Task 4.3

Title

Socio-economic-political drivers

Projects (presented on the following pages)

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Downstream fish guidance systems with horizontal bars

Julian Meister, Helge Fuchs, Robert Boes – VAW, ETHZ

1. Motivation and Objectives

The natural behavior of many fish species involves the migration of up to hundreds of kilometers within river systems. This migration is impeded since the construction of hydropower plants (HPPs). Therefore, the European Water Framework Directive (WFD) and the Swiss Water Protection Act (WPA) demand to restore the free up- and downstream migration. While many HPPs were already successfully equipped with upstream passage facilities, downstream fish passage facilities are still under development.
The "Fishfriendly Innovative Technologies for hydropower" project (FIThydro) was launched as part of the Horizon 2020 EU Research and Innovation program to promote the development of innovative technologies for sustainable and fish-friendly operation of hydropower plants in Europe. As one part of FIThydro, the current research project focuses on the hydraulics and fish guiding efficiency of horizontal bar rack bypass systems (HBR-BSs). Operational aspects like clogging with organic fines will be investigated and live fish experiments will be conducted to quantify the fish guiding efficiency.

2. Introduction to HBR-BSs

HBR-BSs are considered state-of-the-art of fish downstream migration in Europe (Ebel, 2016). They consist of two main elements: (1) the bar rack itself to prevent fish from entering the turbines and (2) the bypass to safely guide the fish to the downstream reach (Fig. 1). To keep the hydraulic losses low, automated rack cleaning systems are used to minimize clogging. Although a number of HPPs were equipped with HBR-BSs in the last decade at small- to medium-sized HPPs (Q_d < 88 m³/s), there is still a lack of systematic studies on the optimization and verification of these state-of-the-art downstream fish passage facilities.

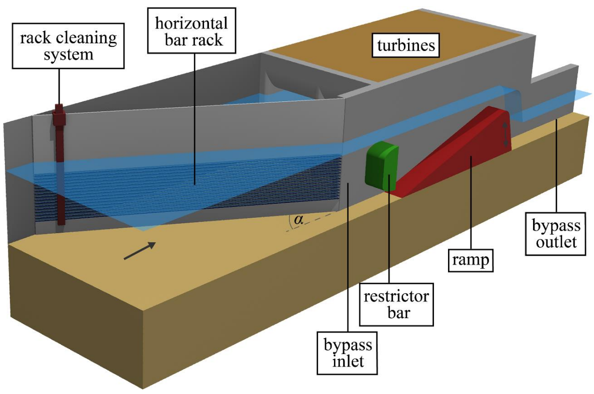

Fig. 1: Principle sketch of a HBR-BS, adapted from Ebel (2016)

3. Experimental setup

To fill the described research gaps, hydraulic experiments with horizontal bar racks (HBRs) are conducted in a laboratory flume (Fig. 2a). The flow depths upstream h_o and downstream h_{ds} of the rack are measured using Ultrasonic Distance Sensors (UDSs) and the velocity field is measured using an Acoustic Doppler Velocimeter (ADV). The governing parameters are the horizontal approach flow angle to the rack α, the clear bar spacing s_b, the bar depth d_b and the cross-sectional bar shape (Fig. 2b). Additional bottom and top overlays can be used to enhance the guiding efficiency for bottom and surface orientated migrating fish.

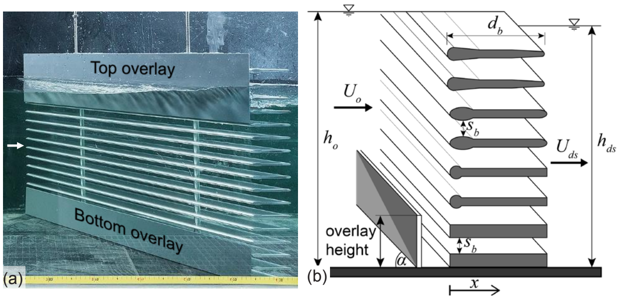

Fig. 2: (a) Laboratory experiment on a HBR with bottom and top overlays
(b) Definition sketch for governing HBR parameters

4. First results

Fig. 3 shows the velocity fields of HBRs (a) without overlays and (b) with a 40% overlay blocking (20% bottom and top overlay each) at mid water depth for an approach flow velocity U_o = 0.5 m/s.

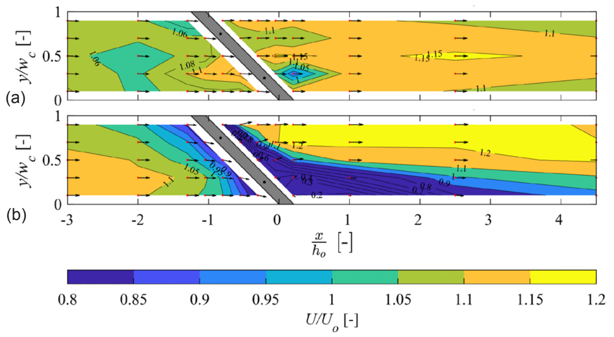

Fig. 3: Velocity fields of HBR with foil-shaped bars, α = 45°, s_b = 20 mm (a) without and (b) with 20% overlay blocking by bottom and top overlays each

The flow field at the rack without overlays is almost unaffected with a homogeneous velocity distribution (Fig. 3a). In contrast, for a configuration with overlays the approach flow is decelerated and a rack-parallel velocity component establishes (Fig. 3b), thereby increasing the guiding efficiency for fish, bed load material and floating debris. Disadvantages of overlays include the larger hydraulic losses and the asymmetrical downstream velocity field, leading to uneven turbine admission and therefore reduced turbine efficiency.

