchments.

During the summer when melt water transports a high volume of bedload and the water catchments have to be flushed out on a daily basis or even several times a day, there is almost no life left in the Borgne d'Arolla; the cold glacial water and the large quantities of bedload sweep along the microorganisms. This is shown by quantitative measurements at various points along the Borgne d'Arolla. In this residual flow stretch, summer occurs in winter. On the other hand, as soon as the melt water decreases in autumn, the stocks of macroinvertebrates recover thanks to immigration from tributaries without water catchments. The existence of small organisms therefore is greatly dependent on the frequency with which the bedload transported by the glacial water is washed out.

On this basis, the researchers tentatively conclude that the provisions of the Waters Protection Act for residual flow stretches are possibly unsuitable for maintaining as near-to-natural conditions as possible beneath Alpine water catchments. On the contrary, bedload control could be more important here than the residual flow rates. The constant flow of cold residual flows together with frequent bedload flushing creates very unfavourable conditions for the life in the water. According to the researchers, bedload control above the water catchments and the abandonment of constant residual flow rates would be better. This is because below the water catchments the inflow of much less cold groundwater ensures the necessary discharge and nutrients – and thus improved conditions for small organisms.

However, current knowledge about the impact of bedload flushing in water catchments remains very limited – as the researchers put on record in interpreting their results just as the Federal Council did recently in an answer to a postulate.[2]

Notes and References

1 Project "Aquatic ecosystem"
2 https://www.parlament.ch/de/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20193298

Landscape

3.3.7. Development and simulation of environmentally relevant indicators

Rocks that protrude out of the water ensure a good gas exchange – and create a preferred zone for fish. *Source: T. Kaiser collection 2019*

As part of the project "Sustainable floodplain management and hydropower"[1], a hydromorphological index of diversity (HMID) was developed. This permits the alluvial landscapes to be described in quantitative terms and for changes due to floods to be measured. The index deals with water dynamics and the transportation of sediment. It is based on the simplified assumption that an anthropogenic impairment of watercourses generally leads to a decline in biodiversity.

For greatly impaired river sections with less morphological variety, the HMID value stands at under five. Values of between five and nine indicate limited variability, while natural reference rivers with significant sediment dynamics and varied morphological habitats have figures of above nine.

The artificially triggered flood in the residual flow section of the Saane in September 2016 allowed for the HMID to be verified. Prior to the flood, the modelled and experimentally confirmed HMID value of the section stood at between eight and nine[2], which corresponds to a river section with limited morphological variability that can almost be designated as natural. Following the flood, the HMID value in the areas with new sediment deposition was a third higher than prior to the artificial flood. The microbiological diversity, however, was much lower than in the natural section of the Sense – there are no dams in the river's upper reaches.

One part of the project "Aquatic ecosystem"[3] investigated how rocks of up to one metre in diameter situated on a riverbed have an impact on the quality of fish habitats under different residual flow regimes. In a simulated model, it was shown that these obstacles are significant for fish if they are only partly and not fully submerged by the water. This is because large rocks that the water flows around create preferred zones for fish and ensure a good exchange of gas with the air thanks to the turbulence they cause. Rocks that are fully submerged in water cannot fulfil this function.

Notes and References

1 Project "Sustainable floodplain management and hydropower"
2 S. Stähly, P. Bourqui, C.T.Robinson, A.J. Schleiss, "Numerische Modellierung zur Bestimmung der Habitatvielfalt an einem mäandrierenden wasserkraftbeeinträchtigten Fliessgewässer", in Peter Rutschmann (ed.), Proceedings of the 18th Hydraulic Engineering Symposium, Obernach, Germany, TUM: TUM, 720-728
3 Project "Aquatic ecosystem"

