ANNUAL REPORT 2023

HydroCen

NORWEGIAN RESEARCH CENTRE FOR HYDROPOWER TECHNOLOGY

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

HydroCen is a research centre for environmentally friendly energy. Our main objective is to enable hydropower to meet complex challenges and exploit new opportunities through innovative technological solutions.

The main research partners in HydroCen are The Norwegian University of Science and Technology (NTNU), SINTEF Energy Research and Norwegian institute for nature research (NINA). The centre has a total budget of 400 million NOK over eight years and is financed by the Norwegian Research Council (50%), the research institutions (25%) and partners from the hydropower industry (25%).

WP 1 Hydropower structures

WP 2 Turbine and generator

WP 3 Market and services

WP 4 Environmental design

2023 – HYDROPOWER IS GEARING UP FOR THE FUTURE

"More of everything – faster" was the conclusion from the Norwegian Energy Commission. Whether you agree or not to the conclusion, the interest in renewal of Norwegian hydropower is ever increasing. HydroCen has spent its seventh year doing world-class hydropower research, to provide solutions that supports such renewal and enable more hydropower – faster. I hope you enjoy this report and join me in applauding our great staff of scientists!

Liv Randi Hultgreen
Excecutive Director,
HydroCen

The Norwegian power market is undoubtably connected to the European power market, linking the Norwegian hydropower sector to changes in European markets and policies. In 2023 we have seen a widespread public interest in how we can produce more energy in a future renewable energy system with hydropower, wind and solar power.

2023 has also been a year with renewed interest in dam safety, extreme weather, changing climate and use of nature. With wilder weather come new challenges for hydropower, but also new opportunities. When the research community collaborates with the industry, we find good solutions.

Several research projects have been completed during 2023, and in this report you can read more about flood capacity during extreme weather, potential upgrades in existing hydropower plants, modelling of environmental constraints, how ultrasound can save fish in rivers and how new generator technology can ensure fast transition from power generation to pumping mode.

As HydroCen is nearing its completion, we give more focus to our knowledge hub – Kunnskapsbanken. Here all research results are communicated, and it is continuously updated with new topics and results as research activities progress and bring forward new knowledge.

In Kunnskapsbanken you will find articles and information about the two PhDs that completed their thesis for HydroCen in 2023 – Linn Emelie Schäffer and Raghbendra Tiwari.

Dissemination and communication of research results has been given much focus in 2023, and HydroCen has been "on the road" to visit several user partners with our concept "Researcher on demand". This is a service for our user partners where they can book researchers for lectures on chosen subjects. HydroCen has visited The Norwegian Water Resources and Energy Directorate (NVE) and Hafslund Eco twice and had a digital seminar for Å Energi. These were received with great enthusiasm by our partners and have been very motivating for our researchers. These seminars will continue throughout 2024 and we encourage our partners to make use of this offer.

International collaboration is still a focus area for HydroCen, and we have continued to co-operate on projects in Sweden, US, Canada, Nepal and Europe in general. When planning hydropower research projects from 2025 and beyond, it is essential to keep growing cooperation with other world-leading international research communities.

I recommend that you read up on the research highlighted in this report and encourage you to reach out to our scientists if you would like more information.

FME HydroCen's success lies in the hands of our world-leading scientists, our engaged and interested user partners, our ever-supportive board and leadership team. On behalf of the administration, I would like to thank you all!

Liv Randi Hultgreen,
Executive Director, HydroCen

EXTREME WEATHER PROVIDED VALUABLE INSIGHT

The extreme weather event "Hans" demonstrated that hydropower facilities must be prepared for major flood events that are likely to occur more frequently in the future. For HydroCen researcher Nils Solheim Smith, it became a unique opportunity to study water behavior during severe floods.

In the project InSpillyFish he looks to identify incremental improvements in the flood capacity of existing hydropower plants so that they can safely manage flooding in the future.