5. Conclusion and Outlook

HBR-BSs are considered as state-of-the-art fish downstream passage facilities in Europe. Despite the successful operation at prototype HPPs, several research questions remain. First laboratory experiments demonstrate small hydraulic losses and minor effects on the velocity field of configurations without overlays, indicating a great potential for further applications. Future experiments will focus on operational aspects of HBR-BSs and the fish guiding efficiency.

6. References

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Fishfriendly Innovative Technologies for hydropower (FIThydro) Swiss case studies HPP Bannwil & HPP Schiffmühle

J. Meister, C. Beck, H. Fuchs, I. Albayrak, R. Boes

Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH Zürich, Switzerland

Introduction

Two case studies at run-of-river hydropower plants (HPPs) in Switzerland are conducted within the scope of the interdisciplinary "Fishfriendly Innovative Technologies for Hydropower (FIThydro)" project which is funded by the Horizon 2020 framework program (grant agreement No 727830) of the European Union for research and innovation. The investigations focus on the velocity field (ADCP measurements and numerical modeling), the monitoring of fish downstream migration, and the sediment connectivity.

Run-of-river hydropower plant Bannwil

The run-of-river HPP Bannwil is a block-unit power plant at the River Aare in Switzerland (Fig. 1) with a design discharge of 450 m^3/s. The gross head amounts to 5.5 – 8.5 m depending on up- and downstream water levels. The three 4.35 m diameter bulb turbines have an installed capacity of 28.5 MW, resulting in an average annual production of 150 GWh. The downstream Aare reach features nine run-of-river HPPs and two nuclear power plants with water abstractions for cooling.

Fig. 1: Head water of block-unit HPP Bannwil with the turbine intakes in the background (Photo: VAW)

Restoration targets

The target fish species in that Aare reach are salmon and barbel. For upstream migration, a fish pass is installed which has to be renewed until 2020. Downstream migrating fish are routed through the turbines or over the weir in case of flood events. Fish protection and bypass systems have to be installed until 2025.

Field measurements within FIThydro

Within the FIThydro project, 250 fish will be equipped with radio-telemetric tags. Their migration routes in the vicinity of the HPP will be observed for 2 years. The fish behaviour will be further observed with DIDSON sonar systems at specific locations (e.g. in front of the intake rack).

VAW will conduct ADCP measurements of the velocity field (Fig. 2) and will set up a 3D numerical model. Hydraulics and fish data will be evaluated to assess the current situation and the effectiveness of operational measures (e.g. spill flow). Furthermore, the installation of a fish guidance structure with vertical bars and an adjacent bypass system will be considered in the numerical study.

Fig. 2: ADCP measurements downstream of HPP Bannwil (Photo: VAW)

Partners: BKW, PETER FISHCONSULTING

Residual flow hydropower plant Schiffmühle

The HPP Schiffmühle is located at the River Limmat some 30 km downstream of Zurich. The 400 m long Schiffmühle side weir divides the river into the headrace channel of the main HPP and the residual flow reach. The residual flow HPP is located at the upstream end of the side weir and is equipped with a 1.45 m diameter bulb turbine to use the residual flow for electricity production. With a gross head of 2.97 m and a design discharge of 14 m^3/s the installed capacity is 285 kW. The annual electricity production is 1.9 GWh corresponding to the electricity consumption of approx. 430 households. Aiming at a natural sediment continuum, a vortex tube was installed on the headrace channel invert at about half the channel length to divert bed load material into the residual flow reach (Fig. 3a). The residual flow HPP Schiffmühle is equipped with a natural fishway and a vertical slot fish pass for upstream migration. In 2013 it was equipped with a horizontal bar rack bypass system for fish downstream passage (Fig. 3b). Resulting from the lateral HPP intake, the horizontal bar rack is arranged parallel to the main flow. The bars with rectangular profiles have a clear spacing of 20 mm. The approach flow velocity at design discharge is 0.5 m/s. At the downstream rack end 3 bypass openings are located at different water depths (near-bottom, mid-depth, and near-surface) leading into a vertical shaft. The subsequent downstream passage into the residual flow reach is provided via a 0.25 m diameter bypass pipe.

