The Future of Swiss Hydropower:
The Design of Variable Water Fees and its Impact on Profitability

Preliminary Draft

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1 Introduction

The exploitation of natural resources, such as hydropower, generates so-called resource rents, which are defined as the difference between the revenue of selling a natural resource and the cost to extract it. In the case of hydropower, it is the value of the generated electricity minus the cost for hydropower generation, e.g. capital investment, labor, and taxes. The rents can be allocated to the resource owner, e.g. by a tax on the rent, otherwise they are absorbed by the user, here the electricity companies.

In the case of Swiss hydropower, there is no tax on the resource rent but a fix water fee, which has to be paid by the operators of hydropower plants to the owners of the water resource right. According to federal legislation (Art. 76 IV of the Swiss Federal Constitution and Art. 2 I of the Water Rights Act, WRG), this right is with the cantons[1] and can entirely or in parts be transferred to other communities, such as municipalities, districts and cooperatives. The Confederation has the right to determine the maximum water fee level (Art. 49 I WRG). Currently, the fee is based on the gross capacity of the plant and estimated using the gradient and the amount of water that can be used for electricity generation depending on the hydrological conditions as defined in the concession. It is thus not based on economic but on physical principles. Hence, in contrast to a tax on the resource rent, it does neither account for changing market conditions nor for different production costs across power plants.

This implies, that cantons and municipalities have a constant income from water fees, because the whole market risk lies with the producers: If revenues are high, they earn high rents and water fee payments are only a small share of their resource rent, but if revenues are below cost, i.e., there is no resource rent, they have to pay the same water fee. Consequently, due to the recently difficult economic situation because of low electricity prices, Swiss hydropower producers call for a change in the water fee regime, which shifts part of the market risk from producers to the owners of the resource. The currently most probable option[2] are flexible water fees, which depend on the revenue potential, i.e., the electricity prices. However, as this would lead to lower revenues for resource owners during years with low electricity prices, cantons and municipalities oppose a more flexible design.

This paper contributes by analyzing the impacts of different water fee reform options – and how they depend on market conditions - from two perspectives: hydropower producers and owners who receive the payments. Specifically, we ask the following questions: What is the impact of different flexible water fee designs on profitability of hydropower? How are resource owners affected by different

[1] Besides the earnings from water fees, cantons where hydropower plants are situated receive proceeds from taxes on income and property. The majority of this tax revenue flows to cantons, a smaller share to municipalities. In addition, the cantons may receive dividends when holding the shares of the hydropower utilities and profit taxes. Some of the latter may also generate revenue to the federal government.

[2] Following the Swiss council, six variations are to be assessed (Bundesrat, 2018a): Flexible water fees (with a fixed and a variable part); fee on the resource rent; no federal maximum of the water fee, instead qualitative guidance; cantonal regulation only, no maximum given by federal level; levy on consumers e.g. via network surcharge (instead of holders of the concession); integration in the national fiscal equalization.

regimes? In addition, we also analyse the impact of differentiating the water fee by the plant types. Or in other words, what is the impact if run-of-river and storage/pump-storage plants are affected by different water fee levels?

For our analysis, we combine a sample of cost data for 62 companies (Partnerwerke) with revenue data derived from an electricity market model Swissmod (Schlecht&Weigt, 2014) based on the WASTA (BFE, 2016, 2017) data base. We match cost and revenue data in order to calculate net profits of hydro power under different water fee approaches.

We analyze different sets of scenarios for the years 2020, 2025 and 2030. Specifically, we distinguish between four market developments ranging from optimistic to pessimistic developments of electricity prices. Furthermore, we analyze five water fee scenarios, including three regimes, today's regime and a scenario without water fees. Finally, for the flexible regime we analyze three different ways how to define the reference market price which determines the water fee level.

The following main insights emerge: First, electricity market price developments dominate the water fees, i.e., for the profitability of hydropower, electricity prices are more important than water fee levels. Second, for a range of electricity prices of 40-60 CHF/MWh, water fees can make a difference. Third, there is a larger variance between individual plants than between water fee scenarios. Fourth, a uniform water fee favors storage/pump-storage compared to run-of-river, which are favored by a differentiated water fee. Fifth, the water fee scenarios have a high impact on the water fee revenues for the cantons, which receive up to 60% less compared to today's water fee regime. Sixth, flexible water fee regimes (partly) shift the risk from producers to resource owners. The extent of this risk shift depends on the detailed design of the flexible regime.

Existing literature has analyzed cost of hydropower in Switzerland (Filippini&Geissmann, 2014, 2018) and the design of a resource rent based system – as alternative to the current water fee regime (Banfi&Filippini, 2009). We contribute by relating production cost to revenue options, both for different assumptions of market development and for different water fee approaches.

The remainder of this paper is organized as follows. In the next Section, we present the situation of hydropower in 2015 and explain the cost data construction and the electricity market model, which we use to calculate revenues of hydropower. Section 3 presents the scenario design for future market conditions and water fee regimes. Sections 4 and 5 present the impacts on profitability of hydropower and owners, respectively. Section 6 analyses the impact of different reference market prices. Section 7 concludes.

2 A first look at the data

The aim of this section is twofold. First, we provide some policy context on water fees in Switzerland and present the economic situation of Swiss hydropower in 2015 based on our data set. Second, we describe the construction of the cost data and the electricity market model Swissmod, which we use to derive electricity prices and revenues of hydropower.

2.1 The situation of Swiss hydropower in 2015

The water fee level has been adjusted several times since its introduction in 1918 when it started at a level of 6 CHF/PS (around 8.16 CHF/kW). The last increase was in two steps from 80 CHF/kW to 100 CHF/kW and 110 CHF/kW in January 2011 and 2015, respectively. Launched in 2008 by a parliamentary initiative, the last increase was justified with higher peak and balancing electricity prices, the higher value of energy storage as well as the compensation for inflation (Bundesrat, 2018a). However, soon after the increase of the water fee maximum the situation changed and the electricity wholesale market prices and corresponding profits of hydropower plants were falling. The economic crisis, the low prices of coal and CO_2 certificates as well as subsidies for renewable energies in European countries, that also reduced the spread between peak and off-peak prices, have led to a significant drop in overall electricity wholesale market prices: Peak prices dropped from 152 CHF/MWh in 2008 to 44.79 CHF/MWh in 2016 and the spread from 34 CHF/MWh to 3.5 CHF/MWh (Bundesrat 2018a). These developments significantly decreased the revenue options of hydropower, particularly for storage and pump-storage plants. Therefore, the profitability of hydropower plants got under pressure.

Figure 1 shows the average production cost and revenues for the 62 companies in our sample. The average cost levels using a financial cost accounting is about 53.2 CHF/MWh, of which 12.0 CHF/MWh or 23% are due to water fee payments. This implies that costs net of water fees are 41.2 CHF/MWh on average. Revenues on the same time only amounted to 46.5 CHF/MWh.[3] Hydropower plants therefore on average suffered from net losses in 2015/16. However, without water fees they would still have been profitable.