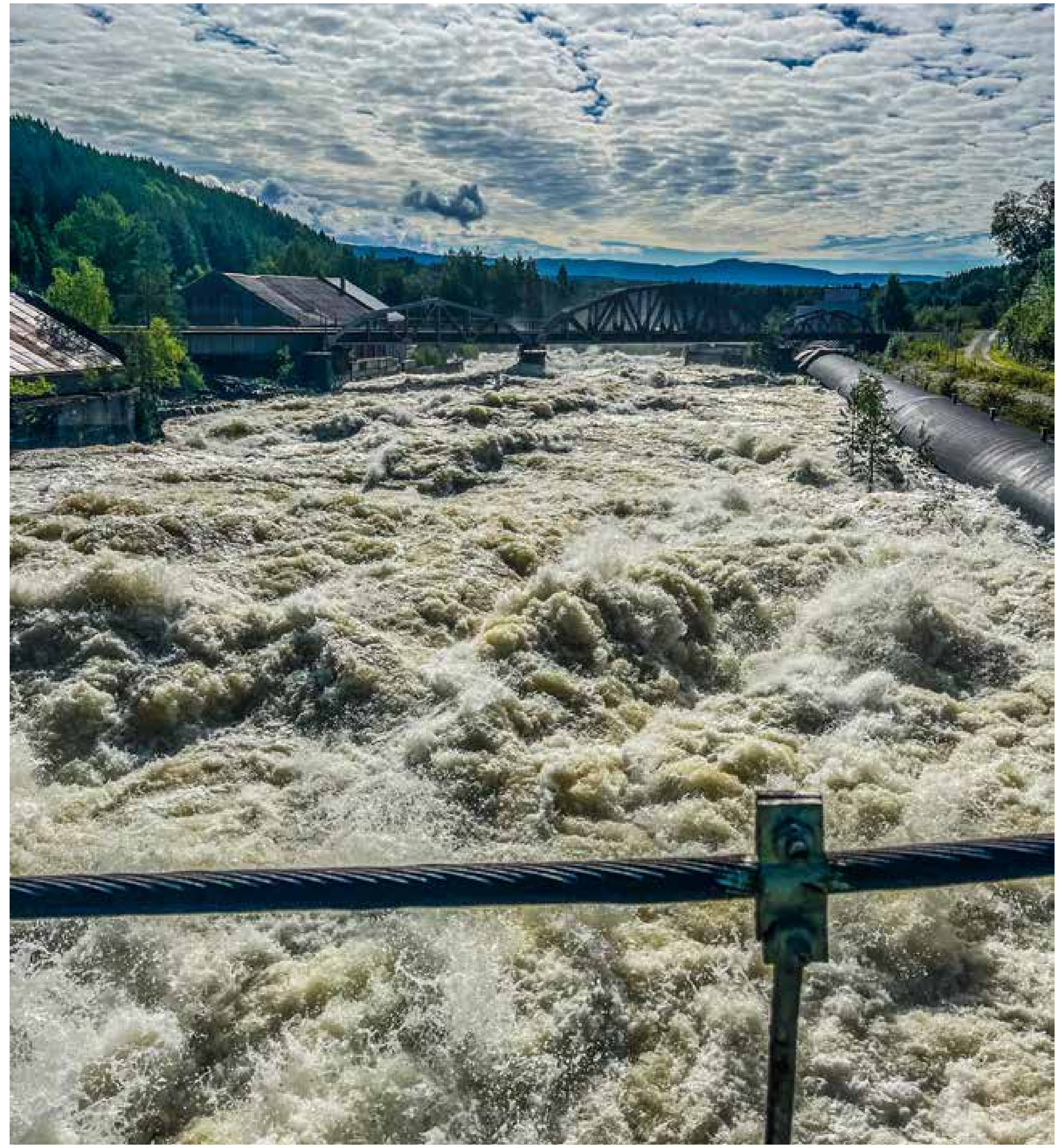
During Hans, he had the opportunity to join HydroCen partner Å Energy to inspect several of their facilities in the Drammen watercourse. The flood in 2023 was classified as a 50-100 year event, a stress-test many facilities haven't encountered in decades.

It can be crucial to document visual observation during such events because it is not always possible to predict where the water flows.

–It was dramatic but a great learning opportunity to experience it up close. The flow patterns and losses that emerged were not always anticipated in the theoretical assessments of the facilities, says Solheim Smith.

In spring 2024, Solheim Smith will be visiting the unit of Hydraulic Engineering at The University of Innsbruck, where they specialize in eco-hydraulics.

Contact: Nils Solheim Smith, NTNU.



Hensfoss seen from the spillover. Photo: Nils Solheim Smith/NTNU.