Landscape

3.3.8. Alluvial landscapes, residual flows, bedload: conclusion

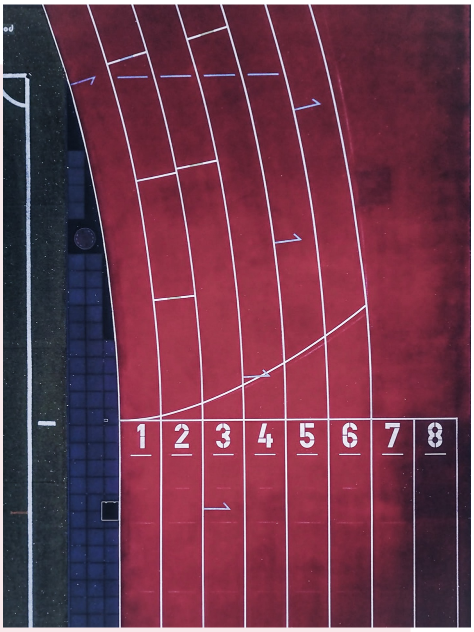
- The requirements for residual flow and bedload management in regulated waters stipulated in the current Waters Protection Act are inadequate for preserving as near-to-natural conditions as possible in residual flow stretches if only implemented to a moderate extent – this is because despite the implementation of the measures aimed at river protection, the dynamics that were caused by the past natural fluctuations and which gave rise to considerable biodiversity are largely lost in regulated waters.
- The research results show that artificial floods and the addition of bedload with dynamic changes between flood and low-flow conditions as well as between wet and dry periods that replicate nature to the greatest extent possible are required if the original biodiversity is to be preserved.
- The groundwater level, which is also key for the maintenance of near-natural biological conditions in rivers, also falls in regulated waters. The interaction between groundwater and flowing water (the infiltration of flowing water into the groundwater and the exfiltration of groundwater into the flowing water), which is important for ensuring an ecosystem in floodplains that is as close to natural as possible, is being lost.
- For Alpine water catchments, on the other hand, it is primarily bedload flushing, which takes place several times a day, that destroys the natural condition of the river despite dynamic residual flows. During the summer, they lead to lifeless rivers beneath the catchments; life first returns in autumn and winter as microorganisms immigrate once more from tributaries. The summer becomes winter and vice versa. Here, on the basis of their preliminary results,

the researchers propose a more detailed investigation of management above water catchments as a more suitable measure.

The research results show the conflict that exists with the requirement of expanding hydropower in Switzerland. The objectives of environmental and water protection and the goals of Energy Strategy 2050 must be carefully weighed up against each another.

4. Eight recommendations to various stakeholder groups

The issue of hydropower and market affects a wide range of stakeholder groups. These include energy providers, power plants owners, regulators, representatives of interest groups and service providers.



The recommendations are aimed at those stakeholder groups that have a direct influence on the future of hydropower or aspects of the electricity market. In particular, these include the following:

- Energy suppliers – energy supply companies; power plant owners
- Politicians – federal government, cantons, municipalities
- Stakeholders – associations and NGOs;

Recommendations have exclusively been formulated that can be derived from the research work conducted in the NRP "Energy" and that are also relevant to the transformation of our energy system.

Energy storage # Energy provision # Energy suppliers

4.1. Examine potential for new reservoirs in periglacial zones!

In the areas surrounding retreating glaciers, lakes are forming at the end of the glaciers that offer potential for reservoirs and new hydropower plants. There is, however, a significant conflict of objectives between the use of hydropower, on the one hand, and the protection of nature and landscapes, on the other. This conflict must be resolved politically by weighing up all advantages and disadvantages.

According to estimates, reservoirs situated beneath retreating glaciers could increase electricity production in Switzerland by around 3 %. Approximately half of these could contribute to seasonal storage and thus to electricity production during the winter. This was the finding of a study conducted by ETH Zurich, which identified the seven locations best suited for the establishment of new reservoirs from those sites that are generally considered for this purpose. Their theoretical storage capacity stands at 1.3 TWh, which equates to 14 % of the storage capacity offered by existing reservoirs.