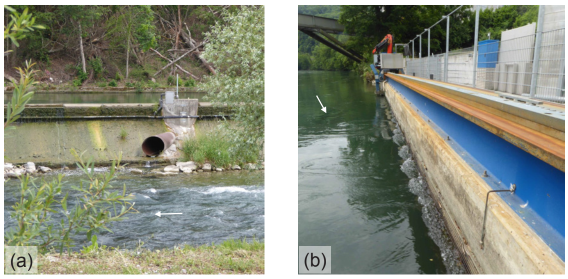

Fig. 3: (a) Vortex tube connecting the headrace channel with the residual flow reach (Photo: VAW)
(b) Horizontal bar rack for fish protection (Photo: VAW)

Field measurements and numerical modeling

The velocity field around the residual flow HPP Schiffmühle will be measured with an ADCP. More than 1000 individual fish will be marked with PIT-tags to monitor their migration. To track their swimming paths, all upstream and downstream migration corridors are equipped with RFID antennas. To quantify the sediment balance, the bed load transport in the vortex tube and sediment deposition and erosion will be monitored. For the residual flow reach the investigations include sediment sampling, habitat and shelter mapping and the quantification and numerical modeling of flow conditions.

Partners: LKW Limmatkraftwerke, NTNU, PETER FISHCONSULTING

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Downstream fish guidance systems for large run-of-river hydropower plants

C. Beck, I. Albayrak, R. Boes – VAW, ETHZ

1. Motivation and objectives

Run-of-river hydropower plants (HPPs) disrupt fish migration routes decimating fish populations worldwide. While various technologies for the fish upstream migration technologies are well developed, there is still a lack of knowledge on downstream fish passage technologies with regard to fish species, hydraulic conditions and operational issues at HPPs.

The main goal of this research study is to develop a fish protection and guidance technology for downstream migrating fish with minimum impact on power plant production or operation. The focus lies on fish guidance systems with vertical bars (i.e. louvers and angled bar racks) for large HPPs with design discharges above 100 m³/s (Fig. 1). The present study contributes to a fish-friendly and sustainable usage of hydropower.

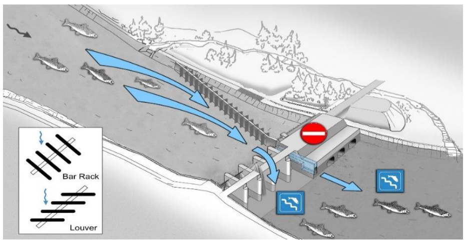

Fig. 1: Fish guidance structure with bypass at a run-of-river HPP

2. Fish guidance structures with innovative bar design

Although modified bar racks (MBR) developed based on louver design provide high fish guidance efficiency (Kriewitz, 2015), they still negatively impact HPP production due to high head losses and poor admission flow quality. To mitigate these negative effects an innovative curved bar design was developed (Fig. 2). In the present study, these so-called *modified curved-bar racks* (MCR) are studied with regard to hydraulic conditions and fish guidance.

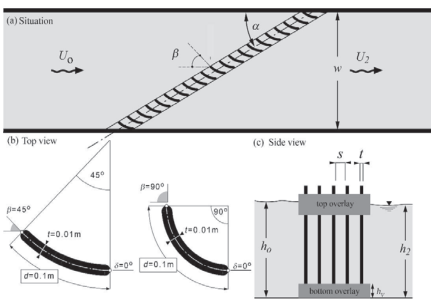

Fig. 2: Geometric and hydraulic rack parameters of modified curved-bar racks (a) rack top view, (b) bar shape top view, (c) side view

3. Research plan

To meet the objectives, different models are set up (Fig. 3). The effects of main rack angle, bar angle, bar spacing, bar depth and top or/and bottom overlays on the hydraulic head losses and flow fields at MCRs are studied in a 1:2 scaled detailed model (cf. Fig. 2). Different bypass systems are developed and optimized with 1:1 scaled experiments. Fish guidance efficiencies (FGE) of the optimized MCR-bypass system are assessed with life-fish tests. Finally, operational issues such as large wood accumulation and sediment transport are investigated.

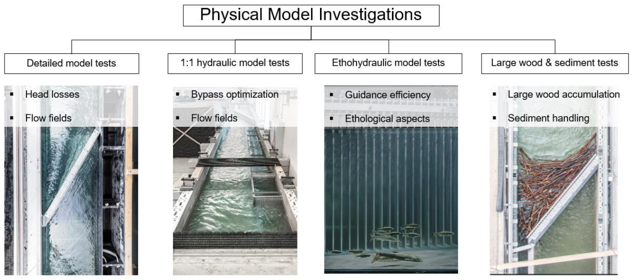

Fig. 3: Different model setups to optimize the design of FGS and bypass and maximize the FGE

4. First results

With the new bar shape, head losses are significantly reduced. The head losses of MCRs are up to 5.5 times lower than those for MBRs and are in the same range of $0 \leq \xi_R \leq 3$ as for most trash racks used at Swiss hydropower plants (Meusburger, 2002). The bar angle β has the largest effect on head losses and the flow field as shown in Fig. 4. Upstream of the rack, flow velocities steadily increase up to 1.25 U_o and 1.85 U_o for β = 45° and β = 90°, respectively. The mild acceleration for β = 45° is a good indication for a high FGE (Boes & Albayrak, 2017). Fig. 4a also shows the flow straightening effect of curved bars with β = 45° resulting in a quasi-symmetrical velocity distribution downstream of the rack as compared to the low admission flow quality for β = 90° (Fig. 4b). In the next step, the recommended MCR configuration with α = 30°, β = 45° and s = 50 mm (Fig. 4a) will be tested in the 1:1 model and with live-fish experiments.

