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The Future of Swiss Hydropower Realities, Options and Open Questions

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The Future of Swiss Hydropower
Realities, Options and Open Questions

Final Project Report, March 2019

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The NRP70 project 'The Future of Swiss Hydropower: An Integrated Economic Assessment of Chances, Threats and Solutions' (HP Future) addresses the challenges Swiss Hydropower faces in the changing electricity market environment. In particular it aims to answer four main research questions:

1. What are ***short-term operational*** options for Swiss HP to cope with the volatile market situation?
2. What are ***long-term investment*** options for Swiss HP and how can ***uncertainty*** be accounted?
3. What are the ***regional impacts*** from a comprehensive ***sustainability perspective***?
4. What are the ***effects*** of different ***water fee*** reform options?

The project started in fall 2014 and lasted until December 2018. This final report provides a summary on the main findings and recommendations for decision makers.

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Executive Summary

The NRP70 project 'The Future of Swiss Hydropower: An Integrated Economic Assessment of Chances, Threats and Solutions' (HP Future) has been initiated in 2014 with the objective to identify options for Swiss hydropower (HP) to adopt to the ongoing and expected electricity system changes. The project has been finalized in 2018 and this final report provides an overview of the obtained results and insights. Following a short summary of the main findings is provided.

Troublesome years

The decline of wholesale electricity prices in the last years has initiated a cascade of effects within the Swiss energy landscape: companies' books were in the red and concepts for selling HP assets were issued, calls for subsidies emerged with the Confederation granting support for vulnerable HP installations for the next five years, water fee reduction and adjustments were put on the agenda, and overall the envisioned role of Swiss HP for the Energy Strategy 2050 was questioned. Even though the discussion has slowed down a bit, the 'crisis' highlighted the main challenges Swiss HP needs to address: *market and political, legal and social aspects.* The importance of those drivers has also been identified by Swiss HP stakeholders in a project workshop conducted in 2015 and the relation between market challenges and the Swiss regulatory and policy framework forms the basis of our assessment.

It's the markets, stupid!

The Central European market development is the single most important driver for Swiss HP profitability. Albeit HP flexibility is seen as a valuable asset and allows diverse trading strategies, our assessment shows a limited payoff in today's markets. Additional revenue potential from optimized trading across multiple markets is likely in a range of 10% to 25%. This in turn can be expected to be insufficient if prices remain below 40CHF/MWh for prolonged periods but could be crucial for cost recovery in the 40 to 60CHF/MWh range. Given that the future market development is uncertain and low price trajectories cannot be ruled out, the development of global fuel prices and of the European Emission Trading System are of central importance for Swiss HP. As influencing those market dynamics is out of reach for Swiss decision makers, companies need to prepare for such developments!

Uncertainty will be certain

In the long run the uncertainty of general market developments dominates investment decisions. Due to the long lifetime, high capital costs and long construction phase, HP investments usually require a long payback period. The high operational flexibility of HP does not necessarily compensate for its lack of managerial flexibility in an environment that is characterized by easily scale-able and faster installed renewable capacities. In the coming decades new technologies are likely to increase the competitive pressure even further. As breakthrough innovation in HP is unlikely, companies need to focus on increasing the flexibility of their investment project plans. One strategy could be that investors carry out small installations first and keep open options to increase the scale later on; in other words they should "start small and think large”. This represents an effective approach to deal with uncertainty, as it eases the adaptation process to a changing environment and could also provide an approach to achieve the envisioned increase of HP generation even in uncertain market conditions.

Its more than just energy

HP investments and operations cause impacts (externalities or distributional effects) in a multitude of domains and the different involved stakeholders need to find a compromise between companies’ profit perspectives, federal energy targets, cantonal and municipal budget requirements, regional development goals, as well as national and international regulations. To this regard a comprehensive sustainability assessment is needed, as it provides a structured frame for the evaluation of HP projects and can raise the awareness of stakeholders regarding the manifold facets of HP . This approach allows taking the full value chain of HP into account and deriving the “social net present value” of projects; in other words, potentially enabling projects to obtain positive indications even in uncertain electricity market environments. This approach can also become relevant under favorable market conditions to enhance the acceptability of HP projects.

To fee or not to fee?

Water fees have taken a center stage in the discussion on Swiss HP in recent years. The main challenge is aligning the different interests of the paying companies and receiving cantons and municipalities. Our assessment of net profits under different potential market developments and water fee systems shows that the market dimension dominates the water fee impact. The fee design is mostly relevant for a subset of firms and within a specific electricity market price range of around 40 to 60 CHF/MWh in which the impact of the fee can make a difference between profit and loss as well as investment and no investment. The revenues generated by the fees and the differences caused by different designs are important for cantons and municipalities and can cause indirect feedback effects that complicate a general assessment of winners, losers and potential for trade-offs.

Leftovers for 2024

With the water fee adjustment postponed until 2024, resolving the conflict between paying and receiving parties will be the central element calling for a stakeholder process to bridge the real and perceived gaps and find a compromise all sides can agree upon. Similar the upcoming concession renewal calls for adjustments to handle the market uncertainty and enable HP companies to compete with other energy and storage providers. Finally, the role of potential new market components and the impact of a full liberalization need to be considered, linked to the above challenges and fed into the stakeholder process. Five years seems like a lot of time to address those points but the experience from the last five years should have illustrated that actual change requires a clear and target oriented approach to succeed.

1 Introduction

Swiss Hydropower (HP) is not only the cornerstone of the Swiss electricity supply, but with over 1'000 stations of various size all over Switzerland, HP can also be seen as a form of Swiss 'heritage' that factors into and has influence on many regional economic decisions (Gaudard, Romerio and Voegeli, 2016). The more than 17GW of installed capacity and ca. 36TWh in annual generation output have a market value of several billion CHF each year. Swiss HP is also a crucial component in attaining the intended Energy Strategy 2050 targets. It is seen as a perfect complement to accommodate the large shares of new renewable generation, and – as Switzerland is highly interconnected to the European electricity network – often envisioned as a battery for neighboring countries.

Despite those seemingly positive aspects, Swiss HP has experienced a crisis since 2011 due to the electricity wholesale price drop on the European markets: prominent companies' books were in the red, calls for subsidies emerged with the Confederation granting support for the most vulnerable HP installations, water fee reduction and adjustments were put on the agenda, and finally the outlook for new pumped-storage facilities planned in the Nineties was also jeopardized by the narrowing of the gap between peak and off-peak prices.

As the wholesale prices are on the rise again – mostly thanks to a change in Europe's emission trading system leading to a price jump for emission allowances – the discussion has slowed down a bit, but a lot of the fundamental challenges are still unresolved. However, with the prolonged time window for an adjustment of the water fee framework until 2024 a deadline is set until when a restructuring of the Swiss HP framework should be achieved. The crisis also highlighted the dependence of the Swiss Energy Strategy 2050 targets on external effects as the projected increase in hydro production (which includes the need for retrofitting older plants) relies on revenue prospects.

Against this backdrop, the NRP70 project 'The Future of Swiss Hydropower: An Integrated Economic Assessment of Chances, Threats and Solutions' (HP Future) has been initiated in 2014 with the objective to identify options for Swiss HP to adopt to the ongoing and expected changes in the Swiss and European electricity system. The focus of the project was along three lines: first, operational strategies to optimize revenue streams utilizing the flexibility of HP; second, investment strategies to cope the increased uncertainty in todays and future electricity markets; and third, an assessment of regional impacts of Swiss HP from a comprehensive sustainability perspective. With the increasing debate on the role of water fees and potential adjustments of the underlying mechanism the project has been extended to include a fourth topic cluster on the effects of different water fee reform options.

The project has been finalized in 2018. This final report aims to provide an overview of the obtained results and insights with respect to the four topics. Moreover, it derives conclusions and recommendations for company strategies as well as policy and regulatory adjustments. Finally, it closes with an outlook for open points and needed next steps to obtain a sustainable and stable framework for Swiss HP until 2024.

2 Drivers, Uncertainties and Challenges for Swiss HP

To identify the challenges that Swiss HP faces in its current and future environment, we conducted a comprehensive review on drivers and uncertainties (see Barry et al. 2015 for details) and challenged our insights by carrying out a questionnaire and a workshop in March 2015 with Swiss HP stakeholders. To this end, we clustered the different drivers into five general domains:

(1) *Natural factors* representing boundary conditions of the hydrologic system,

(2) *Technical factors* representing engineering aspects,

(3) *Political, legal and social aspects* that relate to the regulatory features influencing Swiss HP,

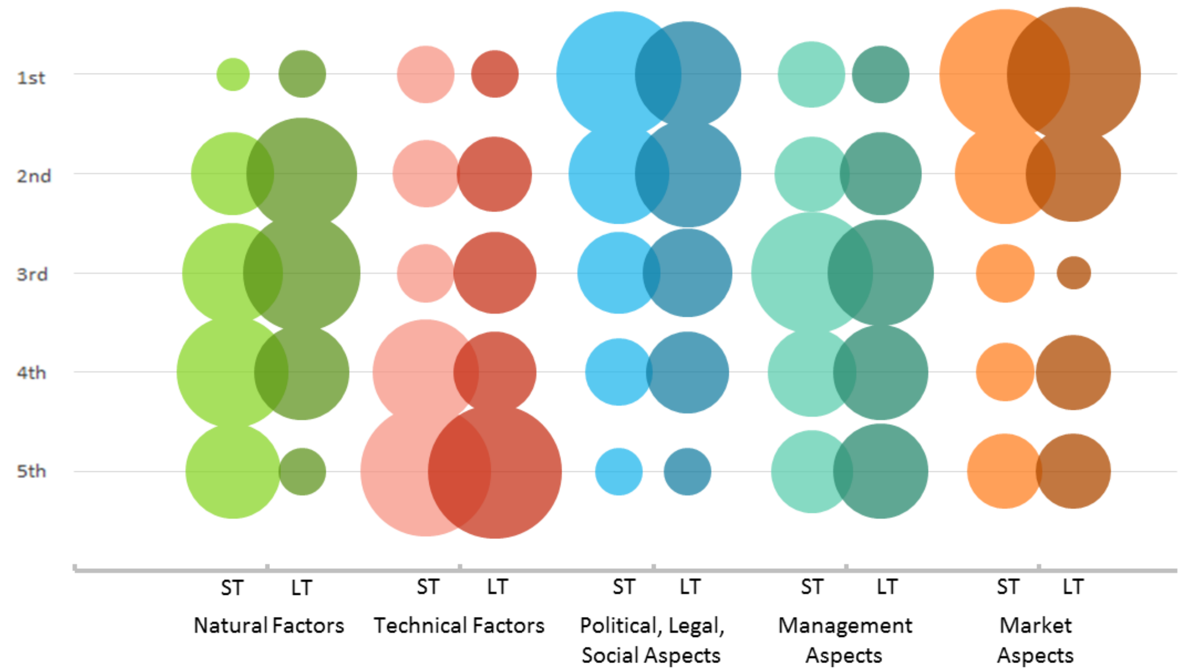
(4) *Management aspects* representing the active decision-making within a company, and

(5) *Market aspects* capturing revenue opportunities and the various market influences

Regarding the importance of those drivers we differentiated short and long term perspectives. The feedback from stakeholders showed that all factors are perceived as being generally important, but with a clear ordering (see Figure 1).

First, *market aspects* along with *political, legal and social aspects* are considered by key stakeholders and experts to be the most important issues, both in the short and the long term – even though there are slight shifts in evaluation between these time periods. Second, management aspects are considered important at least in the short term. Finally, while natural factors, especially related to climate change, are perceived as important drivers in the long term, technical factors are not perceived as challenge in the current environment. Nevertheless, they are seen as an important part of the solution process, especially by increasing operational flexibility.