With the exception of the Trift Glacier, however, all of these locations are situated in protected areas. Without a change to the current protection provisions, the Federal Office for the Environment therefore only views the Trift Glacier as representing a realistic legal opportunity for a new reservoir. The Gorner Glacier also offers certain potential as it only has national protection. As part of the UNESCO World Heritage Site, the Grindelwald Glacier would not be a realistic option, while the other glaciers enjoy precautionary protection under Art. 12(2) of the Alluvial Zones Ordinance. Politicians therefore need to find a compromise between ensuring supply security and the protection of the environment and landscapes that is suitable for Switzerland and, where necessary, create the basis for utilising part of this potential.

At the Trift Glacier in the Bernese Oberland, a proglacial lake situated at the end of the glacier has already formed. It is located on terrain where a dam wall could be built with relatively little effort.

Investment # Financing # Europe / EU # Energy provision # Energy suppliers

4.2. Make systematic use of the few remaining options for increasing profitability!

The current relatively low market prices for electricity mean that it is necessary to make systematic use of the few options available for optimising power plant operations. These include the reduction of turbine maintenance costs, the staggering of major investments and greater participation in the balancing market.

In the absence of an electricity agreement with the EU, Switzerland's options for participating in European electricity trading will remain limited. Participating in the "Swiss intra-day market" is a possibility but it is less liquid and less volatile than the German market. With greater participation in the balancing market, however, additional income can be realised even if this potential is declining due to an increasing number of participants.

To make investments profitable once more, researchers recommend the so-called "real option method". This is based on a time-staggered process. Alongside short-term investments, it also earmarks future options that are not yet profitable and incorporates these in the planning. The optional investments are deferred. To this end, however, the approval and concession process would have to be adjusted. This is because it currently requires a plant to be clearly described and also realised within a certain period of time.

Water from reservoirs always carries sand and other sediments with it. These loose materials block pressure pipes, turbines and guide apparatus if they make their way into the intake water channel. With a correctly dimensioned desanding system – a special sedimentation tank – the sediments can be removed. With correctly dimensioned sedimentation tanks, the researchers estimate that maintenance costs could be reduced by around CHF 6 million per year.

Sustainability # Investment # Energy provision # Public administration # Energy suppliers # Politics (federal government, canton, municipality)

4.3. Conduct stakeholder dialogue on the basis of an integrated sustainability assessment for new projects!

Projects in the electricity sector can be structured in an optimal way according to environmental, economic, regional policy and regional economic criteria through joint planning – involving an integrated sustainability assessment with stakeholder dialogue – and gain acceptance.

Projects in connection with the construction or renovation of power plants are prepared together with all stakeholder groups as part of a joint planning process and the groups' respective interests are weighed up against one another. The individual criteria are assessed by experts, while the stakeholders develop the "trade-offs".

As power plants in Switzerland are usually owned by the public sector, the researchers believe that it is justified not only to assess the use of hydropower on the basis of purely economic factors, but also according to macroeconomic, social, political and environmental aspects. Important prerequisites for this include mutual trust and the greatest possible transparency with respect to all data, including financial details.

Guidance # Energy provision # Energy suppliers # Politics (federal government, canton, municipality)

4.4. Base water fees on earnings!

The water fee regulations due for 2024 should be based on the produced volume of electricity and the market price rather than gross capacity. Regional policy and regional economic aspects should also be taken into account and a fair distribution of risk should be targeted. To this end, complete transparency with respect to earnings figures is required.

Water fees are a remuneration paid by electricity producers to the mountain cantons and municipalities for the use of their water resources. In 2015, they totalled around CHF 560 million. In the canton of Uri, water fees account for approximately 25 % of cantonal income. In individual municipalities of the canton of Graubünden, they can make up more than 50 % of municipal income.