IMPROVED SAFETY FOR ROCKFILL DAMS

New research shows that risk of dam breach can be drastically reduced in overtopping situations. By improving the placement of the rocks protecting the downstream slope of rockfill dams against erosion and securing the "dam toe" at the foundation, the risk of damages can be reduced – and in extreme cases it can prevent or delay collapse.

Rockfill dams constitute some of the largest dams in Norway, with reservoirs holding several billions of liters of water. This allows us to produce renewable energy at any given time. However, if something were to happen to the dams, the consequences would be severe.

If you stand downstream a rockfill dam and look up, it can appear as a hundred-meter-high heap of rocks. There are over 600 of these dams in Norway, and the majority were built about 30 to 50 years ago. Today's dams consist of various layers of rocks supporting a dense core. In addition, most of the larger dams have an outer layer of placed big rocks, called a riprap, that increases the dam's strength.

When water flows over the top of a rockfill dam, a scenario called "overtopping", the materials will lose stability and begin to erode. However, if the dam has a layer of riprap erosion protection, it can withstand a surprising amount of overtopping.

The Norwegian rockfill dams are considered safe, but due to the significant damage potential of a dam breach, the safety must be continuously assessed. HydroCen researchers have therefore conducted multiple experiments in the laboratory to determine how safety can be further improved and aiming to gain a better understanding of what happens when a dam overflows and potentially breaches.

In the Hydraulic Laboratory, they have constructed models at a 1:10 scale and simulated how rockfill dams withstand water overtopping, and how the dam behaves if the overflow leads to a dam breach.

The dam toe and rock placement are critical for the stability

One observation from the experiments is that the dam toe at the foundation of the dam is a critical component and is subject to the most intense throughflow of water. It is therefore important that the dam toe is strong and stable if it is to withstand the throughflow if the dam is overtopped.

In an extensive fieldwork, Ph.D. candidate Ganesh Ravindra mapped nine rockfill dams in Norway with heights ranging from 5 to 142 meters. He discovered that only a minority of dams have a secured dam toe.

The researchers therefore suggest that the dam toe is secured in new dam constructions and in rehabilitations. This could be done either by placing the dam toe in a toe trench, or by other methods. Lining a dam with a placed riprap is an expensive measure, but this method will ensure the best possible security for the investment. Further, it is important that the rocks are placed closely together in an interlocking manner to minimize movement. If the rocks are placed too loosely, they will not support each other, and be more likely to move so the dam will withstand significantly less waterflow before it breaches.

The Roskreppfjord dam in Sirdal (Sira Kvina).
Photo: Juliet Landrø/HydroCen.

New method for researching dam breaches
Even though the rockfill dams are built with large margins to prevent overtopping, climate change with more rainfall and unpredictable seasons may increase the risk of unexpected events. Many dams have closed flood channels that run in tunnels, which in the worst-case scenario can become blocked, and lead to an unforeseen significant rise in the water level in the reservoir. Therefore, doctoral candidate Geir Helge Kiplesund also wanted to investigate how a dam breach develops if the worst-case scenario were to happen.

The model used for the experiments in the Hydraulic Laboratory was equipped with sensors and cameras that captured every movement as the researchers let the water flow freely over the crest of the dam. This equipment has made it possible to create dynamic models of the dam throughout the dam breach and allows the researchers to more extensively quantify how the breach process unfolds. The method developed by Kiplesund and postdoc Théo Dezert in the Hydraulic Laboratory can also be used in bigger dam breach experiments outdoors to make more accurate measurements than previously available.

The experiments also show that we need to improve or develop entirely new methods to describe such events.

Improved stability and future utility
The two projects show two clear measures that can improve the stability of rockfill dams. Individually, the dam toe and riprap will both improve the stability of the rockfill dam, however it is when combined that they truly will make a significant impact.

Read more about these results on the HydroCen Knowledge Hub.

Contact: Geir Helge Kiplesund, NTNU/Multiconsult

PhD candidate Geir Helge Kiplesund documenting how the dam collapses during overtopping of a model at the Hydraulics laboratory at NTNU.
Photo: Juliet Landrø/HydroCen

TWINLAB - DIGITAL TWIN LABORATORY FOR HYDROPOWER

Norwegian hydropower plants are currently undergoing a digital transformation in which access to, and utilization of, data are crucial. Within the HydroCen project, researchers have established a laboratory where the hydropower industry can test and develop digital twins.