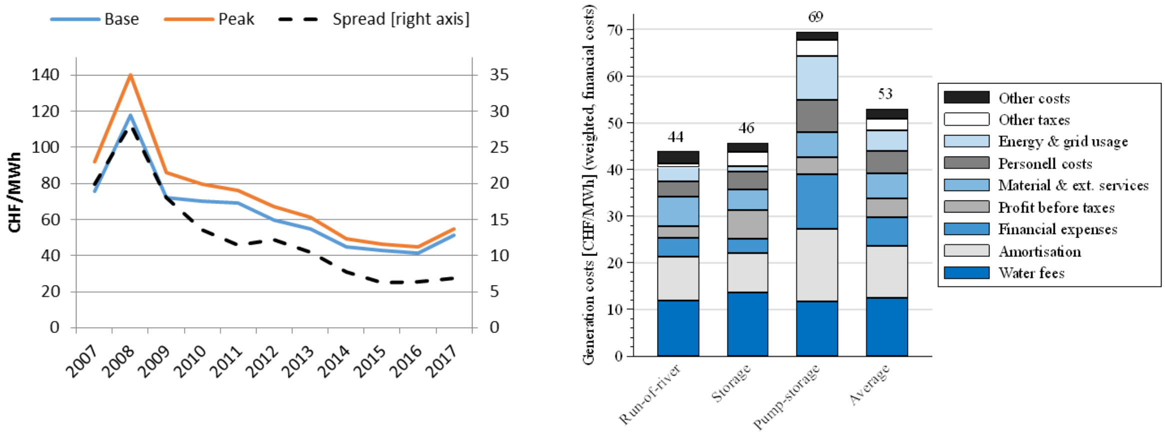
Figure 1: Comparative Ranking of Drivers in the Short (ST) and Long Term (LT)



Note: Taken from Barry et al. (2015). The size of the circles represents the relative number of answers from stakeholders involved in the research

The review and the results of the questionnaire match the discussion points of the last years: market and revenue developments due to the decreasing wholesale prices (Figure 2, left panel) and the increasing mismatch between revenue and long-term costs (Figure 2, right panel) lead to depreciations in the accounts of several large HP companies. The legal requirement to review the water fee levels in 2019 lead to a debate between the different stakeholder groups how to adjustment the water fee framework with respected input from different groups (e.g. see SCCER CREST White Paper on Hydropower; CREST, 2016) or the revenue study from the Governmental Conference of the Alpine Cantons (Frauendorfer and Schürle, 2017)). The process finally led to an extension of the current scheme with a new adjustment deadline until 2024. Meanwhile a support scheme for large scale HP from 2018 to 2022 has been initiated, financed by a network charge of 0.2 Rp./kWh by end consumers and providing about 100 mn CHF per year. For 2018 about 37% of Swiss HP generation has benefited from the support measure (BFE, 2018).

Figure 2: Price development Swiss wholesale market and average costs



Note: Prices based on EPEX Spot, the price spread represents the difference between the average peak (8am-8pm) and off-peak (8pm-8am) prices; cost estimates from Betz et al. (2018) based on a sample of 60 HP companies for the years 2015/2016. Generation costs are weighted according to the electricity generation of the plants in the years 2015 and 2016.

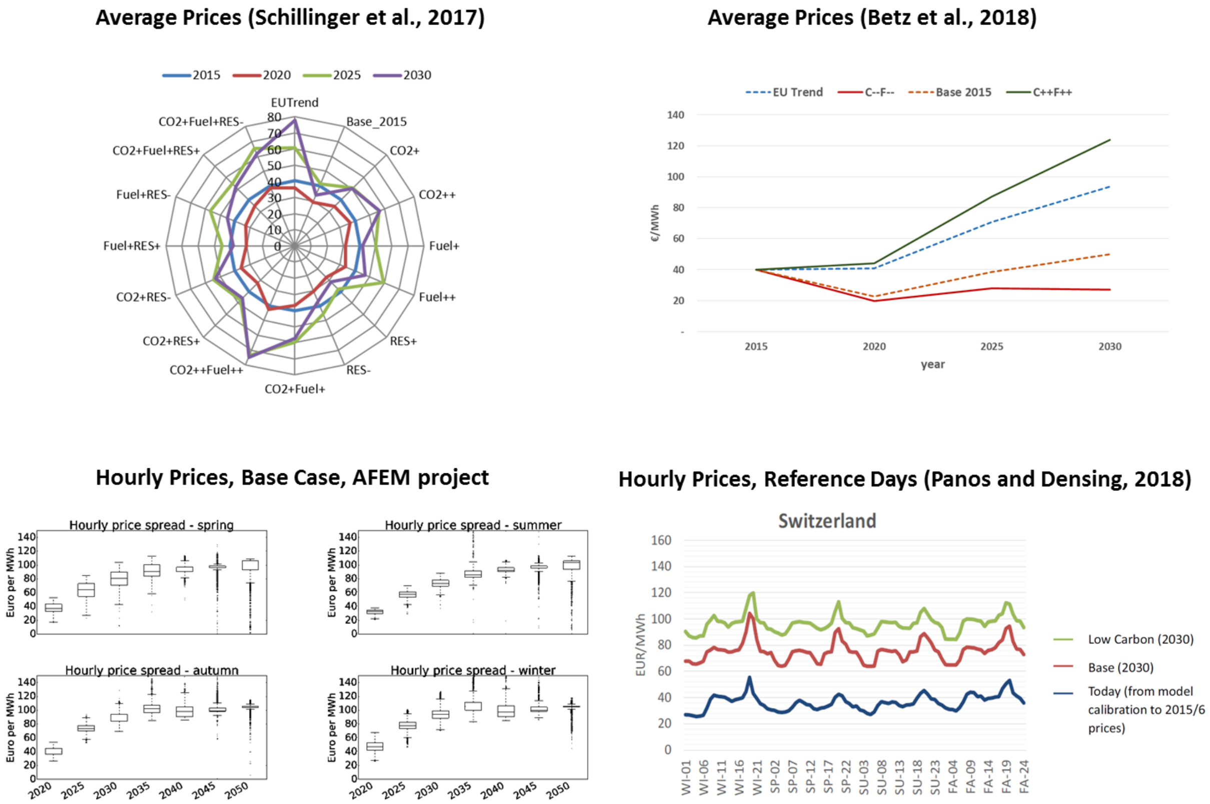
The dominance of market and policy aspects within the HP debate does not mean that technical and environmental aspects are negligible. But given the maturity there are no expectations on significant technology breakthroughs. There is a large research focus on the role of climate change on HP (e.g. see Hydro-CH2018), the environmental aspects of HP (e.g. at the EAWAG), and improvements on robustness and flexibility of hydro assets (see also SCCER SoE).

3 Coping with Market Realities

Regarding the market challenges, the general consensus is that neither Swiss energy companies nor Swiss energy policy has much influence on the underlying drivers like fuel and carbon prices or system developments in neighboring countries. Naturally, the companies need to adopt as far as possible to the new circumstances by improving their performance, reducing costs, and potentially adjusting their financial management to account for the higher risk. An important issue in the whole discussion is the relationship between Switzerland and the European Union. While the European market developments are the main drivers of those market aspects that condition the future of Swiss HP, the continuing uncertainty about the integration of the Swiss electricity market in the ongoing process of European market coupling adds to the complexity of the issue. In addition, the stakeholders consider the differences in HP-specific regulations between Switzerland and European countries to be very important.

The main driver for Swiss HP profitability will be the general price level in Central Europe. This is subject to uncertainty on fuel and emission prices, further renewable support structures, network coordination and extension, and potential additional market components like capacity mechanisms. Naturally, the potential range of price expectations varies strongly depending on the underlying assumptions (see Figure 3 for a selection of price scenario studies for Switzerland)

Figure 3: Price Scenarios for Switzerland



Note: The selection of different price scenarios is not meant to represent all possible cases or exiting simulations but showcases the range of potential market developments and the embedded uncertainty in future market conditions. Details on the NRP 70 project Assessing Future Electricity Markets (AFEM) can be found here.

While there is the general perception that the price level in the long run will need to increase – on the one hand due to the proposed European climate targets that call for an increasing price tag for emissions and on the other hand due to the need for market prices to enable refinancing of investments[1] – the dynamic of the future price pathway and the potential and duration of lower price periods is highly uncertain.[2] Price levels beyond 70 to 80€/MWh will provide ample earnings for the majority of the existing Swiss HP stations whereas prices below 40€/MWh pose significant challenges (especially coupled with a strong Swiss Franc). Particularly in the range 40-70 €/MWh optimized trading strategies can play an important role to make the difference between loss or profit. Whether and how such optimized trading provides benefits was subject to the first project work package and the findings are presented in Section 3.1.

The price levels and uncertainties also pose a significant challenge for investment decisions; both new sites and retrofitting/upgrading investments. While existing stations may cope with longer times of low prices, new investment projects call for a sufficiently high price expectation to be projected and realized. Given the desired increase in Swiss HP production for the Energy Strategy 2050 the question remains if Swiss HP can adopt to those uncertain market conditions and find profitable investment strategies. This question was subject to the second project work package and the findings are presented in Section 3.2.

3.1 Value of Flexibility

The first work package addressed HP operational decisions and market developments with the objective to identify potentials for Swiss HP to optimize their proceeds across different electricity markets. The focus was on trading in the hourly day-ahead and the weekly and daily balancing markets using the flexibility of HP stations for fast output changes with nearly unconstrained ramping. Given the large variety of hydro plants in Switzerland we focus on general assessments based on generic plant types (i.e. big seasonal storage plants, small scale run-of-river like plants, and in between medium sized plants, see Schillinger et al. 2017) and cross-validated our findings within two case studies on HP cascades in Valais and Ticino.

Since the day-ahead market price decreased on average from 2011 to 2015 the spot market revenues decreased as well (Figure 4). We observe that the decline is more pronounced for smaller plants. This is in line with the storage potential of the different plant types. A seasonal storage plant aims to use its stored water in the highest priced hours and is less subject to a decline in average prices if peak prices remain high. This effect is visible in 2012. While the spot prices decreased on average between 2011 and 2012, high price hours were more frequent and more pronounced in 2012. These first results already highlight the importance of plant specific conditions for the profitability assessments.

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[1] Note that the refinancing could also be provided via supplementary markets/mechanisms that keep wholesale prices low.
[2] The same is true for the development of the price spread. While the increase in renewable generation is often assumed to lead to more pronounced low price periods the transition towards such a system can be accommodated by a prolonged with rather low price differences (e.g. see Schlecht and Weigt, 2016).

Based on the above reference revenues the potential benefit of cross-market trading on energy and balancing markets was investigated. Figure 5 contrasts the obtainable revenues on the respective markets with a spot-market only strategy for each year. In theory, the balancing markets could provide significant additional revenues: for the big plants by 50-130%, between 50-100% for medium plants and between 40-90% for small plants. Having a look at the individual balancing markets, the secondary reserve market offers the highest potential.

For all plant types the theoretic revenue potential due to balancing market participation would have been sufficient to ensure at least as high revenues as on the 2011 spot market. In other words, switching to a combined energy-balancing trading strategy could have compensated the price decrease on the spot market.

Figure 4: Historic day-ahead market prices and revenues by HP category and year.