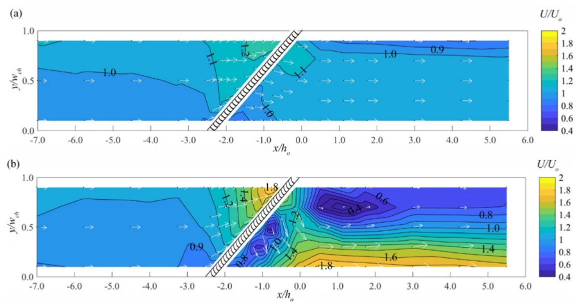

Fig. 4: Measured flow field of U/U_o at MCR configuration α = 30°, s = 50 mm (a) β = 45° and (b) β = 90°.

Given the highly reduced head losses and improved flow field, MCRs present a promising potential over louvers and MBRs for fish protection and guidance facilities at HPPs.

5. References

Kriewitz, C. R. (2015). Leitrechen an Fischabstiegsanlagen – Hydraulik und fischbiologische Effizienz (Guidance racks at fish passage facilities – Hydraulics and fish-biological efficiency). VAW-Mitteilung 230, R. M. Boes, ed., Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH Zurich, Zürich, Switzerland [in German]

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Media Analysis on Hydropower: First Results

Dr. Corinne Moser (ZHAW), Dr. Selma L'Orange Seigo (ETHZ), Fabienne Sierro (ETHZ) & Dr. Olivier Ejderyan (ETHZ)

Goals of the project

- Identification of most important media frames on hydropower (HP) in Switzerland
- Complementing media analysis on deep geothermal energy DGE (already completed; Stauffacher et al. 2015, Ejderyan et al., 2019)
- Providing a basis to test impacts of media frames on public acceptance of hydropower
- Exemplary headlines (Source: tagi.ch, nzz.ch):

SCHWEIZ

Zukunftsängste der Wasserkraft-Gemeinden

Die veränderte Lage auf dem Strommarkt hat Auswirkungen auf die bedrohlichen Strategien

Wasserkraft vor Durststrecke

Studie des Bundes ortet langfristig eine schlechte Rentabilität von Kraftwerken

Die tiefen Strompreise verhindern Investitionen in die Wasserkraft. Laut einer Studie des Bundes ist eine Entspannung noch lange nicht in Sicht.

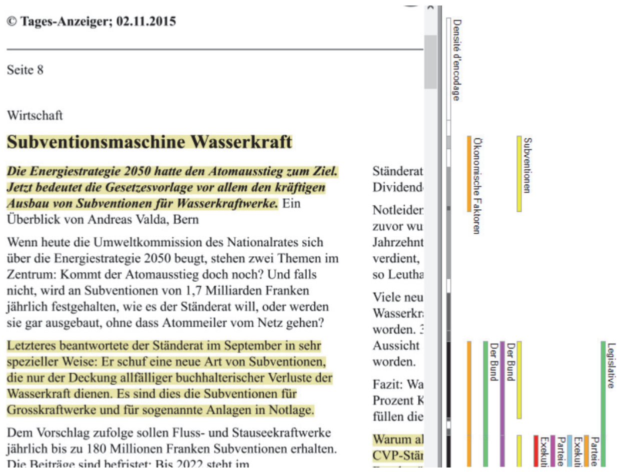
Brisante Studie zur Wasserkraft

Eine neue Untersuchung der ETH Zürich relativiert die Schwarzmalerei der Branche

HANSUELI SCHÖCHLI

Method

- Coding of newspaper articles (NZZ, Tages-Anzeiger, Le Temps)
- Timeframe: 1.01.2011-31.12.2017
- Key words: hydropower, energy strategy (DE: Wasserkraft + Energiestrategie / F: "stratégie énergétique» + barrage, «énergie hydraulique»)
- *N* = 170 articles
- Coding tree has been developed iteratively
- Coding was done with the software N'Vivo (illustration below)



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Seite 8

Wirtschaft

Subventionsmaschine Wasserkraft

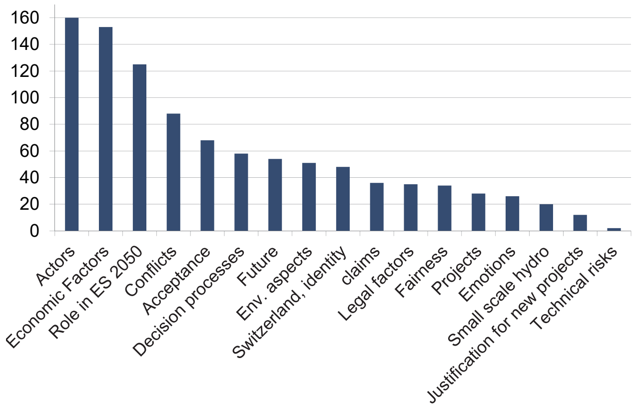
Die Energiestrategie 2050 hatte den Atomausstieg zum Ziel. Jetzt bedeutet die Gesetzesvorlage vor allem den kräftigen Ausbau von Subventionen für Wasserkraftwerke. Ein Überblick von Andreas Valda, Bern

Wenn heute die Umweltkommission des Nationalrates sich über die Energiestrategie 2050 beugt, stehen zwei Themen im Zentrum: Kommt der Atomausstieg doch noch? Und falls nicht, wird an Subventionen von 1,7 Milliarden Franken jährlich festgehalten, wie es der Ständerat will, oder werden sie gar ausgebaut, ohne dass Atommeiler vom Netz gehen?