This difference between cost and revenues illustrates that there is a disconnection between the variable profits of hydropower plant owners (depending on electricity prices in a very volatile market environment) and fixed water fees. This development is additionally enhanced by the partial liberalization of the electricity market in Switzerland, i.e., producers can no longer sell (all) their electricity at generation cost to captive customers, but have to sell at market prices.[4] These

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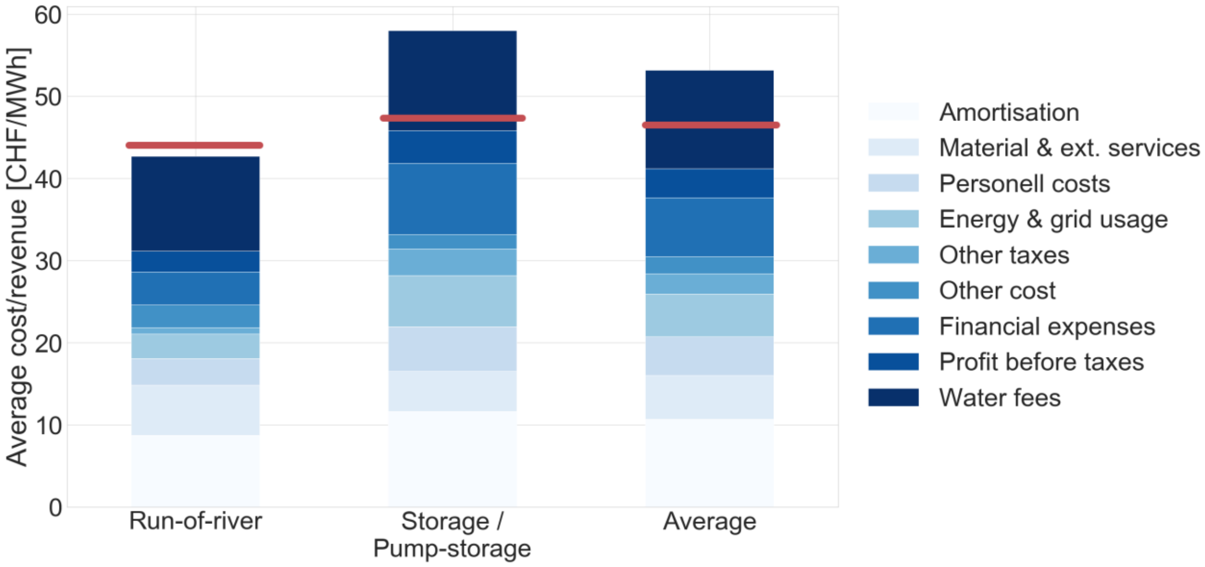
[3] In 2015 we observe a simulated day-ahead market price of 43.6 CHF/MWh.

[4] In Switzerland can large consumers choose their suppliers since 2009 (first part of liberalization). It is likely, that after 2020 also small consumers (households) can choose their suppliers (complete liberalization).

developments, and the legal requirement to review the water fee levels by 2024, have led to a recent discussion of a reform of the water fee regime. The currently most likely policy option are flexible water fees, which level depends on electricity market prices, i.e., water fees are higher when economic conditions for hydropower are good and lower when they are difficult.

Figure 1: Production costs in 2015/16 (using financial cost accounting)



Notes: Red lines indicate average unit revenues. (Revenues do not consider captive customers.)

Currently there is one fee level, relevant for all plants. However, there is substantial heterogeneity between plant types (and also between power plants) regarding cost, water fee payments and revenues. Figure 1 distinguishes between the two categories run-of-river (RoR) and storage / pump-storage (Sto/PSP). The cost structure of the company types varies significantly, with companies classified as storage / pump-storage showing significant higher cost levels (58.0 CHF/MWh) compared to run-of-river plants (42.7 CHF/MWh). The main reason for the difference between the two categories are the PSP, which have higher cost due to three main reasons: Firstly, pump-storage plants are more capital intensive than the other technologies because their technological complexity is higher. Secondly, they incur higher operating costs due the electricity consumption to pump water at times of low prices. Thirdly, several large construction projects were undertaken in recent years (e.g. Linth Limmern) to expand the pump-storage capacity in Switzerland, which increases capital costs of this technology.

The share of the water fee of the total production costs is 27% or 11.6 CHF/MWh for run-or-river and 21% or 12.2 CHF/MWh for storage/pump-storage. This implies that costs net of water fees are 31.2 CHF/MWh for run-or-river and 45.9 CHF/MWh for storage/pump-storage. And also the revenues differ between the two plant types: Storage/pump-storage having much higher revenue options at 47.4 CHF/MWh, due to their possibility to dispatch electricity during peak price periods, versus

44.1 CHF/MWh for run-of-river plants. However, due to a reduction of peak prices and price spread in recent years, also these technologies got under economic pressure.

In a flexible water fee regime this heterogeneity could be accounted for by individual water fees based on differentiated reference market prices, which determines the level of the water fee. Possible options are average electricity prices, peak prices, individual prices depending on the revenue possibilities of each technology or firm, etc.

2.2 Data construction and model overview

We first show the construction of the cost data; we then present the electricity market model, which we use to derive electricity prices and revenues; finally, we comment on the matching of the two data sets to calculate net profits.

2.2.1 The cost of hydropower

The cost are derived for a balanced panel data set of 62 hydropower companies for the years 2015 and 2016. Most of these companies are so-called “Partnerwerke”, which means that different utilities are jointly holding the concession for a hydropower plant. Based on the annual reports, income statements, and balance sheets, financial information is gathered and combined with the amount of electricity generated, the pump energy consumed, and the accumulated installed generator power, as provided by the Swiss Federal Office of Energy (SFOE) in the statistics of hydropower plants in Switzerland (WASTA).

Following Filippini and Geissmann (2014, 2018), hydropower companies can be classified into four distinctive technical categories reflecting the predominant technology of the stations operated by a company. However, for the purpose of this study, we only distinguish between the two categories run-of-river and storage / pump-storage[5] resulting in the following number of types covered by our sample: 36 run-of-river companies, 28 storage / pump-storage companies. Although only around 25 % of the hydropower plants listed in WASTA belong to the 62 companies surveyed, this sample represents around 63% of total expected hydro generation. Looking at individual plant types, it represents around 86 % of the total expected storage production, 76 % of the expected pump-storage production (79% of total combined storage / pump-storage generation), and around 44 % of the expected run-of-river production in 2016.

[5] A company is categorized as run-of-river if at least 50% of the expected yearly generation stems from run-of-river stations. Analogously, a company is of type storage / pump-storage if at least 50% of the expected electricity generation is generated by storage units.

In general, the calculation of the production cost of hydropower companies can be estimated from a financial or imputed costs perspective.[6] For our analysis we currently use a financial cost perspective. Some results using imputed cost perspectives can be found in the Appendix.

2.2.2 Modelling prices and revenues

As the electricity market in Switzerland is only partially liberalized, revenues consist of two parts: a) revenues from selling electricity on the free market, and b) revenues from sales to captive customers.

For the market revenue estimates, we rely on simulation runs with Swissmod—a Swiss and Central European electricity market model developed at the University Basel (Schlecht&Weigt 2014). Swissmod is a classical cost minimizing or welfare maximizing dispatch model which is based on a DC-Load-Flow Approach. It represents Switzerland in detailed spatial resolution (approx. 230 nodes and 400 transmission lines) while the surrounding countries Austria, Germany, France and Italy are aggregated. Beside the detailed network representation, Swiss hydropower is represented in high detail (approx. 400 hydropower stations/ 96% of Swiss hydropower production). Hydropower revenues are derived from the simulated hydropower dispatch (generation and pumping) and the resulting market prices. While Swissmod reproduces the dynamics of the day-ahead spot market, the market revenues do not include additional revenue options from future, intra-day or system service markets.

Regarding the revenue from captive customers, we assume that the tariffs are based on the underlying generation cost level; the revenues consist of the unit cost of the electricity production (including costs of equity) multiplied with the amount of electricity sold to captive customers. As we expect full market liberalization starting in 2021, we only consider captive customers in 2015 and assume the market to be fully liberalized for all future scenarios.

2.2.3 Matching cost and revenue data

To calculate the net profitability of hydropower companies, we need to match the revenue data, which we calculate on a plant level, to the cost data, which are only available on a company (“Partnerwerk”) level. Using publicly available data on the plants that belong to a company, we manually match the two data sets. During this process we drop some information on the revenue side, as our company sample only includes around 63% of total hydropower production while the revenue side can be calculated for 96% of total production.

[6] The imputed costs perspective is based on exogenous values of the interest and return on equity as proposed by Filippini and Geissmann (2018). For the imputed costs, a weighted average cost of capital (WACC) of 5 % is assumed (see Filippini and Geissmann (2018) for a description of the derivation of this number).