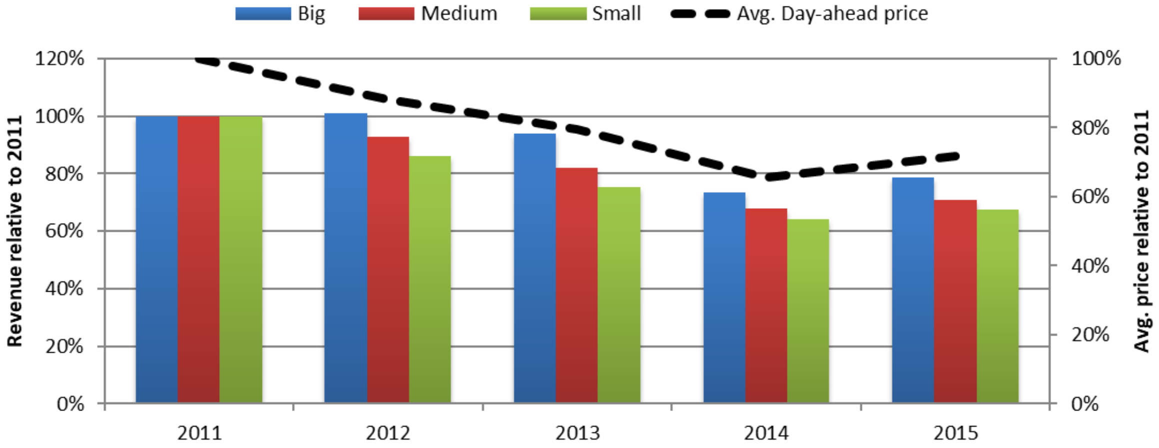
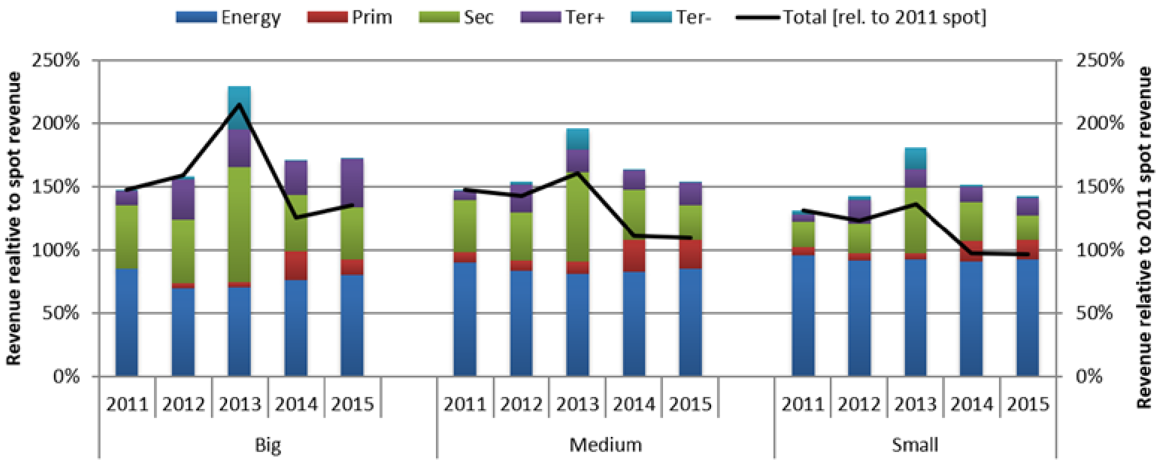


Figure 5: Historic day-ahead and balancing market revenues by HP category and year.

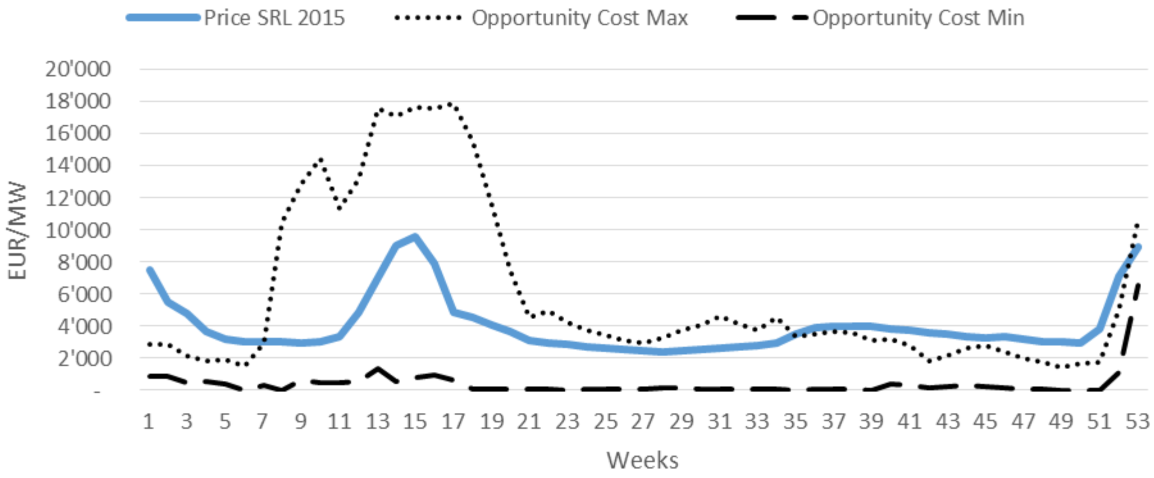


Note: Taken from Schillinger et al. (2017). ‘Big’ refers to a large scale seasonal storage plant with 100MW, ‘Medium’ to an in-between sized plant with medium storage volume and 50MW, ‘Small’ to a run-of-river type plant with limited storage and 22MW. Balancing markets are separated into primary, secondary and tertiary reserves, with the latter being distinguished in positive and negative provision.

These first results look promising. However, the analysis represents a theoretical maximum upper bound for the additional revenues due to the deterministic nature of the underlying model and the simplified representation of technical plant characteristics. Subsequent assessment of specific balancing related constrains (i.e. the uncertainty of the actual call-up, the limited size of the Swiss balancing markets, and imperfect trading behavior) show a significant reduction of the obtainable additional profit. Overall our analyses show that the lower range of estimates for taking part in balancing marketes would provide additional revenues in the range of 4-13% (compared to a spot-only strategy, Schillinger et al. (2017)).

And in depth follow-up assessment (Schillinger and Weigt, 2019) confirmed this conclusion: the balancing price pattern in Switzerland can largely be traced to represent an opportunity cost match with the hourly wholesale price patterns if one accounts for the underlying market, company, technical and stochastic aspects (Figure 6). In other words, trading on either the balancing or spot market yields similar revenue streams.[3]

Figure 6: Secondary reserve prices and opportunity costs range of Swiss hydro stations to provide balancing service



Note: Taken from Schillinger and Weigt (2019), the min/max range is derived by accounting for different market and technical aspects

A second potential revenue stream – that has not been investigated in detail in the project – is short term trading on intra-day markets. Studies by colleagues at the University St. Gallen (Frauendorfer and Schürle, 2017) show a high volatility at the intraday markets that allow additional revenue generation (i.e. the volatility in the early morning and afternoon hours has significantly increased in the last years, see also Frauendorfer (2018)). Respective trading strategies can provide additional

[3] While the projected adjustments to the Swiss balancing system are likely reducing overall costs for balancing provision they are likely not altering the opportunity cost linkage (see Schillinger 2019 for an assessment).

revenue streams of about 1 to 2 Rp./kWh or roughly 20% to 25% more proceeds compared to day-ahead only strategy.

Coupled with the market price trajectories presented above the operational and trading assessment shows that while there is potential additional revenue in the range of 10% to 25% this is likely insufficient if prices remain below 40CHF/MWh for prolonged periods but can become crucial for cost recovery in the 40 to 60CHF/MWh range. However, one can assume that companies with respective trading departments are likely already pursuing short-term and multi-market trading and therefore are close to an optimal market income. If the respective trading and flexibility structure is not already in place, the costs for establishing and operating the department need to be compared to the additional revenue that could be obtained. At least for participating in the balancing markets this revenue potential seems to be rather limited. The results also translate into a rather bleak outlook for investments to increase a plant's flexibility: they are likely not providing significant profit increases, at least in the current market environment. However, with higher market price levels and/or increased price spreads this picture could change.

3.2 Uncertainty and Investments

The second work package assessed the long-term impact of the most important drivers for Swiss HP with a focus on uncertainty, as well as the definition of practical options for decision-makers. The long lifetime of HP plants and the large dependence of their revenues on external factors require the development of a long-term framework for the assessment of greenfield and retrofitting investments. This framework accounts for the most important sources of uncertainty, such as climate change, water concessions, new storage technologies and market fluctuations (here we focus on the two last drivers) (Gaudard and Romerio, 2016). To this regard a number of scenarios have been developed, which focus on trend-breakers and highlight uncertainty.

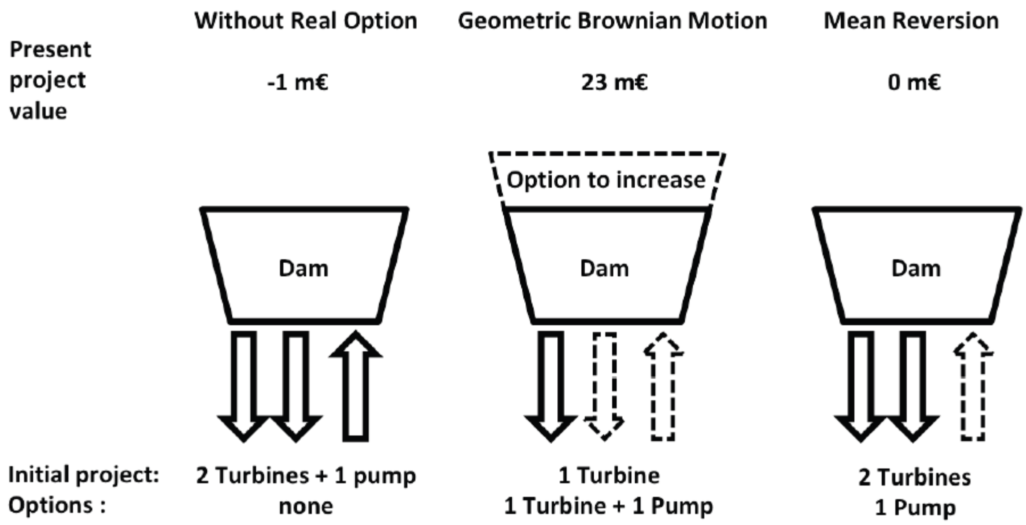
The first assessment focuses on the competition between HP and new renewable energy sources (NRE) which are supposed to dominate the future electricity system. The analysis is based on Net Present Value (NPV) and Real Option Analysis (ROA) with a least-square Monte Carlo approach (Gaudard, Romerio and Taschini, 2016), and two stochastic price processes: a Geometric Brownian Motion (GBM, Black and Scholes, 1973) model assuming significant uncertainty, and a Mean Reversion (MR, Schwartz, 1997) model providing a more conservative benchmark because it supposes the asset value draws back towards a constant value.

Comparing investments in HP and NREs the main differences are their managerial and operational flexibility. The former depends on the ability to manage the scale and timing of a project, while the latter on the ability to generate during peak hours. The main NRE's drawback, due to their intermittency, is the lack of operational flexibility. The consequence is that the revenue per kWh generated is lower than in the case of storage HP. However, a project can be built step by step (i.e. small scale wind turbines or photovoltaic installations), even stopped if it turns out to be unprofitable. In contrast, thanks to their storage capacity, HP plants have high operational flexibility as they can generate electricity during peak hours. However, their managerial flexibility is low. It is a capital-intensive technology and the construction phase as well as the lifespan of operation are long, with water concessions having a duration of up to 80 years.