Flexible and earnings-based water fees are now deemed to be more in line with the market than fixed maximum values that are solely dependent on capacity, i.e. not on the actual value of the electricity produced. However, flexible water fees increase the risk faced by the resource owners and reduce that of the power plant operators. For the latter, the level of the water fee is an important cost component at market prices of CHF 40 to CHF 60 per MWh that are close to the production costs. Market dynamics can easily lead to prices above or below this range.

Flexible, earnings-based water fees should therefore be introduced that are structured according to the principles of revenue sharing between the resource owners, i.e. the municipalities, and the power plant operators. To this end, complete transparency with respect to earnings figures is required. The new regulations should, however, not only take account of purely economic aspects, but rather also incorporate regional policy and regional economic factors and ensure an overall view is adopted.

Landscape # Energy provision # Energy suppliers # Politics (federal government, canton, municipality)

4.5. Restore and maintain biodiversity beneath dams!

Source: Bild: wsl: Sensegraben (BE/FR) aus www.waldwissen.net/wald/naturschutz/gewaesser/wsl_auen_schweiz/index_DE Foto: M. Roggo)

The imbalance between environmental protection and water needs to be corrected: residual flow management must become more dynamic. Where there is a lack of natural flooding, artificial floods are required on a regular basis.

The Waters Protection Act of 1992 provides the cantons with certain discretionary powers in assessing economic interests and applying exceptions. According to the research results, however, the only moderate implementation of the residual flow regulations in rivers situated beneath dams does not suffice for the re-establishment and preservation of biodiversity in regulated waters. The maintenance of natural discharge dynamics as well as occasional, natural or artificially triggered floods and appropriate bedload management are prerequisites for the preservation of biodiversity. In principle, the Waters Protection Act allows the cantons and the Federal Council to enforce environmentally friendly solutions – for example, by providing zones which compensate for these changes.

Landscape # Energy provision # Energy suppliers # Politics (federal government, canton, municipality)

4.6. Restore and preserve water catchment biodiversity!

In the Alpine area, where primarily cold glacial water is captured and fed into the reservoirs, microorganisms are faced with different conditions to those in lower altitudes. According to the initial research results, regular bedload flushing, which sometimes can take place several times a day, can damage habitats beneath the water catchments. The research on this subject should be continued in order to clarify how the residual flow regulations for Alpine water catchments can be improved with a view to protecting biodiversity.

Beneath the Alpine water catchments, the life present in watercourses can be eradicated by bedload flushing – this is shown by the initial research results at the Borgne d’Arolla. Bedload clusters destroy the river’s natural morphology and the cold melt water that comes as part of the flushing process can wash away small organisms – “the summer becomes winter”. Bedload management above the water catchments, possibly without residual flows, appears an appropriate measure for preventing this.

Sustainability # Energy provision # Associations and NGOs # Energy suppliers # Politics (federal government, canton, municipality)

4.7. Acknowledge new research findings and take them into account for strategies and measures

All stakeholders should incorporate the research results in their work – whether this relates to the new technical potential for reservoirs in periglacial zones, the insufficient impact of moderately implemented residual flow provisions or water fees as a source of income.

Numerous decisions relating to the expansion of hydropower expected in Energy Strategy 2050 will necessitate trade-offs and a certain willingness to compromise by the different stakeholder groups. Those representing the protection of nature and landscapes as well as water conservation believe that a further expansion will endanger the environment: Energy Strategy 2050, on the other hand, anticipates that an expansion will partially compensate for the loss of electricity generated at nuclear power plants.