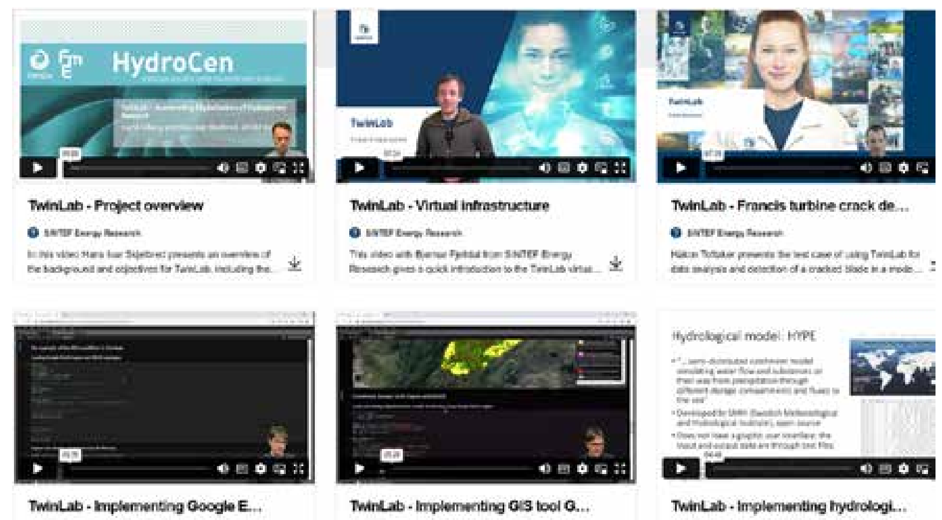
A digital twin is a tool that can be developed for efficient decision-making and operation of hydropower plants. It combines both numerical simulations and real-time measurements data to best represent the system. Developing a digital twin of a hydropower plant requires various models and data for hydrology and inflow in the catchment area, tunnel, waterway, turbine and generator.

Power producers can connect to the digital laboratory
TwinLab aims to enhance collaboration across these disciplines and facilitate the faster adoption of digital solutions, new methods, and models within the hydropower industry.

In this project, a method for secure streaming has been demonstrated in collaboration with Skagerak Kraft. Other power companies can also connect to TwinLab and make relevant data from their power plants accessible if desired.

Several pilot projects have been conducted to demonstrate the utilization of TwinLab such as:

- Accessible real-time data from the hydropower laboratory
- Real-time data from the Grunnåi power plant accessible to utilize in collaboration with Skagerak Kraft
- Analyze laboratory data for detecting runner blade damage
- Develop a model for real-time estimation of turbine efficiency
- Test and incorporate simulation models for hydrology and river hydraulics into TwinLab



Video tutorials on how to connect are accessible on the HydroCen Knowledge Hub:

Contacts:
Hans Ivar Skjelbred, SINTEF Energi
Ingrid Vilberg, Statkraft

SUSTAINABILITY IN HYDROPOWER

The sustainability of hydropower is a widely discussed topic both in Norway and internationally, but how does the industry perceive themselves? A HydroCen survey has reached out to Norwegian hydropower companies to hear their voice on the topic of sustainability.

– We believe that this study will be beneficial for the companies' ongoing efforts towards sustainable hydropower production because it will provide more specific findings that can shed light on new opportunities and challenges, says HydroCen researcher Berit Köhler from the Norwegian institute for nature research (NINA).

In light of the UN biodiversity agreement (COP15) and the introduction of the new EU taxonomy on sustainable finance hydropower faces new demands for addressing sustainability. The study therefore reached out to the 48 largest hydropower companies in Norway.

Anticipate increased sustainability

In the survey the companies were asked to assess their current sustainability and how sustainable they expect to be by 2030 "according to their company's strategy". Although they already rate themselves relatively high on sustainability (69%), there is a general expectation of becoming even more sustainable in the future – the score reaching as high as 86% on the question "According to your company`s strategy, how sustainable will you be by 2030?"

Await regulatory demands

The survey also shows that the majority consider that "some nature needs to be offered so that Norway can reach it's climate targets", and this may also be connected to the notable variations in the attitude towards environmental measures. While some reported that they have a proactive strategy, the majority await demands for implementing environmental measures.