Letzteres beantwortete der Ständerat im September in sehr spezieller Weise: Er schuf eine neue Art von Subventionen, die nur der Deckung allfälliger buchhalterischer Verluste der Wasserkraft dienen. Es sind dies die Subventionen für Grosskraftwerke und für sogenannte Anlagen in Notlage.

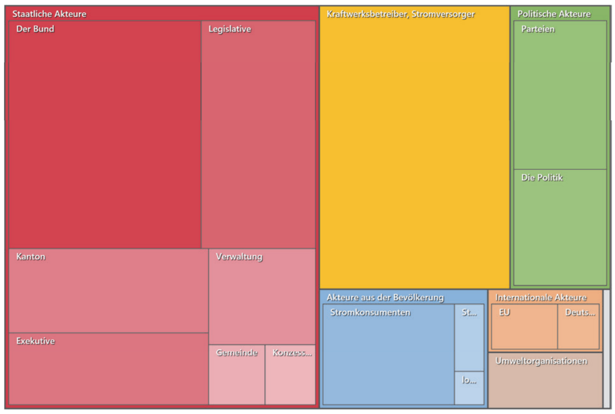
Dem Vorschlag zufolge sollen Fluss- und Stauseekraftwerke jährlich bis zu 180 Millionen Franken Subventionen erhalten.

Results: Frequencies of superior codes



- HP is mainly framed as an economic issue with important themes being the level of subventions received by the industry, falling market prices, remittances and current investment levels
- HP is presented as having an important role in the Energy Strategy 2050 because of its energy storage capacity and complementary role to other renewables
- HP is framed as a conflictual issue. Environmental conflicts are reported but most often conflicts about economic factors

Results: Most frequently mentioned actors



- Operators and the federal state are the mains actors appearing in media reports
- The public appears mostly as consumers

Preliminary conclusions

- HP in the ES 2050 is mostly discussed as an economic issue and from the perspective of the operators and the (federal) state
- Other actors appear as marginal.
- Technical risks and periglacial hydropower are non-issues

References

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Challenges to Swiss hydropower. Perspective from cantonal authorities

Olivier Ejderyan [a], Fintan Oeri [b], Fabienne Sierro [a], Aya Kachi [b] ([a] ETH Zürich, [b] University of Basel)

Background and goal of the study

Cantons are the authority delivering the authorisation for the building of new hydropower (HP) infrastructure or improvement of existing ones. They are often shareholders in utilities operating HP plants. In some cases they might also own water rights and as such grant concession to operators. More generally, cantons are responsible for land use and energy planning, which makes them crucial actors for the development of Swiss HP capacity.

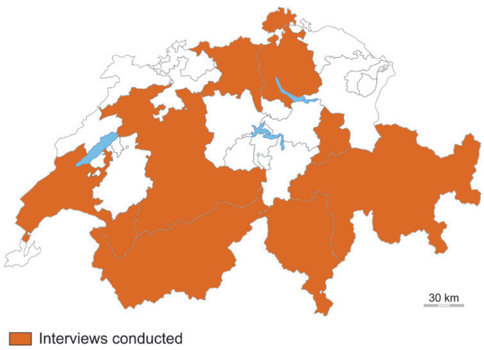
Yet public debates about the governance of Swiss HP focuses mainly on the Federal state and operators as the driving actors of HP. The role of mountain municipalities as concession givers is often discussed with regard to the amount of remittances they receive. The role of cantons is overlooked despite their key role.

In order to make relevant and realistic recommendations for the development of Swiss HP it is therefore necessary to examine the role of cantons. The goal of this study is to provide base knowledge to make relevant recommendations for decision-making in HP.

Methods

The study takes a practice based approach to identify the main challenges encountered by cantonal officers responsible for HP in their daily work.

- 9 Interviews with cantonal officers in charge of supervising authorisation processes for HP infrastructure
- Interviewed cantons cover 83% of Swiss HP production
- Theoretical sampling: Maximum variation in cantonal structure + wide coverage of production.
- Semi-structured narrative interviews to produce thick description of daily activities about HP
- Interviews covered five topics:
  - Challenges in daily work
  - Interaction with stakeholders
  - Public involvement
  - Description of projects
  - Vision for HP.



Map of interviewed cantonal authorities in charge of hydropower.

- Interviews are analysed through qualitative content analysis Explicit and implicit content of the interview is coded and statement categorised according to thematic closeness

Analysis of the interviews is ongoing.

First insights

The following first insights can be made from the analysis of the explicit content of the interviews:

Finances
In contrast to the main framing of HP in news media, financial questions are not considered as a pressing issue. Most cantonal officers believe that current discussions about profitability or remittances are conjunctural and will evolve.

"If we look into the future, when coal prices will rise again, when Germany will phase-out nuclear plants in 22, then things will look clearer."