In the long run, in the current uncertain market situation, HP's operational flexibility value does not compensate for its lack of managerial flexibility. Swiss HP plants would need a plant configuration that allows them to release all its storage content within the 175 (GBM) and 2190 (MR) most expensive price hours to equal the NRE's managerial flexibility value.[4] This configuration is not achieved by a typical HP plant, which usually generate in about 30 to 50% of the hours of a year. Therefore, nowadays, it is more profitable to invest in NRE.

The question arises if HP's managerial flexibility can be enhanced. Based on generic studies and case studies in Valais a set of 'options' has been identified that can reasonably be considered in an investment project: increasing the power (i.e. a set of sequential turbines), increasing the reservoir (i.e. a binary decision), and adding a pump. Figure 7 shows that the NPV of an unprofitable project can be turned positive, or at least avoid losses, if a real options approach is considered. If the managerial flexibility is overlooked, the optimal configuration consists of two turbines, a pump and a small reservoir. However, this setting would provide a negative NPV. Considering a scenario that simulates high uncertainty (GBM), the investors should carry out a small installation and keep open the option of installing another turbine and a pump. In other words, they should "start small and think large". In this case, the penstock and power house must be big enough to integrate the additional facilities, as well as the basement of the dam must be designed in regard to the highest option. The additional cost is compensated by the added flexibility providing a high pay-off in an uncertain market.

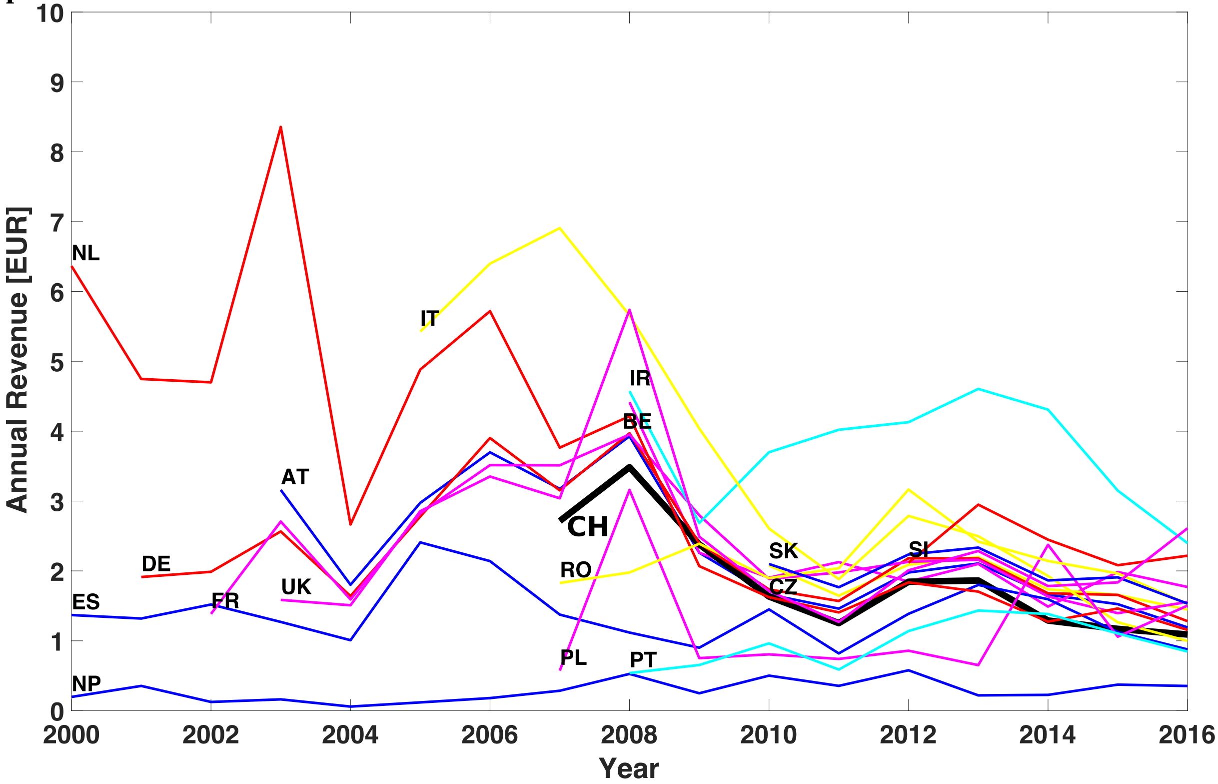
Figure 7: Present value of a project with and without real options



[4] For example, a plant with 1TWh per year should generate all its electricity during the 2190h (25% of the year) or 175h (2% of the year) highest price hours. This is equivalent to a capacity of 460 or 5710MW; ignoring all further reservoir constraints.

Besides NRE, a second important and highly uncertain driver for future electricity markets is the impact of new electricity storage technologies (NST). This represents a threat for HP, as the historical revenues for hydro pumped-storage facilities (PS) installations in Europe dropped in recent years while the variance amongst the European markets tends to diminish. Figure 8 shows the revenue converges with the increasing integration of the European markets.

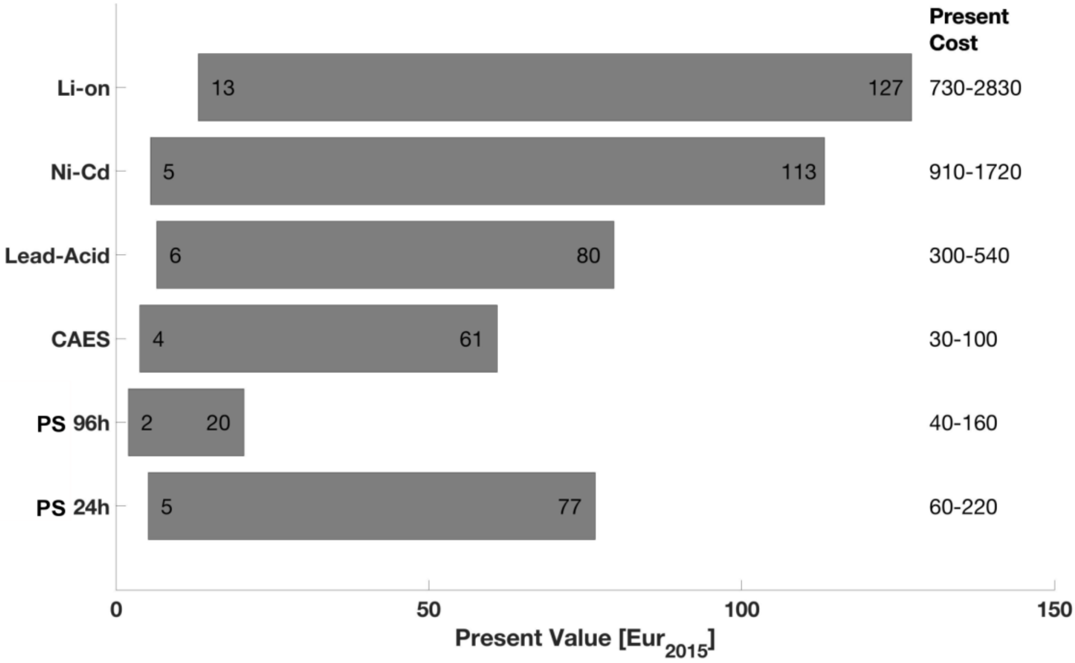
Figure 8: Historical revenue of a closed-loop pumped storage installation over 17 European power markets



Note: Taken from Gaudard and Madani (2019). Underlying assumptions: round-trip efficiency=0.8, discharge duration=24h, energy storage=1kWh. The normalization to 1kWh means a 100MWh PS earned about 200k€ in 2016.

Also, compressed air energy storage (CAES) is getting competitive, if we consider energy-only markets, as highlighted by Figure 9. Whereas NST are likely becoming more competitive due to future cost reductions, PS's costs will probably remain relatively constant given the maturity of the technology. A shift to these new technologies can be expected, although PS could take advantage of the fact that to some extend it can provide seasonal storage.

Figure 9: Present cost and value of various energy storage installations



Note: Taken from Gaudard and Madani (2019)

In the coming decades new technologies are likely to increase the competitive pressure even further. NST are assumed to possess a higher managerial flexibility due to their smaller size and lifespan. Consequently, the future new storage technologies could capture most of the profits within electricity markets. The results also show that nowadays markets favor investments in PS with daily (PS 24h) rather than weekly or monthly discharge duration (PS 96h in Figure 9). However, in the long-term the weekly and monthly storage installations will be less exposed to the NST competition.

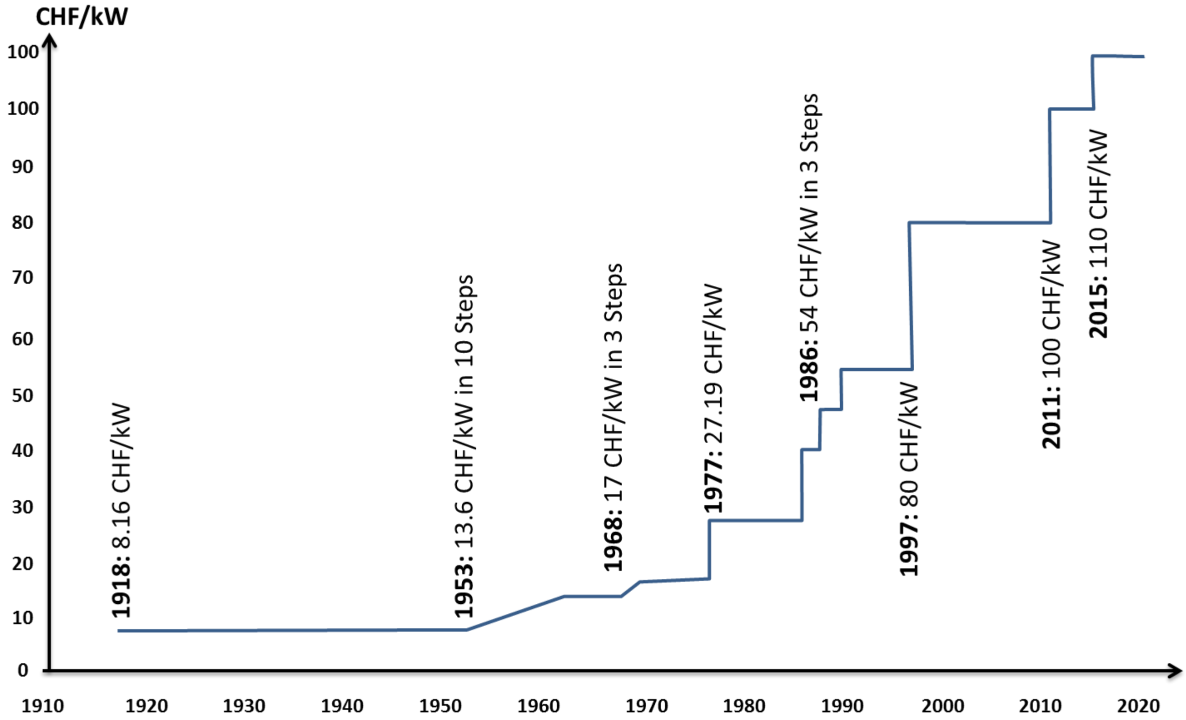
NRE and NST become competitive and currently jeopardize the futures of HP. But also, these new technologies have a smaller scale and lower lifetime. In other words, they provide managerial flexibility, which has high value in the current uncertain electricity system. As breakthrough innovation in HP is unlikely, HP operators should focus on increasing the flexibility of their investment project plans. This represents the most effective approach to deal with uncertainty, as it eases the adaptation process to a changing environment.