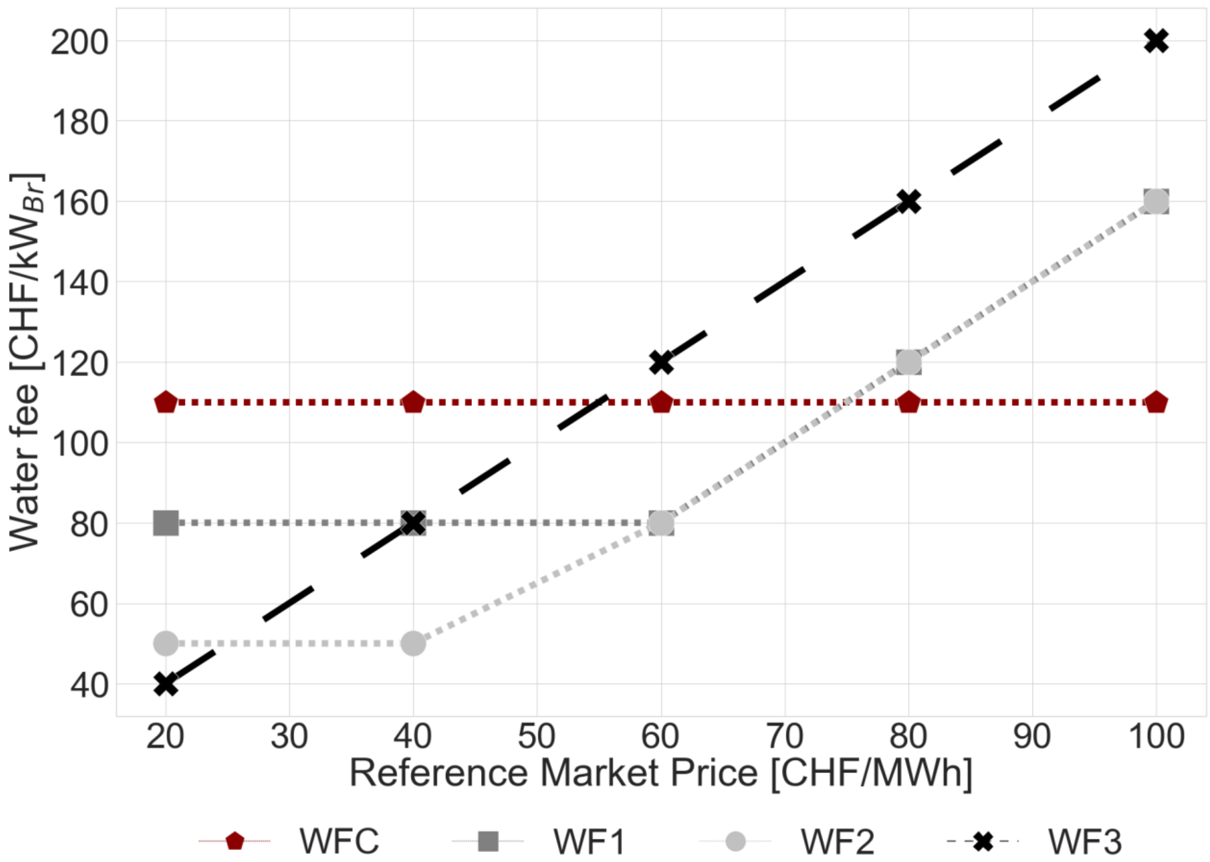
3 Scenario design: Water fee design options under various electricity market developments

After presenting the situation in 2015/16 and the rational for flexible water fees, we now turn to future developments. In this section, we introduce five different water fee approaches, based on the current political discussion in Switzerland. We include three flexible approaches, the current fix water fee level and the total removal of water fees, to analyze a broad range of design options. Then, we present four different fuel and carbon price developments for the years 2020, 2025, and 2030, and how they define the revenues of hydropower. The combination of five water fee approaches and four electricity market developments results in twenty different scenarios for each year.

3.1 Water fee scenarios

The main idea of flexible water fee regimes is that the water fee level depends on a reference price which reflects the revenue possibilities of hydropower. It can be either completely flexible (WF3) or consist of a fix part (minimum fee) and a flexible part which starts when the reference price reached a given value (WF1, WF2). In this case, three parameters need to be determined: What is the minimum fee? From which reference price does the flexible price start? How steep is the slope?

Figure 2: Selected water fee scenarios



Notes: Own scenarios based on Bundesrat (2017) and BFE (2018).

Figure 2 and Table 1 show three different flexible water fee approaches as well as the current fix water fee (WFC) at a level of 110 CHF/kW$_{Br}$ and the situation in which all water fees are removed (WF0). Two flexible scenarios contain of a fix minimum water fee level of 80 CHF/ CHF/kW$_{Br}$ for WF1 and 50 CHF/kW$_{Br}$ for WF2, respectively and a flexible part with a slope of two, starting at a reference market price of 60 CHF/MWh (WF1) or 45 CHF/MWh (WF2). The reference market prices of 45 or 60 CHF/MWh respectively, reflect the range of market conditions in which water fee levels determine whether hydropower is (on average) profitable or not. The third scenario (WF3) is completely flexible and the level of the water fee (WF) is given by WF = 2P.

Table 1: Water fee scenarios

Approach	Water fee (WF)	
WF0	No water fee	WF = 0
WFC	Current water fee level	WF = 110 CHF/kW$_{Br}$
WF1	Partly flexible water fee	WF = 80 + max(2P-60,0)
WF2	Partly flexible water fee	WF = 50 + max(2P-45,0)
WF3	Comletely flexible water fee	WF = 2P

Notes: Own scenarios based on Bundesrat (2017) and BFE (2018).

How exactly the reference market price is defined, also needs to be determined. Different options are discussed in Section 6. Until then, we use the average unit revenue of hydro production as reference price, which, in turn, is highly dependent on the wholesale electricity market price.

3.2 Possible market developments for fuel and carbon prices

When water fees are flexibly designed, market developments play an important role. To analyse a broad range of possible developments, we use four different fuel and carbon price assumptions (see Table 2), which result in different developments of the wholesale electricity market price (see Figure 3) and revenue options for hydropower (see Figure 4) for the years 2020, 2025, and 2030.

Table 2: Fuel and carbon price developments

Name	Fuel and carbon price development
Base 2015	Fuel and carbon prices as in 2015
EU	Fuel and carbon prices as in EU Reference Scenario (European Commission, 2016)
C++F++	Fast linear increase in carbon price (50€/t in 2030) and fuel prices (+100% until 2030)
C--F--	Linear decrease in carbon price (4€/t in 2030) and fuel prices (-50% until 2030)

The scenarios are meant to capture a range of possible market developments and are not to be seen as a forecast of the most likely developments. The underlying demand and power plant portfolio (generation capacities) develop according to the Swiss energy perspectives 2050 (Prognos, 2012) for Switzerland and the EU Reference Scenario (European Commission, 2016) for the Swiss neighboring countries. Furthermore, the four price scenarios are based on real 2015 values, i.e. without inflation or changes in exchange rate[7], and the assumption of a completely liberalized market. Thus, it is not distinguished anymore if, and to what degree, a company distributes electricity to captive customers. Consequently, the resulting price patterns and revenue estimates provide an indication of market income potentials for Swiss hydropower companies, but are not meant to capture all market and trading possibilities (i.e. future and intra-day trading, system services, special end-user tariffs for green/local production, etc.).

Under *Base*, we assume, that fuel and carbon prices stay constant at their 2015 levels, this implies that price changes are only due to changes in available capacities. In this case, prices decrease from 2015 to 2020, and from then start to increase again. In the other three possible developments, we additionally alter fuel and carbon prices as described in Table 3. For increasing fuel and carbon price developments (*C++F++* and *EU*) electricity prices are assumed to significantly increase after 2020 up to more than 100 CHF/MWh in 2030. In the case of decreasing fuel and carbon prices (*C--F--*), electricity prices are expected to drop below 40 CHF/MWh throughout the next decade.

Summarizing, the resulting price pathways (see figure below) show a rather steady or even declining trend for 2020 but large diversions in the years after; leading to a difference of about 60 CHF/MWh between the low and high fuel price assumptions in 2025 and 100 CHF/MWh in 2030. This highlights the resulting large variability in price levels and the high dependency of the European market prices as general drivers (fuel and carbon prices).

[7] For the conversion from Euro to CHF, we use an exchange rate of 1.0679 CHF/€ in 2015 and 1.0902 CHF/€ in 2016 (European Central Bank, ECB, 2019: www.ecb.europa.eu/stats).