"Some nuclear power plants were turned off in France in 2017 and immediately the price per KW/h went up. Just a few cents more and hydropower was again profitable."

Exemplary quotes on financial situation of HP

Conflicts with environmental goals
Dealing with environmental goals and regulations appears as the main challenge for cantonal HP practitioners. Primary cause in their perception are not environmental NGOs but the lack of coordination on priority goals between BFE and BAFU.

"Currently, things are floating. And we don't know exactly how courts will rule in the end. That does not make sense, does it? I would say that BFE and BAFU don't really agree with each other."

"In principle, we try to be constructive [in negotiations], and I believe that to a large extent, we are constructive. But in the end, it is clear that environmental NGOs also have their own policy"

Exemplary quotes on conflicts with environmental goals

Public engagement
Cantons do not play an active role in public engagement for HP projects. Negotiations with stakeholders are organised by operators. Cantonal officers see themselves as representatives of the public. They do not consider that the wider public should be more involved in discussions about HP projects.

"We have a water use strategy, in which we, the Canton, have formulated relatively clear goals. And it's validated by the parliaments. This means that there was a form of participation [of the wider public]. I mean they represent the public."

"The project applicant negotiates with NGOs. If an opposition is reached in, we inform the applicant."

Exemplary quotes on public engagement

Outlook

First results indicate that:
- Cantonal officers do not see Swiss HP as being in a deep crisis situation
- However they are rather skeptical about a strong expansion of Swiss HP capacities
- Cantons do not seem to hold an initiating role for HP development.
- A first result from the analysis of the implicit content of the interview indicates that Cantons have very little capacity to plan HP development.

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JA IDEA-HG:
Highlights from a first year of joint research

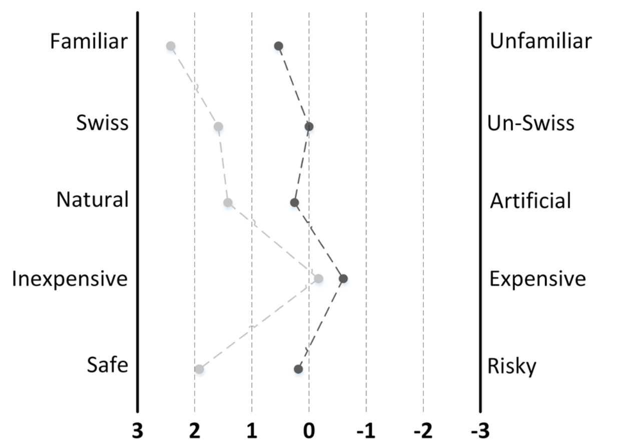
The JA IDEA-HG aims to provide recommendations on how to address conflict related to the legislative framework, governance sturctures and project development processes for hydropower (HP) and deep geothermal energy (DGE). During the first year, researchers worked on integrating methods and concepts developed in SCCER CREST and SCCER SoE. They conducted following tasks:
- Review of legal conditions for HP and DGE at cantonal level;
- Survey on how HP and DGE are perceived in relationship to the federal energy strategy;
- Media analysis on the discourse on HP;
- Interviews on challenges encountered by the authorizing offices in charge of HP

A stakeholder workshop gathering federal and cantonal officers, operators and NGOs from both discussed first insights and narrowed the main challenges to be addressed.

Exploring the role of beliefs in opinions about the energy strategy

In Work Stream 2, research conducted at pilot study to investigate support for HP and DGE within the energy strategy. The study found that while support for the energy strategy depends significantly on their beliefs, support for a specific technology does less so. The figure below illustrates the attributes associated to each technology by the respondants.

Technology attribute pairs



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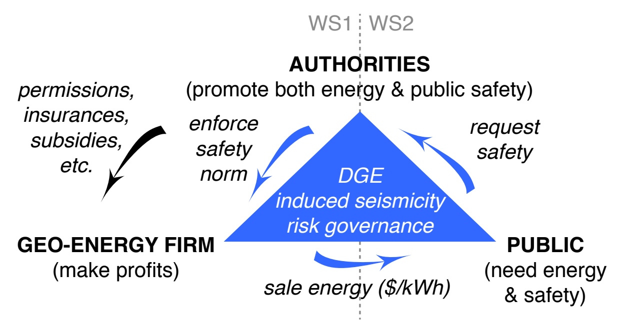
Regulating and governing risks to local communities by DGE projects

Researchers at ETHZ and ZHAW from Work Stream 1 developed an approach to make recommendations for regulating and governing DGE related seismic risk. They developed a regulatory sandbox with DGE electricity prices as main metric. It integrates a governance scheme with the goals and priorities of actors (see figure). The regulatory sandbox enables to assess problems and envision possible legislative solutions.



Authors: A. Mignan & G. Seferovic

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SCCER SoE SWISS COMPETENCE CENTER for ENERGY RESEARCH SUPPLY of ELECTRICITY — 70 NRP Energy Turnaround National Research Programme — SCCER CREST

The Future of Swiss Hydropower:
Distributional Effects of Water Fee Reform Options

Financial Flows from Water Fees and Fiscal Equalization on National and Cantonal Level

Background

a) Water fees are the remuneration to be paid by the hydropower operators to the owners of the water resource right (i.e. the cantons, etc.).

b) Fiscal equalization systems aim to mitigate differences between cantons/municipalities in their financial capacity and cost burden.