4 Regulatory Framework

Contrary to the market dimension the policy and regulatory framework is within the influence of Swiss decision makers and can indeed be adjusted and tailored to the changed market environments. There is a multitude of political, legal and social aspects Swiss HP is subject to: residual flow regulation and hydro-peaking restrictions, water fees and taxes, concession periods, flood and risk management and competing water usages. Some of the specificities of Swiss legal aspects rely on interactions between the federal and cantonal level: The federal authorities set a general legal framework for most of HP issues. Within this framework, the cantonal authorities have the legislative power. This leads to a situation with a relatively high degree of diversity between cantonal jurisdictions.

Out of those the discussion on adjustments to the water fee regime has dominated most of the political debate in recent years. Water fees are a remuneration to be paid by the operators of HP plants to the owners of the water resource right. According to federal legislation this right is with the cantons whereas the Confederation has the right to determine the maximum water fee level. The current fee is based on the gross capacity of the plant and the hydrological conditions. The water fee level has been adjusted several times since the introduction in 1918 (Figure 10). Given the challenging market conditions the legal requirement to review the water fee levels in 2019 has initiated a discussion about potential adjustments of the level and mechanism. As the potential adjustments have been postponed to 2024, the discussion of a reform of the system of water levies is ongoing.

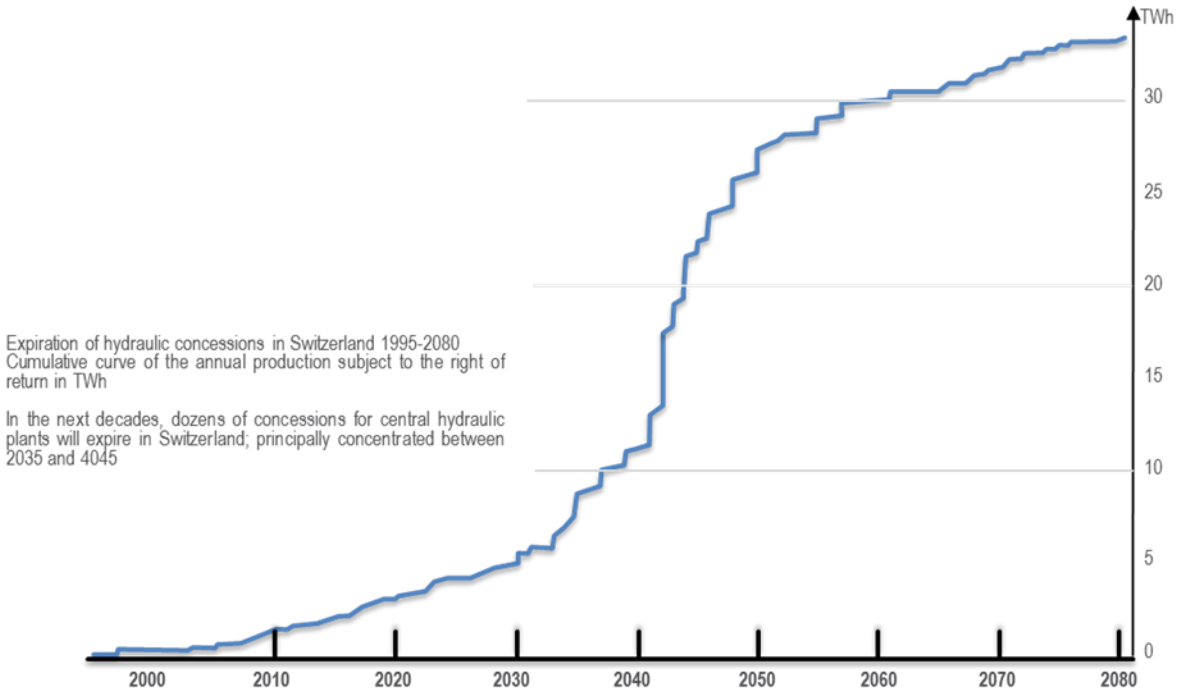
Figure 10: Water Fee Development



Note: Based on Pfammatter and Piot (2016)

The second most important influencing regulatory factor will be the concession renewal coming in the next decades (Figure 11). Swiss federal law entitles the incumbent owner to negotiate the concession's renewal (or to opt for another solution) within a 15–25-year period prior to the concession expiring, which means that such negotiations need to take place in the coming years. The value of these concessions is estimated at about CHF 40 billion, with the Valais' concessions alone being within a range of CHF 10 to 20 billion (ASAE 2012; SWV 2012b).[5] There are three ways to end a concession contract: The first way is by cancellation, ensuing from the end of the contract. The second is caducity, ensuing from a neglected exploitation of the concession right. Finally, there is the use of the buyback right by the granting authority (reversion, "Heimfall"). In this case, a distinction is made between the "wet parts" (all the parts of the HP plant in contact with water, which notably include the dam, pipes and turbines) and the "dry parts" (e.g., the generator and transmission lines). Unless otherwise stated in the concession, the wet parts are acquired for free by the community owning the concession right.[6] Overall the existing concession system has been designed for a regulated electricity market with bound customers. Whether the long concession durations (in general 80 years, with variation between the cantons) are still suited for a competitive and volatile market environment is debatable (Voegeli et al., 2018).

Figure 11: Expiration of Swiss HP Concessions



Note: Taken from Barry et al. (2015) and based on ASAE (2012), SWV (2012b); modified graph.

Against this backdrop a central element for the future of Swiss HP is the interaction of the different stakeholders and a fair compensation between the different interest groups. To this regard an integrated stakeholder assessment from a comprehensive sustainable development perspective has been subject to the third project work package and the findings are presented in Section 4.1. The

[5] In the European Union, the water rights renewal is also a politically charged topic. According to the European Commission, rights to water use should be allocated by a competitive and transparent process (Glachant et al. 2014).

[6] There is a great degree of diversity between the cantons with regard to this point. Considering, for example, the three largest hydropower-producing cantons, Valais allocates 100% to its municipalities (or to the canton, in the case of the Rhone river), Grisons allocates 50% to its municipalities and 50 % to the canton, and finally, Ticino allocates 100% to the canton.

specific role of water fees, the potential impact of adjusted calculation approaches on companies and cantons and municipalities, as well as feedback effects has been subject to the fourth project work package and the findings are presented in Section 4.2.

4.1 Regional Impacts and Sustainability Perspective

When assessing the future perspectives of Swiss HP the social and economic interactions in both the political and market realms need to be taken into account. This assessment must include economic considerations of profitability, a comprehensive perspective of sustainable development (SD), and requires a comprehensive stakeholder process.

As highlighted in Figure 1 the institutional arrangements and social acceptance (political, legal and social aspects) compromise the central concern of Swiss HP stakeholders. Indeed, a major element of the energy transition is the development of the regulatory elements that are required for achieving the targets of ES 2050. In this regard, the electricity market design and the issue of HP concessions and water fees are recognized as the most pressing regulatory challenges to be solved (Bundesrat, 2018), while the relationship between HP and environmental protection has been further clarified and adopted with the revised Energy Act (Energiegesetz, EnG).

With regard to the later, the EnG allows, for the first time, that HP plants – and other facilities for the use of renewable energies – might receive the status of "national interest" just like environmentally protected areas that are registered in the Federal Inventory of Landscapes and Natural Monuments (Bundesinventar der Landschaften und Naturdenkmäler, BLN). Thus, when weighing the interests in the use of renewable energies against of the environment, a departure from undiminished environmental conservation might be considered for BLN areas. In such cases, an integrated sustainability assessment (see below) is highly recommended as a supportive tool for the governing authorities in charge of granting construction permits or concessions. In contrast, new facilities for the use of renewable energies are precluded in biotopes of national importance under art. 18a of the Federal Act on the Protection of Nature and Cultural Heritage (Bundesgesetz über den Natur- und Heimatschutz, NHG) and in waterflow and migratory bird sanctuaries under art. 11 of the Hunting Act (Jagdgesetz, JSG). However, in case of renewing the concession of an existing HP plant, an evaluation of trade-offs will be required within the frame of these (and other) legal norms that, in turn, can be conceived as the result of the social search, learning and coordination process toward sustainable development (Baur & Hediger, 2016).

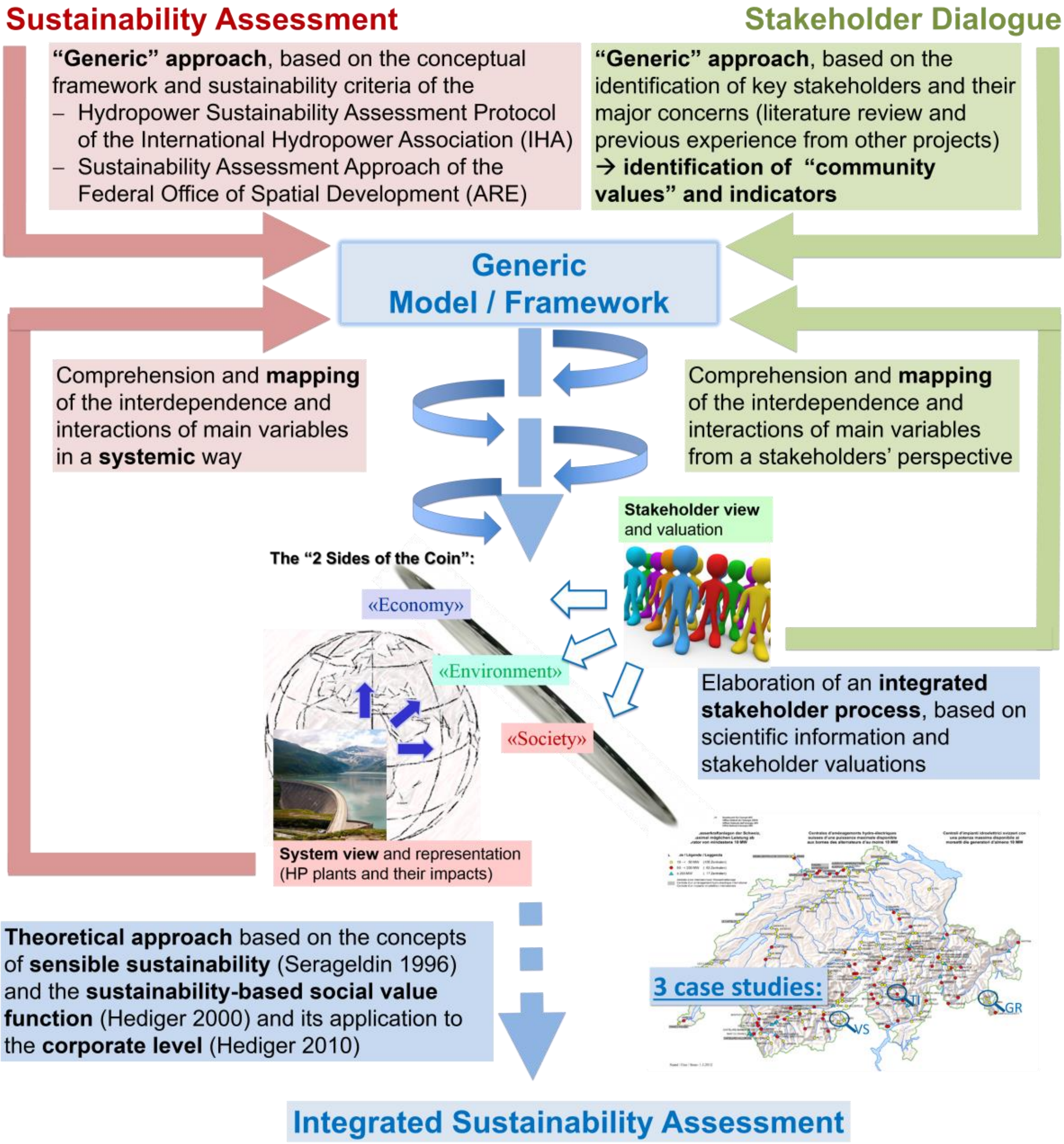
A second important environmental regulation is given by residual water flow constraints. As residual flow restrictions will become binding with the renewal of HP concessions, this will become an important aspect in the coming years (see Figure 11). In the meantime, the existing residual water routes must be rehabilitated to the extent that this is economically viable (BAFU, 2018). The Waters Protection Act (Gewässerschutzgesetz, GSchG) furthermore allows for the evaluation of trade-offs if found to be necessary or of interest for a specific site. However, the evaluation of these trade-offs will be challenging. To be socially acceptable and conform to the goals of SD, a comprehensive sustainability assessment (see below) would be adequate that goes beyond the mere economic assessment of effects on production, costs and profits.