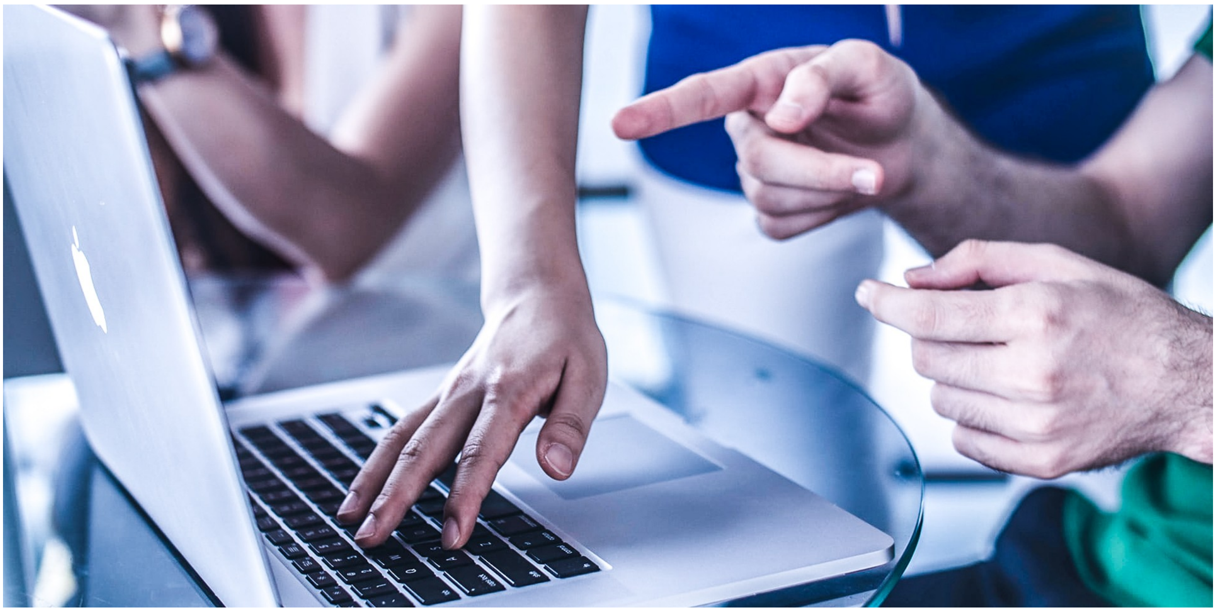
Power plant operators argue in favour of the moderate implementation of residual flow provisions, while researchers conclude that with constant or even proportional residual flows the near-natural conditions of alluvial landscapes and residual flow stretches cannot be maintained or restored. This is especially the case if the conditions that exist at the time of the submission of applications for the renewal of concessions are made decisive for determining the “initial state”. Compensation areas could serve as a means of partial compensation.

Both legal reasons – the location of plants in protected areas – and economic factors often speak against the expansion of hydropower through the heightening of dam walls or in areas with retreating glaciers. Without utilising this potential, it will be difficult to achieve the objectives of Energy Strategy 2050.

Economic and environmental arguments alone will also not do justice with respect to the new water fee regulations from 2024. To ensure a holistic view, regional policy and regional economic aspects must also be assessed.

Sustainability # Landscape # Energy suppliers # Businesses

4.8. Apply new quantitative criteria for residual flow stretches and new design rules for desanders!



The quality of residual flow stretches and alluvial landscapes as a habitat with morphological and biological diversity can be quantified and thus better assessed. The desanding systems at reservoirs can be made more effective with new dimensioning tools.

Simulation and modelling methods developed as part of the NRP Energy can increase understanding for the impact of water protection measures. The habitat quality in residual flow stretches can be measured quantitatively and described. The interaction between groundwater and flowing water can be modelled; the understanding of its impact on the flora in alluvial landscapes and in riverbank zones is improving all the time. However, research results also relate to operational optimisations that can be achieved through a better understanding of sediment flows, bedload management and design rules for desanding systems.

The results must be incorporated in the work of engineering and consulting firms – for example, during the characterisation of the habitat structure of residual flow stretches and for the preservation of conditions that are as near to natural as possible. The success of renaturation projects can therefore be better assessed and the desanding systems can be dimensioned more effectively.