Figure 3: Average simulated day-ahead market price by scenario

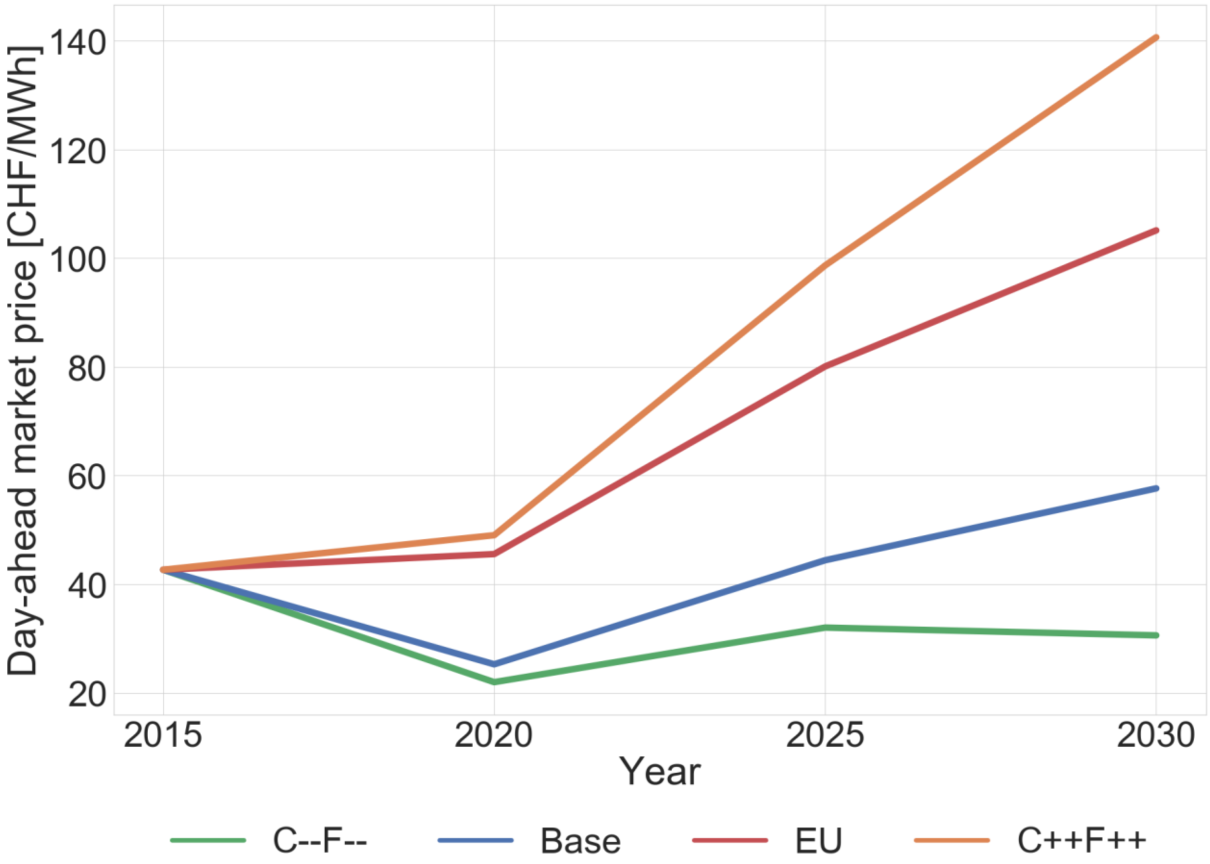
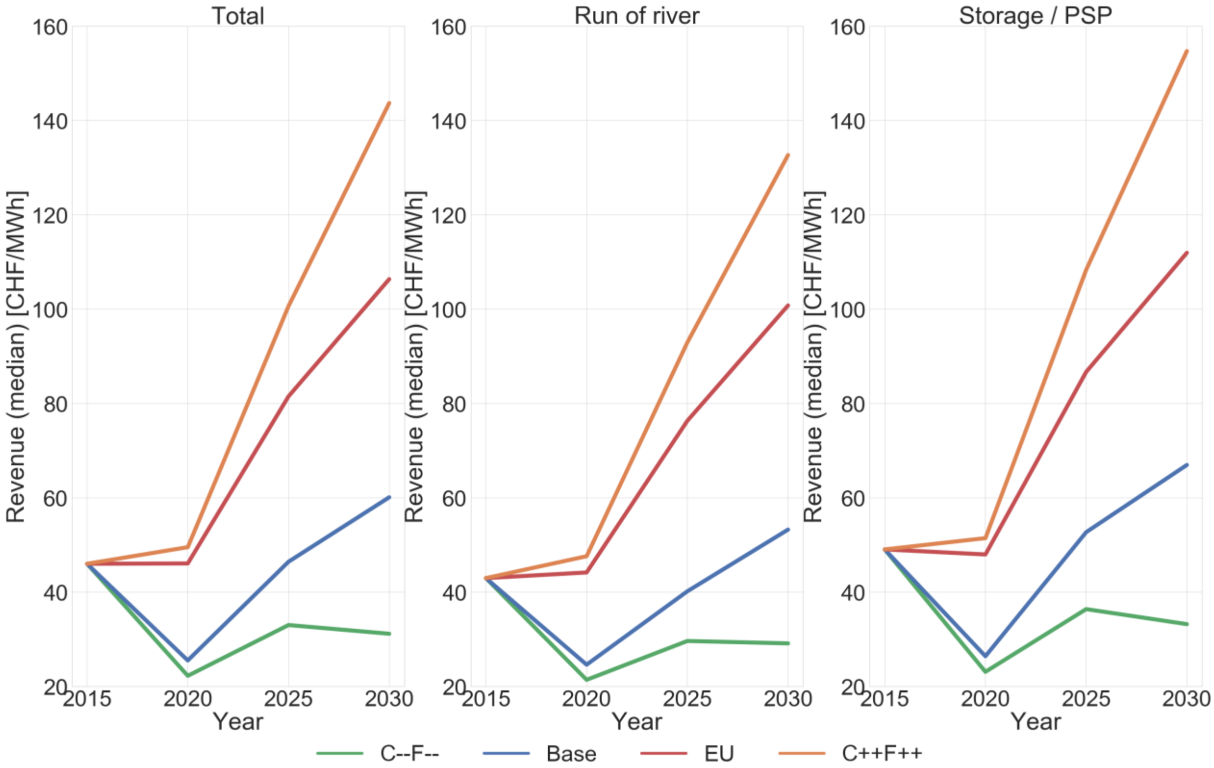


Figure 4 shows the expected revenues for the different categories. We find that expected revenues are higher in the case of storage/pump-storage compared to run-of-river throughout all scenarios. Compared to the day-ahead prices in Figure 3, unit revenues are very close in the case of run-of-river, which are continuously producing electricity, but significantly higher for storage/pump-storage facilities, which can dispatch their electricity during high price periods.

Figure 4: Hydropower revenues for different fuel price scenarios



4 Companies perspective

We now turn to the results. This section presents the combined effects under different market developments and water fee approaches scenarios on profitability of hydropower. We start by presenting an overview up to the year 2030 and then take a closer look at the year 2025 – one year after the potential introduction of flexible water fees. After presenting aggregate impacts by technology, we focus on the heterogeneity between individual power plants.