Regarding the issue of HP concessions and water fees a harmonization between national and subnational jurisdictions as well as a linkage to the ongoing market liberalization and restructuring processes is advised. The European Union, which determines a point of references for the new market design (cf. CREST, 2018), requires the attribution of use rights (concessions) to follow competitive processes and the integration of sustainable development (SD) goals. Though harmonization of national HP regimes is not mandatory for the EU member states, a stronger coordination of these regimes in the common market is currently in the discussion (Glachant et al., 2016). In this context, we analysed the challenges of granting HP rights and propose a procedure based on three goals: i) to ensure the highest rent transfer related to water rights, ii) to prioritize projects closer to SD goals, and iii) to ensure the efficiency of the process itself (Voegeli et al., 2018). This approach is designed to synchronizes market, water rights and sustainability aspects in a comprehensive and efficient way. However, to increase the success rate of the whole process and the social acceptance of the selected project, stakeholder involvement is crucial.

Indeed, as the issue of water fees touches different stakeholder groups, namely the owners of capital (investors) and the holders of the property rights in water (the cantons and partly municipalities), it should also be addressed from two sides: On the one side, water fees reduce HP's profitability and return on investment. They are largely perceived as an important cost to HP companies and are seen by numerous stakeholders as having a discriminatory effect on Swiss HP compared to other energy technologies and imports from other countries. On the other side, the water fee revenues contribute to cantonal and municipal budgets, especially in mountain areas, where HP can also play an important role in providing income and employment to the local economies and thus foster regional development (see next Section for details). Accordingly, changes in the regulatory system of water fees and concessions must not only be regarded from a corporate and industry perspective of competitiveness, but also from a point of view of regional development and public finance (Hediger, 2018a, 2018b; Hediger & Herter, 2018).

The various regulatory challenges in the institutional and environmental domains result from the fact that HP investments and operations cause impacts (externalities or distributional effects) in those domains. Accordingly, the different stakeholders need to find, above all, a compromise between companies' profit perspectives, federal energy targets, cantonal and local budget requirements, regional development goals, as well as national and international regulations. This involves various synergies and trade-offs that are the most suitably analysed within the frame of a regional sustainability assessment (Hediger et al., 2018; Hediger & Voegeli, 2016) whose results can then be transferred to the corporate level (Hediger, 2018a). Moreover, it must integrate the "two sides of the coin", such as illustrated in Figure 12. Those are the "technical" information about the project (system view) and the evaluation of its impacts from a multi-stakeholder perspective (valuation of trade-offs).

Figure 12: Integrating the scientific sustainability assessment and stakeholder dialogue



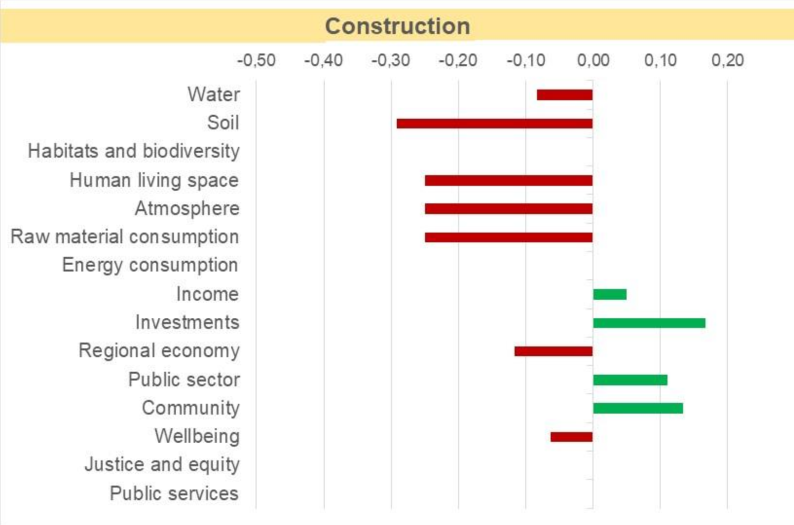
Note: Taken from Hediger and Voegeli (2016)

As an approach for a comprehensive sustainability assessment we extended the SA grid of the canton of Bern (Hediger, 2017), and tested and applied it to two case studies in Grisons and Ticino.[7] It implies an assessment of the impacts of a HP plant on the three domains of economy, society and environment, such as illustrated in Figure 13 for the case study of Lagobianco. The latter particularly reveals the benefit of an integrated stakeholder process that took place in a period when the project has

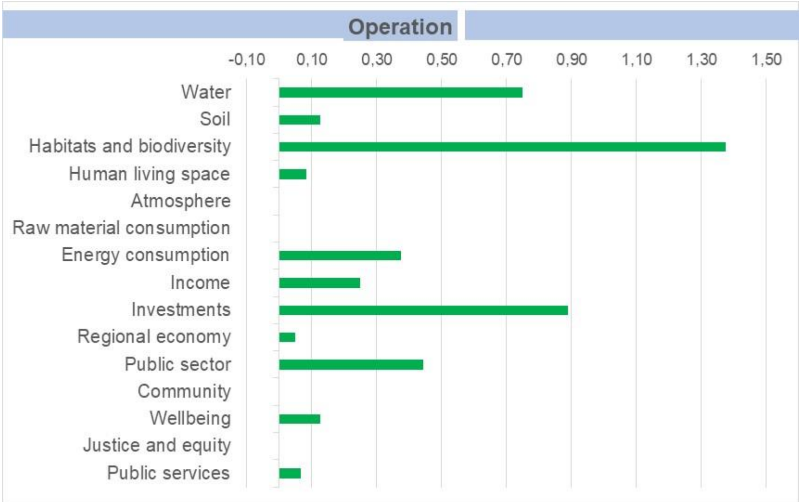
[7] The case studies show that negative effects in the construction phase are largely compensated by the positive effects in the operation phase, despite the low prices on the electricity market and the related lack of profitability (Herter & Hediger, 2018; Schlange et al., 2018, Giuliani, 2019).

been blocked in a legal case. In a constructive and targeted dialogue, the different stakeholders identified critical aspects and optimized the project (cf. Herter & Hediger, 2018).

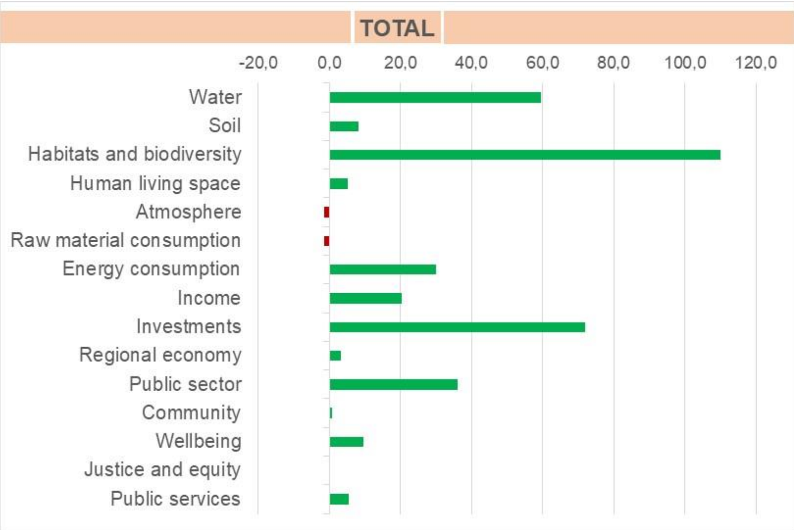
Figure 13: Results of the Sustainability Assessment "Lagobianco" on Sub-domain Level



Negative environmental impacts must be expected during the construction phase. But this also brings additional activities to the region: investments in infrastructure, additional (temporary) residents, who work on the construction site and will also foster local consumption.



The assessment of the operational phase is invariably neutral or positive. The revised project particularly accounts for all environmental concerns previously expressed. Furthermore, this phase will be important for the regional economy, as new operational and maintenance positions will be created.



The aggregation of the assessments of the two phases shows a positive picture (assumption: construction phase = 6 years, operating phase = 80 years; discount rate = 0). The negative effects of the construction phase are mostly compensated by positive effects during the operation phase.

Note: The assessment scale is [-3, 3] and indicates whether negative (red) or positive (green) changes are to be expected in the respective sub-domains. The assessment was carried out at the indicator level. For the aggregation, the individual indicators and criteria were equally weighted.

The framework encompasses 45 criteria with 150 indicators to measure these impacts. They are grouped in 16 subdomains (Hediger, 2017). Separated for the construction and operation phases, the impact assessment on indicator and criteria level must be undertaken by experts, while the evaluation of trade-offs on domain, subdomain and criteria level is part of the stakeholder dialogue (Hediger et al., 2018). This approach is supported by a sustainability-based cause-effect map for large HP projects (Voegeli et al., 2019). This supports decision making processes, in i) raising the awareness of stakeholders regarding the manifold facets of HP, and ii) providing a structured frame for the evaluation of HP projects.

The important advantage of those assessments is that they do not only focus on electricity market benefits, but take the full value chain of HP and the diverse impacts upon the economy, society and the environment into account, such as illustrated in Figure 14. Altogether, the net revenue of hydropower operations (i.e., the resource rent) as well as the external contributions to society (externalities and distributional effects) and the related changes of the firm's reputation capital determine the instantaneous value of hydropower from a societal perspective. The "total value of hydropower" is the net present value of these elements (Hediger, 2018a).

Figure 14: Total value of hydropower

<table>
<tr><td rowspan="3">Change of reputation capital</td><td colspan="4">net revenue (resource rent)</td><td>additional contributions and impacts:</td></tr>
<tr><td colspan="2">profits</td><td rowspan="2">taxes</td><td rowspan="2">water fees</td><td rowspan="2">(regional) economy, incl. wages
social capital
environment</td></tr>
<tr><td>retained</td><td>distributed</td></tr>
<tr><td colspan="3">internal value</td><td colspan="3">external value</td></tr>
<tr><td colspan="6">total value</td></tr>
</table>

Note: Own presentation based on Hediger (2018a).

This "social net present value" allows investments to obtain positive indications even in uncertain electricity market environments. Therefore, it matches with the corporate social responsibility approach. Within the latter, the performance of companies is evaluated from a sustainability perspective and regarding their contribution to society and it further links the whole assessment process to the cooperate governance structure of HP[8]. In the classic form, the fundamental issue of corporate governance is to assure financiers get a return on their financial investment. Moreover, governance is to set norms, strategy and high-level goals and policies, and also to ensure that the organization (e.g., HP company) is working in the best interest of the public, and in particular of the stakeholders who are served by the organization's mission. This is particularly relevant for Swiss HP companies, with their specific ownership structures.

[8] Corporate governance appears whenever one or several groups of stakeholders coordinate their actions in order to increase their benefits at the expense of other stakeholders' benefits.