Research objectives

1. Analyze financial flows from water fees payments between cantons based on ownership through direct and indirect shareholdings:
   → Overview of ownership structure and attribution of water fee flows to shareholdings (Fig. 1)
2. Analyze the distributional effects within cantons:
   → Impact of water fees on municipal and cantonal finance in the canton of Grisons (Tab. 1)

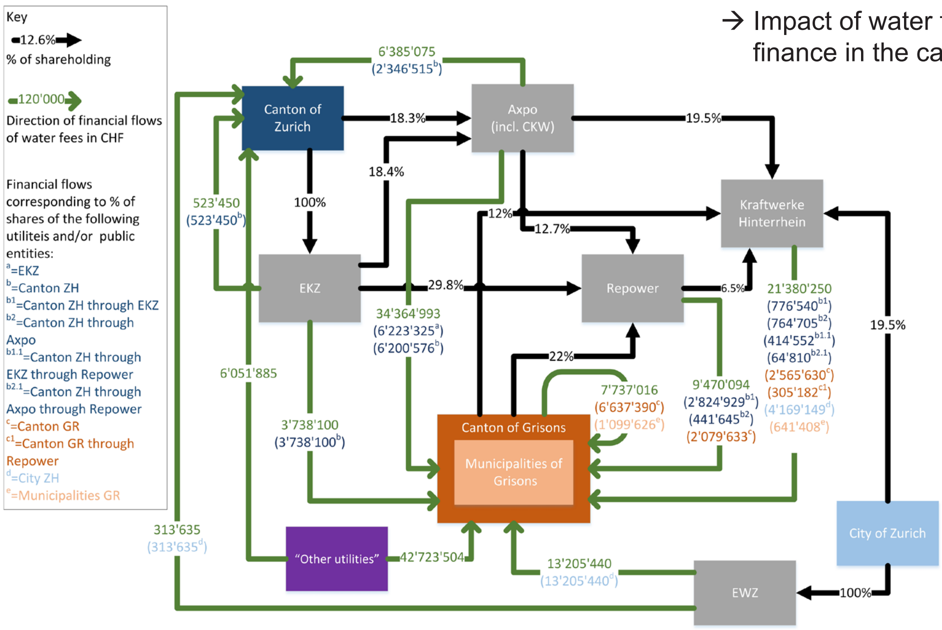

Figure 1: Hydropower in the cantons ZH & GR: shareholdings and financial flows (2016)

First results (objective 1)

The analysis of the shareholdings and **attribution of financial flows** from hydropower between ZH & GR shows (for 2016):

- The canton and municipalities of GR themselves account for approx. 11.5% of their water fee revenues.
- The canton and municipalities of ZH account for over 33% of Grisons' water fee revenues.
- More than 55% of water fee flows to GR are attributable to other cantons.

First results (objective 2)

In GR, a reduction in water fees would

- directly affect the resource potential of "hydropower municipalities",
- alter resource equalization in GR,
- indirectly effect the financial situation of other municipalities,
- progressively reduce the number of resource-strong and thus paying municipalities,

All municipalities and the canton would lose fiscal revenues.

Impact of alternative water fees (CHF/KW) on municipal finance in Grisons

Hypothetical case: fiscal year 2012, with 146 municipalities as of 01/01/2014	Reference	Water fee scenarios			
	110	100	80	50	none
Change in Mio CHF/year:					
– **Municipal water fee receipts :**	0	−4.87	−14.61	−29.21	−53.56
– **Net resource equalization :**	0	−0.14	−0.34	−0.40	−0.63
– **Total change:**	0	−4.96	−14.78	−29.27	−54.19
No. of municipalities ...					
– **paying into ...**	54	54	51	42	30
– **receiving transfers from ...**	90	90	93	102	124
– **excluded from ...**	2	2	2	2	2
the cantonal resource equalization.					

Table 1: Relevance of water fees in municipal finance in GR

Source and further information: Betz et al.: The Future of Swiss Hydropower: Distributional Effects of Water Fee Reform Options. Interim Project Report, 2018.

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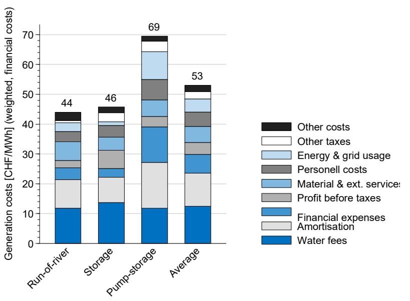
Work Package 3
DISTRIBUTIONAL EFFECTS OF THE REVISION OF SWISS WATER FEES

Hydro power is most important electricity source of Switzerland (around 60% of production)
Situation 2009: Large profits due to high electricity prices, low variable costs, and large price spread. Profits mainly made by cantons who owened large utilities (valley).
Situation Today: Lower returns because of lower prices and spread due to low fossil fuel and CO_2 allowance prices, larger shares of renewables. Utilities have problems to cover fixed costs.
Water fee reform: Water fees are under reconsideration since the Swiss Water law will be revised. Government has decided that up to 2024 there will be no changes, but different options need to be considered for the time after 2024.
Open questions
- What is was the situation of hydro power in Switzerland in 2015/16?
- How will different future water fee options change profitability of hydro power?