4.1 Overview Development 2015 to 2030: Market dominates water fee

Assuming costs (net of water fees) to stay constant at their 2015/16 levels[8] and given the simulated revenues, we can calculate expected net profits. Figure 5 shows the net profitability of hydropower up to 2030 for the four different price and five water fee scenarios. From this figure, we get the following main insights:

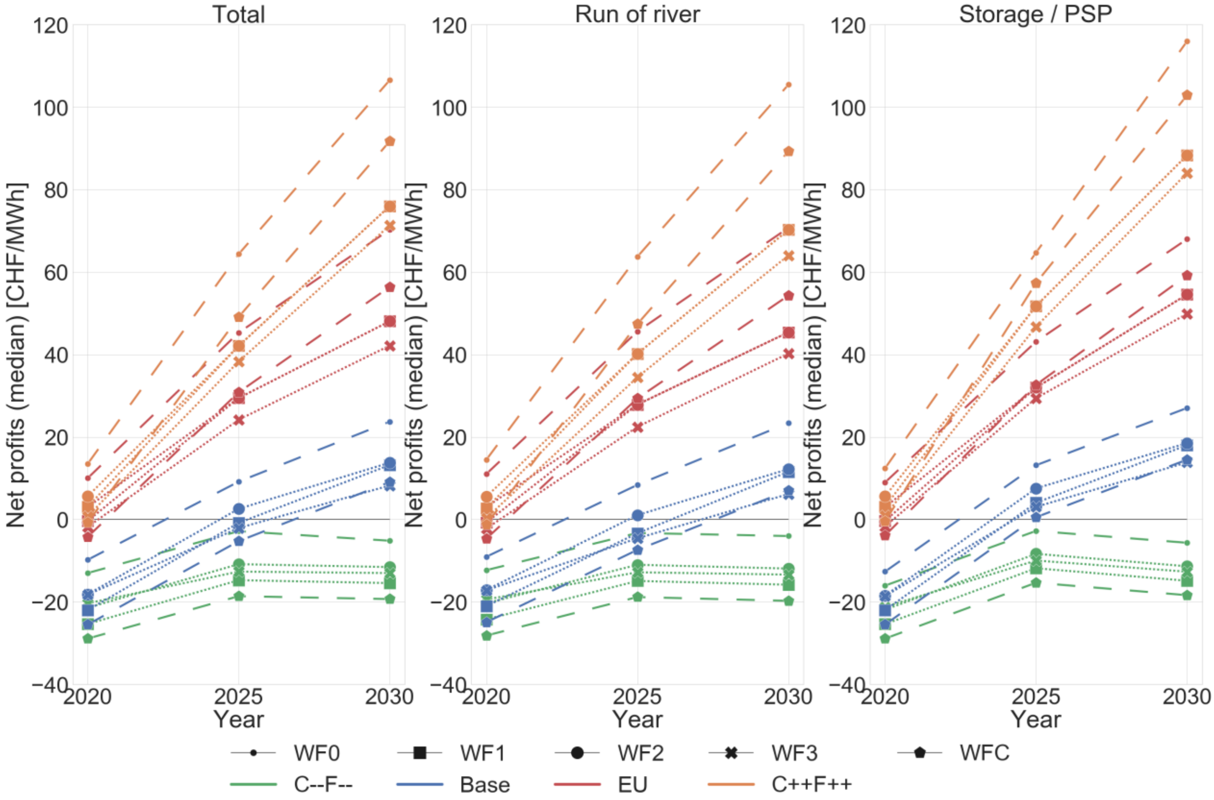
First, we find that the market impacts dominate the impact of water fees: In situations with high electricity prices, hydropower plants on average make profits – even if water fee levels are very high.[9] If, on the other hand, electricity prices are low, hydropower plants on average make losses – even if water fees are zero.

Second, for the *Base* market development in the year 2025, the level of water fees decides whether hydropower plants – on average - are profitable or not. The electricity market price is then at a level slightly above 40 CHF/MWh. Within this range of around 40 to 50 CHF/MWh, cost without water fees correspond to revenues. Consequently, water fee levels can make the difference between profit and loss.

[8] Again, we use real 2015 values, i.e. without inflation or changes in exchange rate.

[9] This was the situation, which we observed for a long time up to around five years ago.

Figure 5: Net profits of hydropower for different scenarios



4.2 Closer look at the year 2025

As discussed above and shown in Figure 5, for most fuel and carbon price scenarios water fees do not decide whether hydropower is profitable or not. Therefore, we do not analyse all the scenarios in detail, but focus on the results for the year 2025. We chose this year for two reasons. First, the flexible fee is likely to be implemented by 2024. Second, the electricity prices of two scenarios in 2025 are close to 40 to 60 CHF/MWh, where water fees can make a difference for the profitability of hydropower.

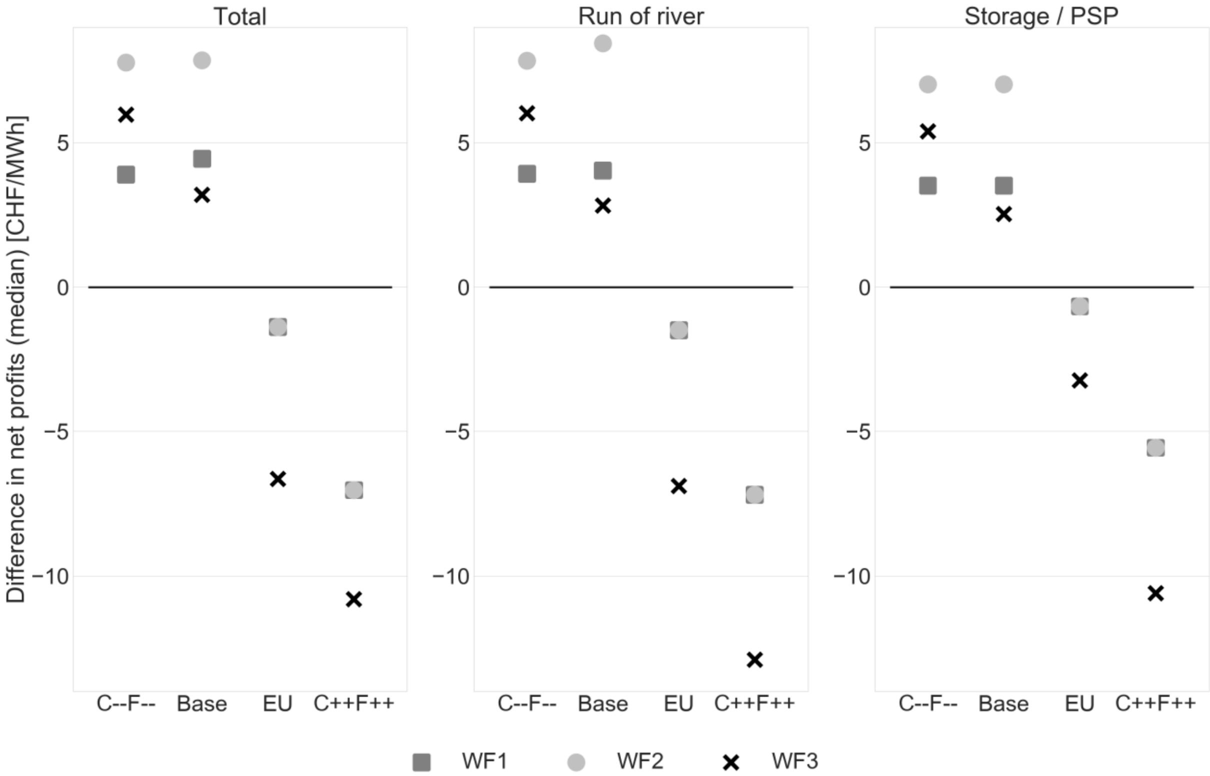
4.2.1 Aggregated impacts

Figure 6 shows the difference in net profits (median) in 2025 for the different price and water fee scenarios – compared to the current water fee level of 110 CHF/kW$_{Br}$.

Naturally, we observe that flexible water fee regimes lead to relatively higher profits when the reference price is low. Vice versa, they lead to relatively lower profits, when the reference price is high. Hence flexible water fees can reduce some of the pressure on profitability of hydropower. Also, the more flexible the water fee is designed, the more pronounced is this effect, e.g. compare the completely flexible WF3 to WF1 with a minimum fee of 80 CHF/kW$_{Br}$.

Note that under the most pessimistic market development (*C--F--*), net profits are higher under the completely flexible approach (WF3) compared to the partly flexible approach with a minimum fee of 80 CHF/kW$_{Br}$ (WF1). In contrast, under the *Base* development, this situation changes and profits are higher for the partly flexible scenario. This switch can be explained as follows: Under *C--F--* (*Base*) the reference market price lies below (above) 40 CHF/MWh. Given the different water fee approaches in Figure 2, this implies a constant water fee level of 80 CHF/kW$_{Br}$ in the case of WF1, but a level of below (above) 80 CHF/kW$_{Br}$ for the *C--F--* (*Base*) development in the case of WF3.