Linking those dimensions is crucial to integrate efficiency and equity. The framework particularly includes dividends to the shareholders, retained profits for future investments, water fees and corporate taxes, as well as impacts on the firm's reputation capital, the economy (incl. wages), society and the environment. It implies corporate and social accounting prices to weigh the external and distributional effects of HP from a societal perspective against the financial concerns of the shareholders and other recipients of revenues from the HP company (Hediger, 2018a). Using the above described approach, one can separate the total value of HP (defined in terms of net present value) into a private and external value. The former encompasses the net present value of profits and contributions to the firm's reputation capital; the latter the distribution of water fees, taxes and wages, and impacts on the economy, society and the environment. Building on this background, investments into HP plants should be undertaken from a societal point of view as long as the total value of HP is positive, even if the private value is negative. Thus, from a societal point of view, investment decisions should not be solely guided by financial considerations but must also take into account the results of sustainability assessment or a similar approach (Hediger, 2018a).

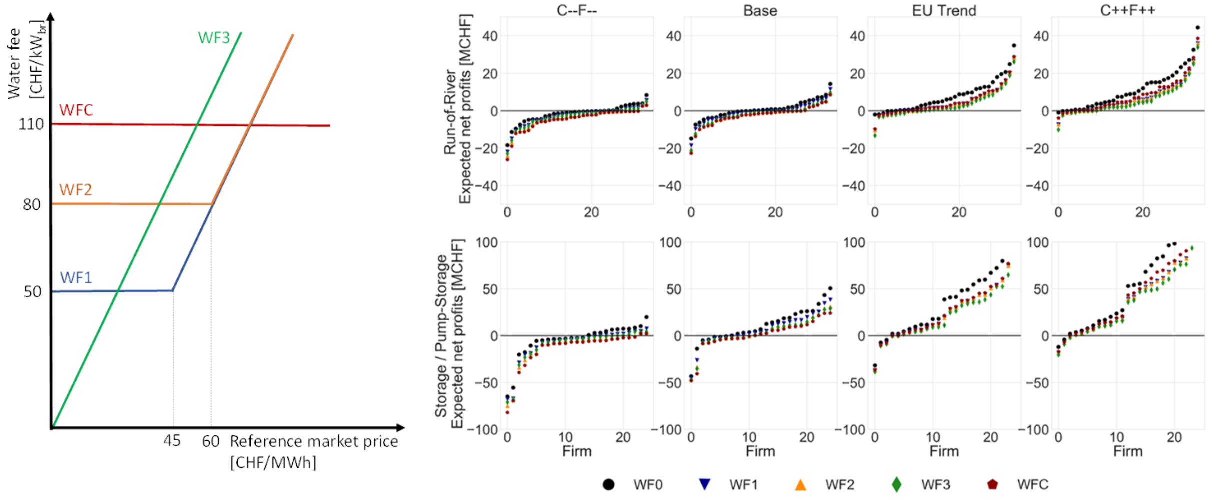
4.2 Water Fee Reform

Water fees have taken a center stage in the discussion on Swiss HP in recent years. So far, no new compromise on how to distribute the resource rent derived from the usage of water among the different involved stakeholders could be found. These stakeholders can mainly be separated into representatives from mountain cantons and lowland cantons. Defined in the federal constitution, the former are the "waterlords", holding the property rights on the natural resource water. Accordingly, they have the right to grant water-use concessions and receive royalties, the so-called "water fees", from the HP companies. Those companies, in turn, are mainly owned by lowland cantons, who are the principal shareholders of Swiss electricity companies.

The rules of implementation and the maximum water fee rate that can be applied by the cantons is defined in the federal Water Rights Act, which has been established in 1916. Since then, this rate has been increased several times by the federal parliament (see Figure 10). Currently, the maximum rate is fixed at CHF 110 per kilowatt installed capacity, while the applied rate is adjusted to hydrological fluctuations. The fees are physically determined and do not account for economic facts, such as fluctuating electricity prices. Different options are under consideration to reform this regime. Those include, amongst others, flexible water fees fully or partly accounting for electricity price variations, and an integration in the federal and cantonal fiscal equalization schemes. Within the fourth work package we investigate the potential impact of different water fee regimes for the paying companies as well as the receiving cantons and municipalities. We distinguish between scenarios (Figure 15, left panel) with no water fee (WF0), a full flexible (WF3), different partial (WF1, WF2) and the current fee level (WFC).

Turning to companies first, an assessment of income streams under different potential market developments (see price scenarios in Figure 3) and different variable water fee systems is in line with the general findings on market aspects in Section 3: market developments dominate the profitability prospects for Swiss HP. Starting from the 2015 base price assumptions and taking a rather negative future price pathway (further decreasing carbon and fuel prices until 2030, C--F--) and positive pathway (strongly increasing carbon and fuel prices until 2030, C++F++) as upper and lower trajectories, income estimations for 60 HP companies showcase the strong difference in the impact of different water fees and different market environments (Figure 15, right panel).

Figure 15: Variable water fee options and net profit impact in 2025

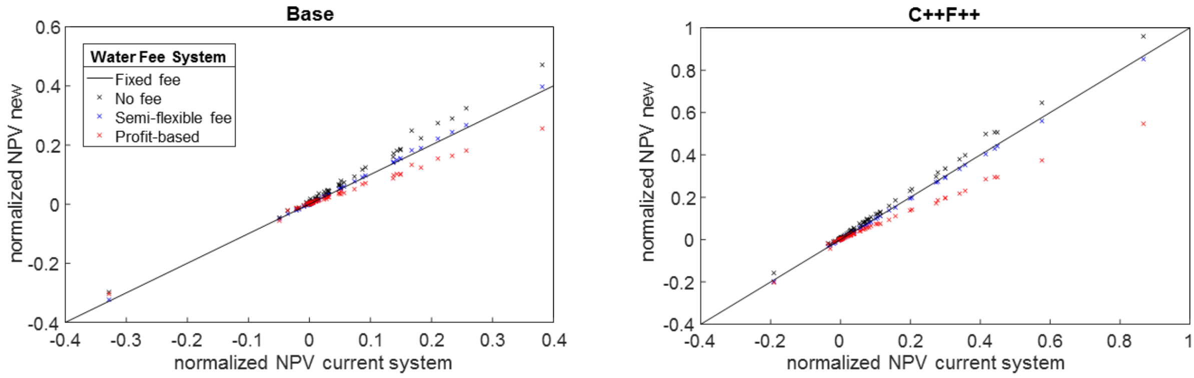


Note: Taken from Betz et al. (2019).

While the market dynamics easily shift the whole company sample up and down, the water fees lead to a more gradual shift that has highest relevance for those companies being close to the break-even point. Under favorable conditions even the current fixed fee does not lead to negative values (losses) for a majority of companies, while under negative conditions a complete abolishment of fees would only push few companies into a positive range with profits. Water fees are a crucial cost component for companies and are of importance whenever market price and cost levels are in close proximity (i.e. within a 40 to 60 CHF/MWh range), but market dynamics can easily lead to price levels above and below this range.

A similar insight is obtained from an investment assessment based on the method presented in Section 3.2. Using data of 148 installations of the company sample for the years 2015 and 2016 (see Figure 2) the companies' investments are assessed by means of a net present value (NPV) approach (Gaudard, Voegeli and Romerio, 2018). The investments represent the remaining capital, including the equity and debt, to be amortized up to the end of the concession of each facility including standard maintenance. Comparing the NPV values of the current fixed water fee regime (110 CHF/kW), a system without water fees (WF0), a combined fixed-variable system with a fixed fee of 50 CHF/kW (WF1 in Figure 15), and a profit-based system, shows the impact an alteration could have on investment incentives. Overall the analysis shows that water fees play an important, but not game changing role. in terms of normalized NPV. Only in the case of a further decreasing price trajectory (e.g. the C--F-- scenario) this would be sufficient to turn a negative NPV into a positive one. For all other scenarios the impact of the different fee regimes is limited to a gradual up or down shift of the NPV levels. Figure 16 highlights this for the 2015 fuel price levels (Base) and for a strongly increasing price trend (C++F++).

Figure 16: Comparison of the NPVs of company's investments under different water fee regimes



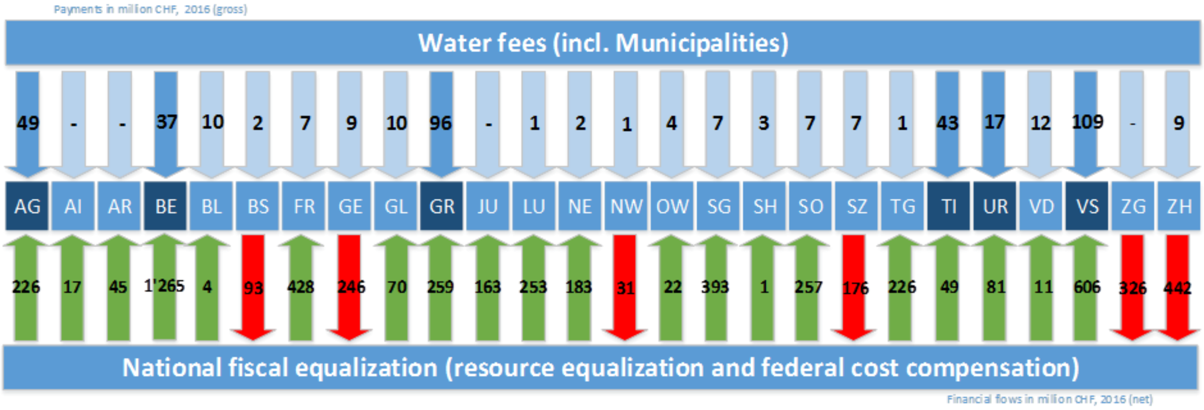
Note: Taken from Gaudard, Voegeli and Romerio, 2018.

Turning to the property rights holder on cantonal and municipal level the direct impact of changes to the water fee regime is more pronounced. Within the fourth work package we also investigated the distributional effects of water fees from a fiscal and regional perspective. Given the complexity of Swiss HP shareholder relations deriving a clear picture of financial flows related to HP operation is not straightforward (e.g. out of the 95 million CHF Grison receives in fee payments 6.6 million CHF can be attributed to the canton and municipalities of Grison themselves, see Betz et al. (2018) for details). Especially, if one accounts for the interrelation of tax returns and company dividends the impact of water fees and market dynamics become less clear.

Figure 17 show cases the gross financial flows related to water fees in comparison to the streams from the national fiscal equalization scheme. It is obvious that water fees represent an important pillar for a handful of cantons, namely Valais (VS) and Grisons (GR) obtaining about 50% of the water fee volume, and Aargau (AG), Ticino (TI), Bern (BE) and Uri (UR) receiving about 30%.

An alteration of the fee regime could easily alter those streams. As indicated in Figure 15 the concept of a mixed fixed-variable system works in a way that the fee level is determined by a reference market price; in other words, the system still leads to a fixed payment independent of the actual power plant performance. However, the total payment is altered yearly depending on overall market conditions. Consequently, the resulting financial impacts for the cantons and municipalities directly mirrors the water fee design structure. For example, in case of low market prices a water fee system with a low fixed and high variable share could lead to water fee payments of less than 50% of today's levels (i.e. in the WF1 regime the fee is fixed at 50CHF/kW for market reference prices below 45CHF/MWh) whereas high market prices could easily lead to a doubling of payments (see also BFE (2018b) for an assessment of reference market prices from 2008 to 2018). This highlights that the debate on flexible water fees is highly relevant for the rights holder (Betz et al., 2019).