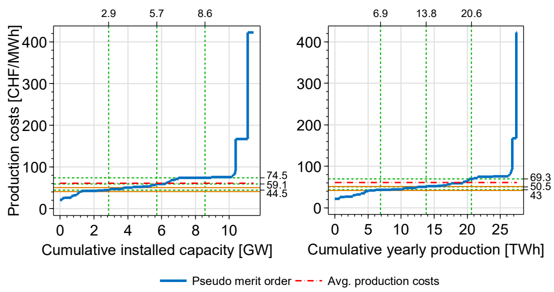
Production Cost 2015/15



Sources: Data based on annual reports, income statements, balance sheets of 62 hydropower companies and statistics of hydropower plants in Switzerland (WASTA) provided by Swiss Federal Office of Energy (SFOE)

- Share of water fee of total production costs varies with type of plant (average share: 23% or 12.4 CHF/MWh)

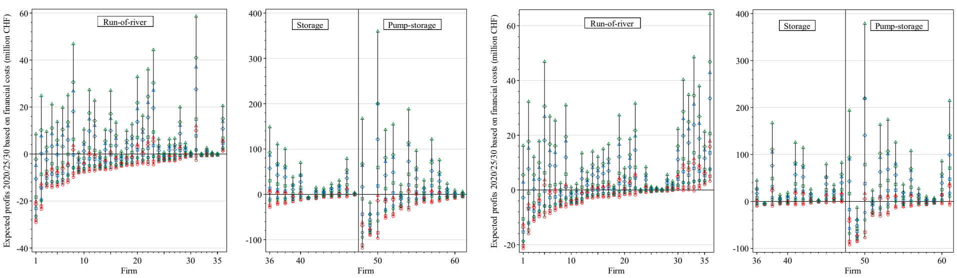
Pseudo Merit Order 2015/16



Green: 25, 50, and 75 % percentile.
Orange: Swissix average base and peak load price 2016

- Average production costs of all 62 hydropower companies for the years 2015 and 2016 (adjusted for inflation)

Profits with (left) and without (right) water fees



Fuel and Carbon Price Scenarios
- Base 2015 :Fuel and carbon prices as in 2015
- EU Trend: Prices EU reference scenario
- C++F++: Fast linear increase in carbon (50€/t) and fuel prices (+100%) until 2030
- C--F--: Linear decrease in carbon (4€/t) and fuel prices (-50%) until 2030

- Profit situation depends on electricity price pathway (Swisssmod: Schlecht & Weigt, 2014)
- Without water fees:
  - Improved situation for companies close to break-even
  - Little impact under favorable market conditions
  - Not sufficient for high-cost companies

Contact
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Work Package 3
Profitability of Swiss Hydro Power with and without Water fees

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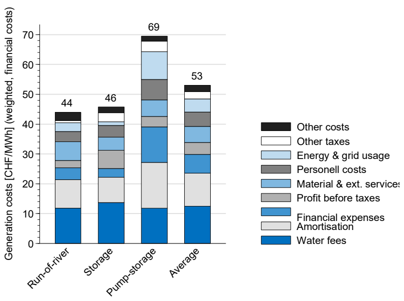

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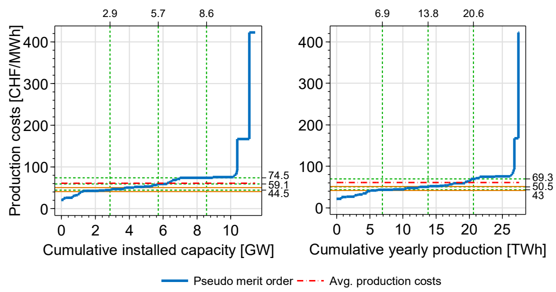

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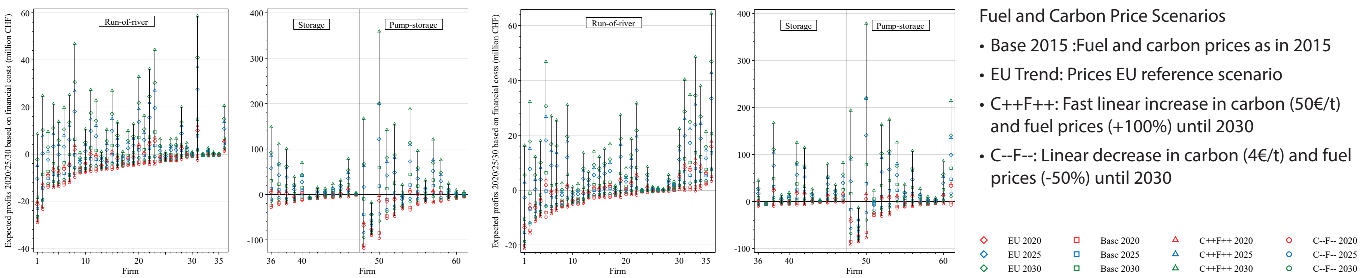

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