Figure 6: Difference in net profits compared to current water fee level for 2025

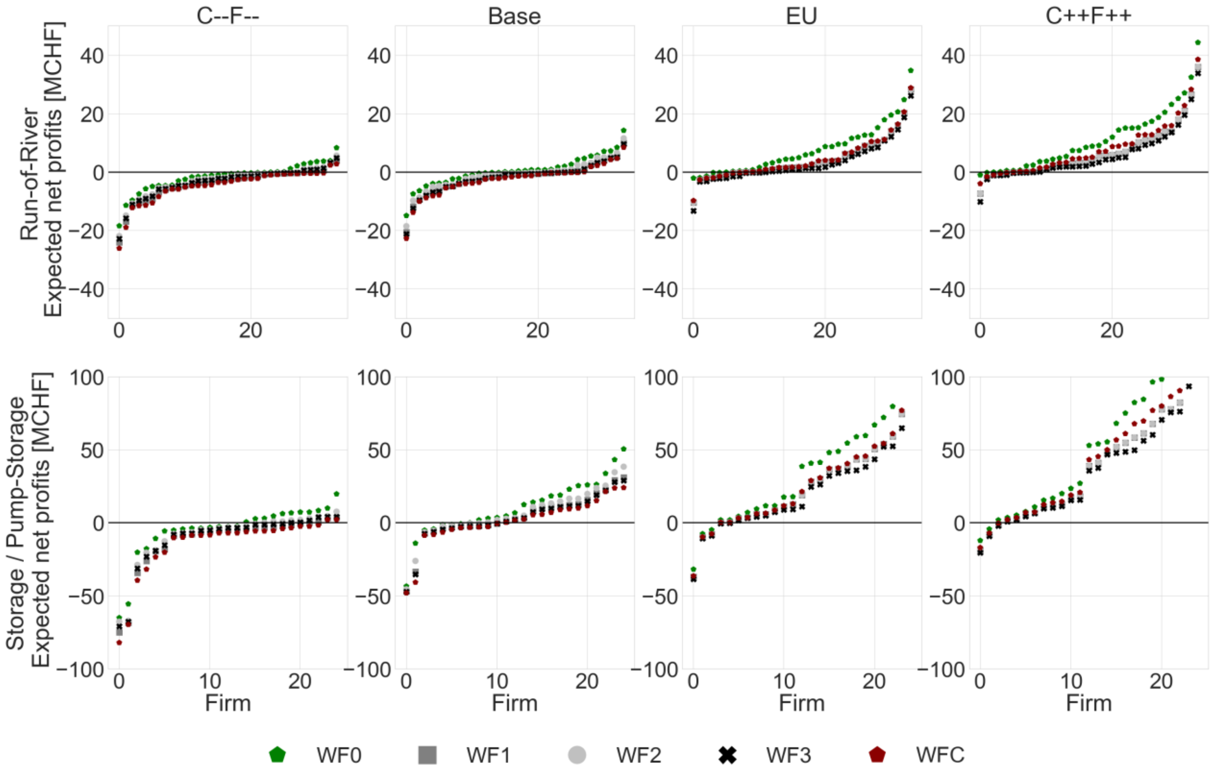


4.2.2 Company level impacts

Until now, we have focused on aggregated impacts or average/median impacts over our company sample. However, there are large differences in unit production cost and revenue possibilities for the different companies. We therefore now turn to a detailed analysis of the impacts of water fee scenarios on expected net profits in 2025 for all companies in the sample shown in Figure 7.

The figure shows a very large variability across firms, yet we can observe the following patterns: First, as expected, in scenarios with high prices, more firms make net profits, when prices are low, they mostly suffer losses. Second, within each price scenario, the water fee level makes the difference between profit or loss for a couple of plants. Although on average the impact of the water fee scenarios is again shown to be much smaller compared to the impact of price scenarios. Third, for all price and water fee combinations there are both, firms that make profits and firms that incur losses. This implies that the variability across firms (for a given scenario) is for many cases larger than the variability induced by different water fee levels. Fourth, there is a larger difference between firms in the case of storage / pump-storage firms while run-of-river companies are more similar. Also the variation of the impact across different water fee scenarios is higher in the case of storage / pump-storage firms – although being relatively small anyway.

Figure 7: Net profits per company in 2025



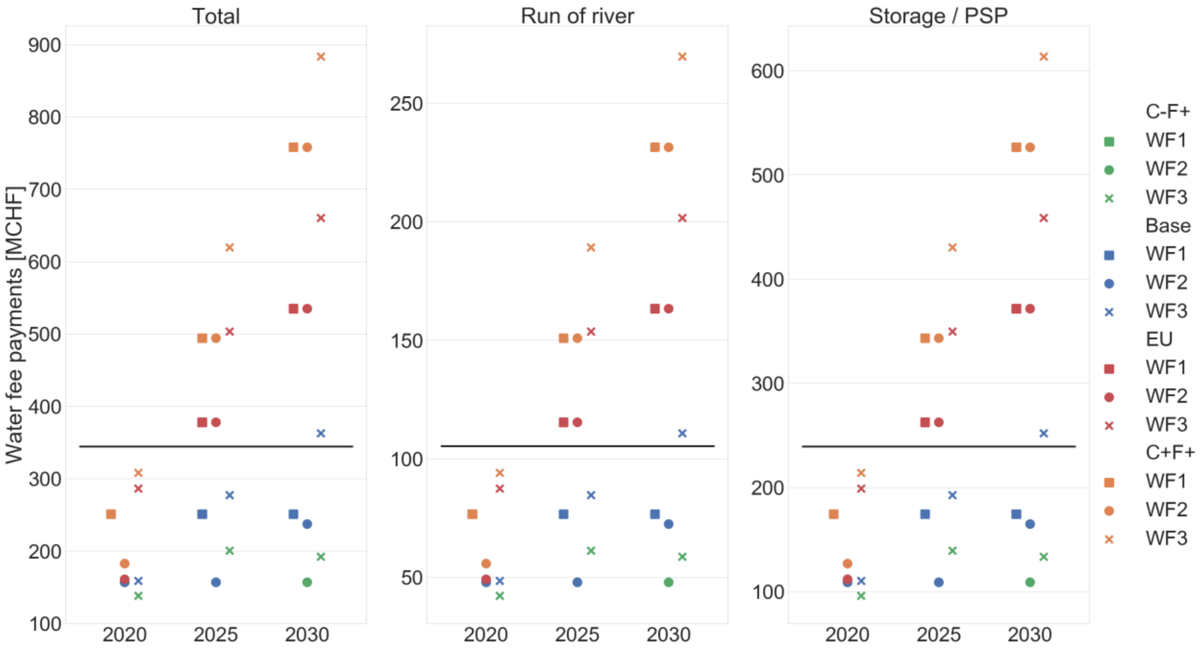
5 Cantons' perspective

While until now we only looked at the producers' perspective, a new water fee regime would also affect the cantons and communities who receive water fee revenues. Again, we first present an overview and then focus on the impacts in the year 2025.

5.1 Overview Development 2015 to 2030

Figure 8 shows the water fee payments for the different price and water fee scenarios. In line with the company's perspective, we find that in years with high electricity prices revenues are higher than under today's water fee regime. However, in years with low electricity prices, revenues can be substantially lower. Also, for the most flexible scenario (WF3) the differences in revenues are largest, whereas in the case of WF1 it is smallest, as this scenario has a relatively high minimum water fee level.