Figure 17: Comparison of financial flows from water fees and fiscal equalization in 2016

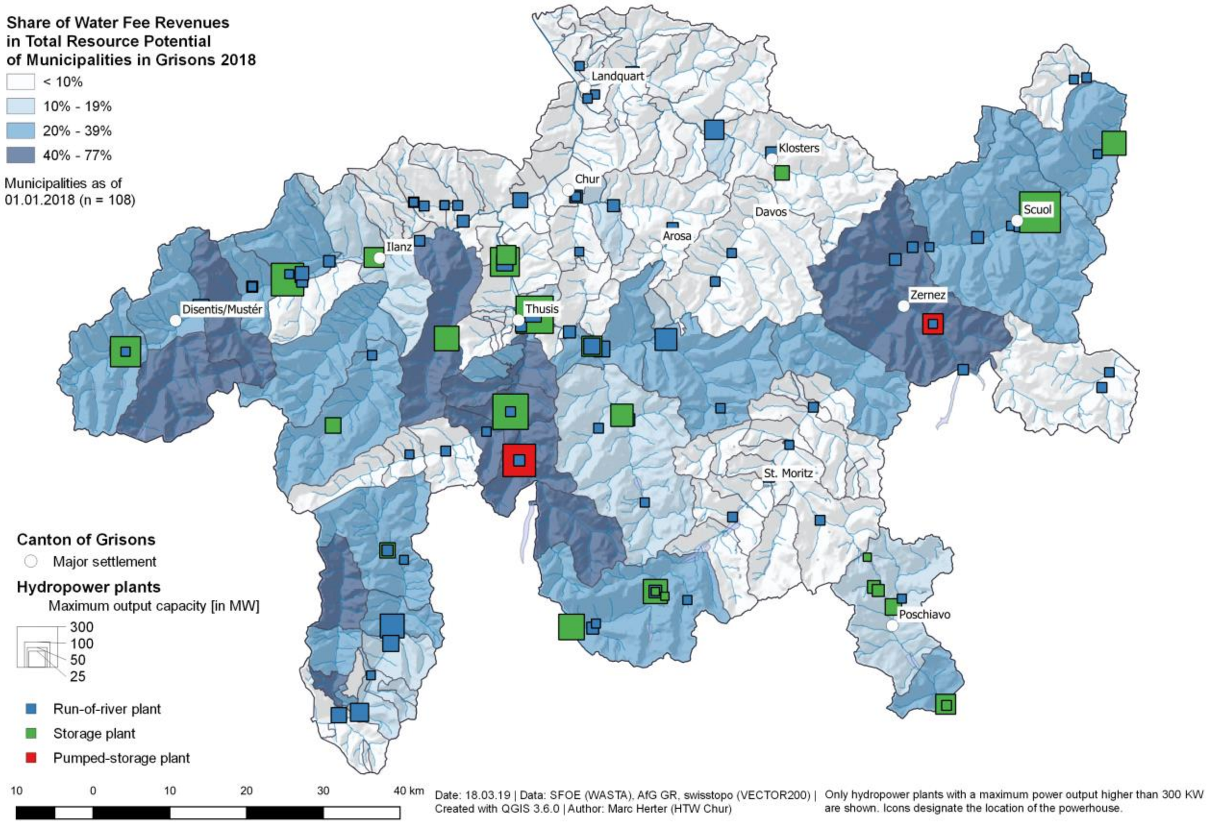


Note: Water fees do not represent actual amounts but are calculated based on production value at CHF 0.0124/kWh in combination with ownership structure analysis from Hediger, Herter and Schuler (2019).

However, as indicated in Figure 17 water fees only represent one element of cantonal revenue and consequently changes resulting from electricity market and water fee adjustments need to be evaluated within the overall cantonal budget. Similar, the income structure of cantons owning energy companies is impacted as well. Albeit the market dynamics are the most important driver for companies the resulting losses or profits have important consequences for shareholder. In case of favorable market conditions and low water fees shareholders can be expected to profit from additional income in form of dividends whereas in times of losses they would be expected to support the companies.

To get a first insight on the potential feedback effects of water fee adjustments we use the case of Grison as an example. For the canton of Grisons, where the canton and the concession-granting municipalities equally share the water fee revenues, our analysis reveals that these proceeds would be a source of substantial disparities without the balancing effect of the inner-cantonal fiscal equalization. As shown in Figure 18, for some municipalities, the water fees currently constitute more than 30% (or even up to 80%) of their resource potential. The latter is the sum of tax revenues plus water fee proceeds and is used to calculate a municipalities relative resource strength, which determines whether a municipality pays a certain deposit into the resource equalization system or is eligible to receive disbursements out of it.

Figure 18: Shares of Water Fees in the Resource Potential of Grison Municipalities, 2018



Note: Own calculations based on AfG (2018) data

The resource equalization mechanism aims to partly equilibrate the different revenue-raising capabilities between municipalities and indirectly redistributes a share of the total amount of water fee revenues among resource-weak municipalities. A change in the water fee proceeds thus affects every municipality – some directly, others indirectly. This must be taken into consideration when assessing potential effects of a revised water fee scheme: A higher water fee rate (i.e. due to high market prices in a flexible system) would benefit the water fee-receiving municipalities directly through higher proceeds and all other municipalities indirectly through increased average disbursements out of the resource equalization system. A reduction of the water fee rate, on the other hand, (i.e. due to low market prices in a flexible system or a general reduction of the fixed rate) would reduce public revenues for all water fee-receiving municipalities and lower their respective resource potential. As a consequence, the number of resource-strong municipalities would decline, and the remaining resource-strong municipalities would be required to increase their deposits into the resource equalization system. This would then particularly put more pressure on those municipalities with a tourism industry, which is the other economic backbone in Grisons apart from HP utilization. Those would have to generate additional revenue in a time, when the number of tourist arrivals is expected to be falling and climate change emerges as another threat to winter tourism.

This is one example that highlights the complex relationship regional economies and between societal impacts and hydropower decision in the Swiss context. In particular, it showcases the importance indirect effects resulting from water fee adjustments and market dynamics. Given the complex structure of relations between companies, municipalities and cantons (see Betz et al. (2018) for details), as well as the heterogeneity across cantonal regulations a general conclusion on potential effects cannot be provided within the scope of this project. However, the first assessment shows that there are multiple effects that need to be accounted across the different involved actors that can differ in scale and importance.

5 Insights and Recommendations

Summarizing the findings from the four project work packages the future of Swiss HP can be classified as a mix of risks and opportunities. The main challenges are associated to the future development of the European electricity markets. Considering the limited influence Switzerland and Swiss companies have on the general drivers of those developments, the only viable strategy is to adapt to the changing market conditions and uncertainties as good as possible.

For companies this translates into an adaption of both short and long term strategies to the reality of an uncertain market. This includes usual aspects like uncertain price trajectories and the risk of income fluctuations that challenge the liquidity and value of assets. Whereas most of the risk was borne by captive consumers in the regulated electricity world, this insurance is already gone for most of the larger companies. It is expected to be gone also for the remaining companies once the agreement with the European Union on electricity markets has been reached and the Swiss market is fully liberalized. Companies that do not adjust to this new reality will likely face problems whenever market conditions are in the lower price range.

The operational assessment has shown some leverage of optimizing trading. However, there are only few low hanging fruits left to benefit from HP flexibility. Current markets have a limited pay-off for flexibility and whether the additional income compensates the associated effort and costs is plant and company specific. However, those companies that are still not valorizing their basic market revenue potential (e.g. focusing on future and day-ahead energy sales) should reconsider their trading strategies. Companies should also develop strategies to cope with longer periods of low prices (and in the case of pump-storage plants phases with low price spreads) of several years like accumulating sufficient reserves in times of high prices.

While prices are likely to rise again in the long run to sufficiently high levels for the existing Swiss HP there are further challenges when it comes to HP's intended role in future electricity markets: renewables pose a challenge due to their investment flexibility, while alternative storage technologies (e.g. CAES, batteries) can pose a long term threat. Those challenges call for an adjustment of investment strategies to convince company leaderships and investors that the embedded uncertainty can be managed. The concept of "Start small, Think large" can represent one potential approach. But the long-term future will also be largely shaped by the regulatory framework determined by policy makers.

Switzerland will not be able to avoid an adjustment of its policy and regulatory environment if it aims to keep HP a valuable asset both for its energy provision and its larger socio-economic structure. The fixed structures of water fees and the long duration of concessions were suitable designs for a regulated system with monopolistic structures but fall short in the current market environments. However, how those main elements should be adjusted is not straightforward as any change will impact several stakeholders with different interests and responsibilities. Similar to the company perspective a central theme of those adjustments will be the management of risk and the allocation of risk between stakeholders. The current approach to fill revenue gaps by a form of "federal emergency funding" (the market premium for hydro companies making losses at the market) is no long-term strategy (see also CREST 2016). The development of a compromise between the different actors will likely need some more time but the general directions are clear: adjust the water fees to the more volatile market reality while accounting for the budgetary needs and constraints of the involved parties and provide a concession framework that enables companies to utilize their managerial flexibility. An integrated sustainability assessment that would incorporate company and societal perspectives and include an extensive stakeholder exchange is highly recommended to achieve a compromise between the different parties and interests. Our results show that investment decisions can be beneficial, even while accounting for its environmental impacts and under challenging market perspectives, if the "total value of hydropower" and thus the larger benefit it provides (the societal dimension) is taken into account. Wasting this potential because of insufficient governance structures would be a pity.

6 Open Points and Needed Next Steps

As highlighted in the previous section the details of the necessary adjustments of the regulatory framework in Switzerland still need to be specified and negotiated between the different stakeholders. The time window for those clarifications and negotiations is open until 2024; until then the water fee regime will remain as is, but afterwards a new regulatory setting is supposed to start. So what are the key challenges that need to be tackled in the next years?

Regarding the water fees the central conflict is the financial risk associated with the different fee designs. A fixed fee puts the risk on the company side, a completely variable fee on the canton and municipality side. Even though the same is true for the potential benefits in case of high market prices but with reversed signs, the 'worst case' seems to dominate the perception. A mixed fee would allow for some form of compromise with the results in Section 4.2 providing a first quantification of potential effects. One important element in variable fee designs is the definition of the 'reference price' that defines the level of the variable share. Given the heterogeneity of Swiss HP the definition of this price is not straightforward. Also alternative approaches could be pursued that avoid a linkage to market dynamics or provide a form of buffer for the two involved sides; which likely comes by using the state or consumers (i.e. via end user charges or taxes) as provider of this buffering. Thus a stakeholder process will be needed to bridge the gap and find a compromise all sides can agree upon.

Regarding the concession and investment challenge the central theme is to handle uncertainty and enable HP companies to compete with other energy and storage providers. Looking at the full life time of HP structures there seems to be little doubt that they should represent an important part of our future electricity system; but given market realities a should is not necessarily enough. In a fast end evolving electricity environment the long lifetime of HP plants has become a liability and not an asset. Our results indicate that there are approaches to improve the managerial flexibility from the company side but those require potential adjustments to the concession framework. Similar the total value of HP assets goes beyond the pure electricity sales. The inclusion of this "social net present value" into the consideration requires that the internal and external value shares are identified and approaches in place that allow both a benefit sharing and a burden sharing. Thus again, a stakeholder process will be needed to find solutions.

Finally, on the more general market design side, the role of potential new market components (e.g. the storage reserve envisioned in the revised energy law, capacity markets in neighboring countries) needs to be considered. Those aspects must be linked to the above challenges and fed into the stakeholder process.

Five years seems like a lot of time to address those points but this requires a clear and target oriented approach. Stakeholders will need to find compromises and likely must forego some of the benefits that were feasible in a regulated electricity system but do not fit into the new realities. Otherwise the 'interim' solution to fill gaps with federal money can become the long-term solution; and sectors relying on state subsidies seldom have a prosperous long term perspective.

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