Figure 8: Water fee revenues

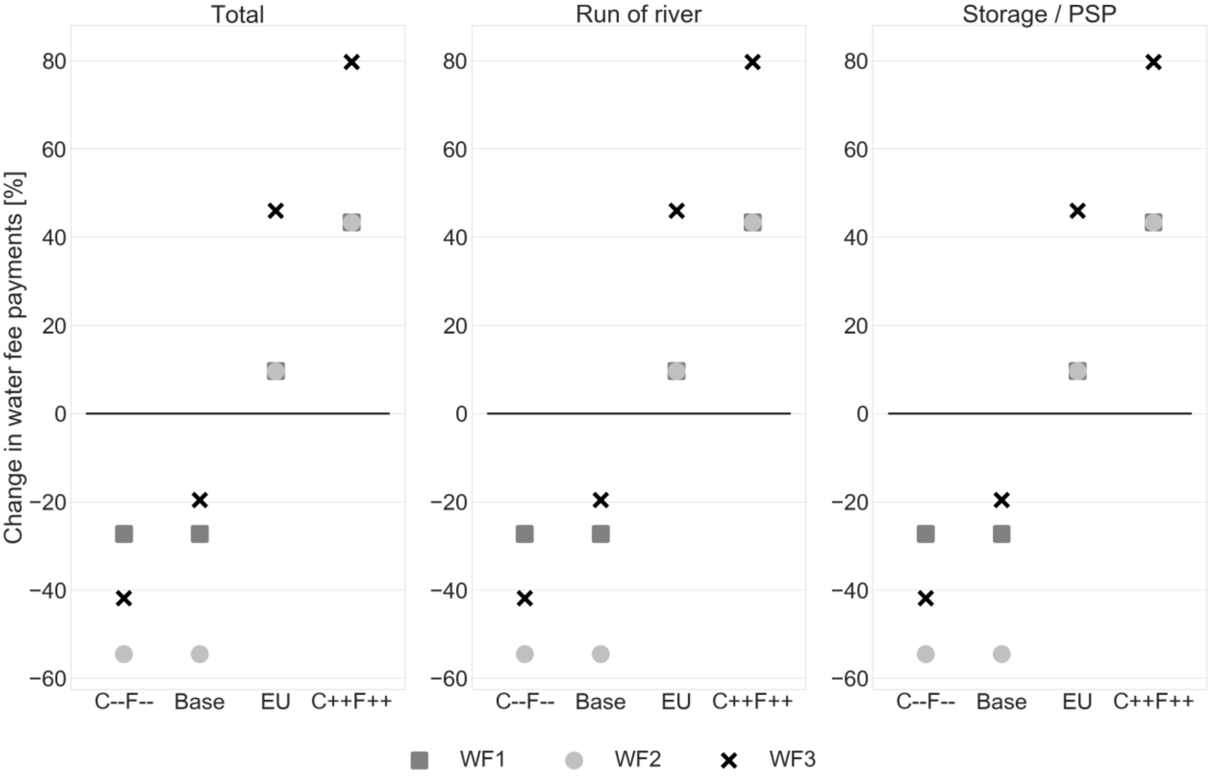


Note: The black line represents today's water fee payments of the plants in our sample.

5.2 Closer look at the year 2025

Figure 9 shows for the year 2025 how the water fee revenues change relative to the current water fee regime. We find that for low reference prices, the water fee revenues of flexible scenarios can be up to almost 60% smaller compared to the current level; for high reference prices, on the other side, water fee revenues can be up to 80% higher compared to the current level.

Figure 9: Water fee revenues in 2025



5.3 The impact of ownership structures

In our analysis we distinguish between producers, which have to pay the water fees, and resource owners, which receive the payments. However, in reality these structures are more complex as hydropower companies in the end are mostly owned by the cantons. While the resource owner cantons which receive the payments are mostly mountain cantons, the cantons which own the hydropower companies are mostly low-land cantons. This means that water fees are some form of income shift from (richer) low-land cantons to (poorer) mountain cantons. Consequently, lower water fees favor on average richer cantons while higher water fees favor on average poorer cantons. But, of course, there are also many feedback effects depending on the ownership structures, which are not considered in this paper. For more information see Betz et al. (2018).

6 Impacts of different reference market prices

So far we only considered one possible design with respect to the underlying reference market price (RMP) for the definition of the water fee level. Given that this is in itself a design element we now look at different options to define the RMP and assess its potential impact.

6.1 Reference market price scenarios

There are several options how the RMP can be determined. The currently most likely policy option, on which the calculations in this paper are based so far, is to define the RMP as the average unit revenue[10] (*Rev*). We now turn to the analysis of two alternative options: First, we consider a RMP which is given by the yearly average spot market price of electricity (*Spot*), which would be the simplest and most transparent option. However, it would not account for the fact that some hydropower plants can adjust their production according to the price, i.e., shift their production to hours with high electricity market prices. Second, we use the average unit revenue *per technology* (*Rev_diff_type*) as RMP, i.e., we have different RMP and consequently water fee levels for run-of-river and storage/pump-storage plants. On the one side, this option accounts for the varying revenue options of different plant types; on the other hand, it is more complex to implement, and less transparent than the other two options.

In summary, when defining the reference market price, policy makers face a trade-off between being simple and transparent and taking into account the different realities of individual producers. By analyzing the three different options described above and summarized in Table 3, we can provide a first estimation of the magnitude of the impact. Or in other words: Is it worth to make things complicated?

Table 3: Reference market price scenarios

Scenario	Definition of reference market price (P)
Spot	Yearly average spot market price
Rev	Yearly average unit revenue for an aveage hydropower plant
Rev_diff_type	Unit revenue differenciated by type

6.2 Impacts of reference prices

Before turning to the impact of different RMP definitions on water fee payments, we analyse how much they differ. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the RMP for the year 2025 for the three scenarios. We find the following patterns: First, in most cases, spot prices are very close to unit revenues of run-of-river plants. In contrast, unit revenues for storage/pump-storage

[10] In reality, not only revenues from the wholesale market but also from the markets of "Regelleistung" ("Systemdienstleistungen" SDL) and "Herkunftsnachweise" (HKN) would be taken into account. However, for our analysis we only consider wholesale market revenues.

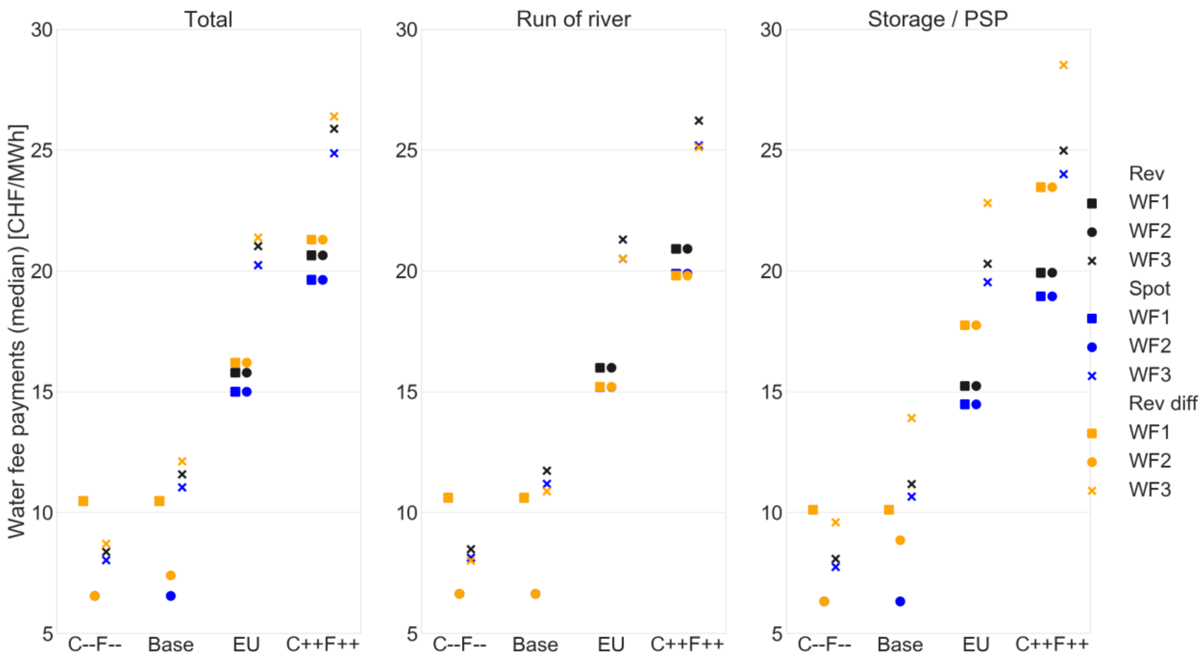
are significantly higher. Consequently, unit revenues of an average plant are slightly higher compared to spot market prices, as they include characteristics of both plant types.

Table 4: Reference market prices in 2025 [CHF/MWh]

	Spot	Unit revenue		
		Uniform	Differentiated	
			RoR	Sto/PSP
C—F--	30.6	32.0	30.2	37.9
Base	42.2	44.2	41.0	55.0
EU	77.3	80.3	77.3	90.2
C++F++	94.9	98.8	94.6	112.8

Combining the different RMP with the water fee scenarios defined in Figure 2 and Table 1, different water fee levels arise. Figure 10 shows average water fee payments by plant type for different RMP definitions in the year 2025. We find the following: First, spot prices lead to slightly lower water fee payments than unit revenues, however, differences are very small. Second, on average the differentiated RMP lead to higher water fees compared to the uniform price. Third, in the case of differentiated RMP, there is a difference between the two technology types: They lead to slightly lower water fees for run-of-river plants, but they substantially increase water fees for storage/pump-storage plants. This result reflects the fact, that storage/pump-storage plants can make use of peak prices, i.e., they have higher revenue possibilities compared to run-of-river plants. This result is especially pronounced for scenarios with high price levels.

Figure 10: Water fee payments for different reference price scenarios



Summarizing, the current definition of the RMP as average unit revenues leads to slightly higher water fee levels than the simpler option of taking the spot prices. Using differentiated RMP would be favourable for run-of-river plants which would have to pay less, but disadvantageous for storage/pump-storage plants, which would have to pay higher water fees.

6.3 Distributional implications

Again, this has distributional implications for the cantons: As storage/pump-storage plants are mainly located in mountain regions, these regions suffer more in the case of a uniform RMP when storage/pump-storage pay comparably less. On the contrary, when water fees are differentiated accounting for individual revenue options, i.e., storage/pump-storage would pay more, mountain regions suffer comparably less from a flexible water fee regime.

Flexible water fee regimes shift the risk from producer to resource owners, or in other words from low land cantons to mountain regions. Differentiated water fee levels, on the other side, increase the water fee payments for storage/pump-storage plants, i.e., increase revenues for mountain regions. Consequently, by differentiating the water fee levels, the risk shift from producers to resource owners still prevails, but the shift from low land to mountain cantons is partly countered. How much those effects impact the financial streams between cantons (and to other shareholders) is beyond the scope of this paper.

7 Conclusions

Instead of a tax on the resource rent, Swiss hydropower plant operators pay a fix water fee to the owners of the water resource right, i.e., cantons and municipalities. This water fee regime has two main implications. First, the level of the water fee is not based on economic but on physical principles; second, income streams from water fees are relatively constant and only vary with the water availability, therefore the whole market risk lies with the producers. Consequently, due to the recently difficult economic situation, Swiss hydropower producers call for a change in the water fee regime, which shifts part of the market risk from producers to the owners of the resource. The currently most probable option are flexible water fees, which would include the revenue potential, and thus be linked to electricity prices. However, as this would lead to lower revenues for resource owners during years with low electricity prices, cantons and municipalities are reluctant to accept a more flexible design.

This paper contributes by analyzing the impacts of different water fee reform options – and how they depend on market conditions – by taking on the one hand the perspective of hydropower producers namely electricity companies and on the other hand the perspective of recourse owners namely cantons and municipalities who receive the payments. For our analysis, we combine a sample of cost data for 62 companies (Partnerwerke) with revenue data derived from an electricity market model. We match cost and revenue data in order to calculate net profits of hydro power under different water fee approaches.

The following main insights emerge: First, electricity market price developments dominate the water fees, i.e., for the profitability of hydropower, electricity prices are more important than water fee levels. Second, for a range of electricity prices of 40-60 CHF/MWh, water fees can make a difference by pushing some plants from losses to neutral or making some profits. Third, there is a larger variance between the cost, revenue and profit situations of individual plants than between water fee scenarios. Fourth, a uniform water fee favors storage/pump-storage compared to run-of-river, which are favored by a differentiated water fee. Fifth, the water fee scenarios have a high impact on the water fee revenues for the cantons, which may receive up to almost 60% less compared to today's water fee regime depending on which scenario is chosen. Sixth, flexible water fee regimes shift the risk from producers to resource owners, or in other words, from low land cantons to mountain regions. This effect can be partly balanced if water fee levels are differentiated and account for different revenue options. In this case, storage/pump-storage plants pay higher water fees than run-of-river, thus mountain regions profit more.

However, to interpret these results some limitations of our analysis need to be taken into account. First, we only have data for a subset of all Swiss hydropower plants, which represents around 63% of total hydro generation. Second, we assume cost (net of water fees) to remain constant throughout the whole period of analysis. Third, a more thorough analysis of the distributional impacts between mountain and low land regions would require a more detailed analysis of the ownership structures of hydropower plants (see also Betz et el. 2018) and is left for further research.

Notwithstanding these caveats our analysis shows, that one year after their expected introduction in 2024, flexible water fees could reduce total water fee payments by up to 200 million Swiss Francs, or around 8 CHF/MWh, if the pessimistic market development realizes. Comparing these number to the "Marktprämie" of 101 million Swiss Francs (on average 7.4 CHF/MWh for around 13 GWh of hydro production) paid in 2018, we find that flexible water fees could replace subsidies to reduce the economic pressure on hydropower plants. However, this naturally would come at the expanse of those cantons receiving water fees. Thus, the final design of a new water fee regime will need to take into account the risk distribution between the different involved parties as well as their financial capabilities to manage changing income streams.

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The project progress can be traced on the project homepage:

https://fonew.unibas.ch/de/projects/ongoing-projects/nfp70-futurehydro/

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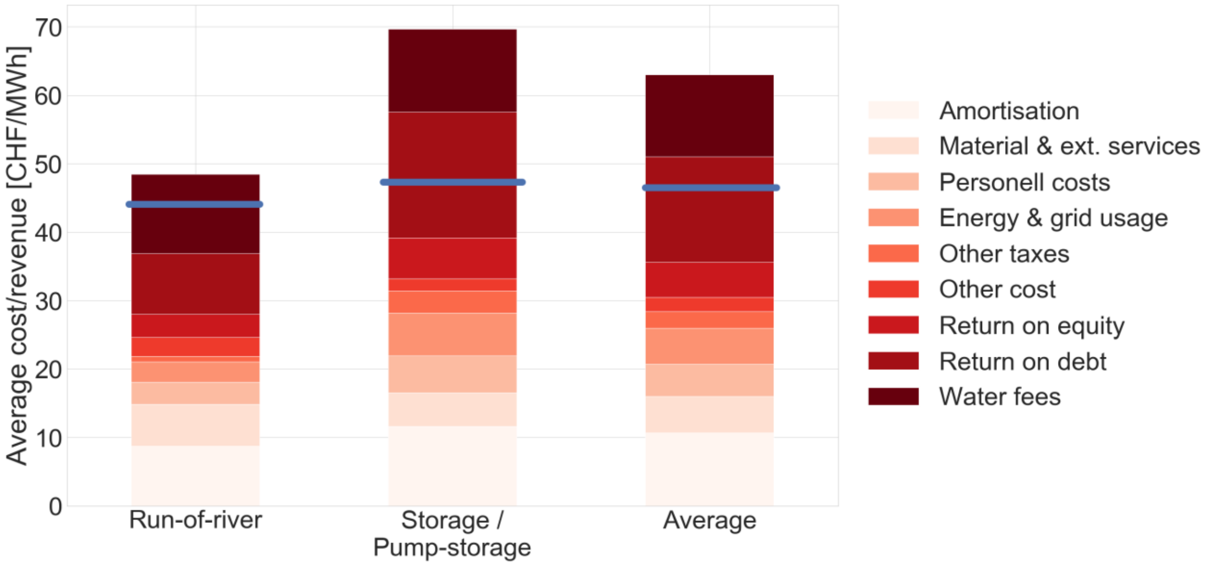
Appendix

Imputed costs

Figure 11: Production costs in 2015/16 (using imputed costs)



Average net profits for different scenarios

Figure 12: Net profits of hydropower for different scenarios