The participants were also asked to rate the importance of various aspects of social acceptance, such as ecological effects, landscape aesthetics, economics, recreational fishing, direct climate risks and public participation and consultation. Although several of these got a high rating, "public participation and consultation" was rated substantially higher than other alternatives.

Uncertain about EU taxonomy and innovation

In terms of the perceived effect of the EU taxonomy researchers found that only about a third of the respondents expect that this will contribute to more innovation in hydropower. 24% think that their company will have a positive effect from it. The results here show a good portion of uncertainty, especially in relation to which relevant ecological and technical measures are demanded to reach good ecological potential that accord to the so-called DNSH (do no significant harm) criteria in the taxonomy.

The researchers hope that this assessment can generate more comprehensive and nuanced knowledge on how the industry can achieve key sustainability goals.

– We hope this study provides a better foundation for the companies' continued work towards sustainable hydropower production that also considers the environment, as well as for the work of the administration setting the regulatory environment for the companies, says Köhler.

Contact: Berit Köhler, NINA

Weir in the river Nea. Photo: Line Sundt-Hansen/NINA

VALUABLE INSIGHTS FROM THE RIVER NEA CASE STUDY

The living laboratory in the Nea River in Trøndelag has led to several specific methods, tools, and valuable collaborations. The power producer, Statkraft, believe they have benefited a great deal from the HydroCen case study in Nea.

–We are very pleased to have been a part of this. Participating in a case study provides extra knowledge that is specific for our watercourse. The knowledge, techniques, and methods developed can be used by everyone, but we have also gained valuable insights that are specific for our area, says Arne Anders Sandnes, project manager at Statkraft Energy AS.

In the Nea project, researchers from different fields collaborated to create a concept of environmental design for multiple interests. They expanded their toolkit so that the methodology could also be applied to watercourses with other species than Atlantic salmon, which the method previously was developed for.

Exclusive bonus for the power producer

The 33-kilometere stretch of river from Hegset-dammen in the north to the outlet in Selbusjøen is characterized by 32 weirs (low dams) built between 1960 and 2000 to sustain a water covered riverbed to benefit aquatic environment and aesthetics. Updated knowledge however shows that the weirs can act as migratory barriers and create unfavorable conditions for fish. The weirs can also change the physical habitat from running water to a more "lake-like" habitat, so typical river species who are adapted to running water will not thrive in such environments. Therefore, many have suggested that the weirs should be removed or adjusted, so it was natural to focus on them.

Using satellites, LIDAR, and aerial photos, researchers created a complete digital river model of Nea. Many river-stretches in Norway have little data on their structure and flow conditions. The method of using remotely sensed data to map both topography and flow conditions is cost-effective and can map several rivers in both time and space.

– The digital river model of Nea is an exclusive bonus we have obtained by making the watercourse available. A really cool part of the project that demonstrates use of technologies which may have many applications in operations of regulated rivers. says Sandnes.

Genetical methods discovered inbreeding

The brown trout is an important species in this river, and researchers used Nea to further develop the population genetics methods, focusing on how of juvenile brown trout are related. The analyses showed a high degree of inbreeding and that fewer parents contributed to spawning than expected. This confirmes that weirs act as barriers preventing trout from migrating to and from spawning grounds.

The environmental DNA method was developed and used to assess the benthic invertebrates, an important food source for fish. The researchers took both water and kick samples from various areas in the river and analyzed them with DNA metabarcoding analysis and morphologically. They found fewer species of benthic organisms in the weir pools than expected in Nea.

–Even though we had already extensive knowledge of the watercourse, this was extra interesting knowledge. When we take measures in the river going forward, we have a much better idea of where the bottlenecks are and which sites to prioritize. But still there is need for further assessments on sites, and to monitor status prior to measures. The latter particularly important in order to evaluate and follow up future results as well, says Sandnes.

Good dialogue and more knowledge

Throughout the project, there was a lot of local involvement and several dialogue meetings. Social scientists at HydroCen conducted several surveys and developed methods for dialogue with the public.

–My impression is that the municipality and the local public also appreciate this project, and we find that they refer to the work in our dialog. At the same time, we acknowledge that it also builds expectations for the results to be implemented, says Sandnes.

HydroCen researchers have proposed several environmental design measures that can improve the environment in Nea. These include suggestions for modifications of weirs, such as "ramp weirs". Sandnes says that Statkraft is considering these and working to find practical solutions for this work.

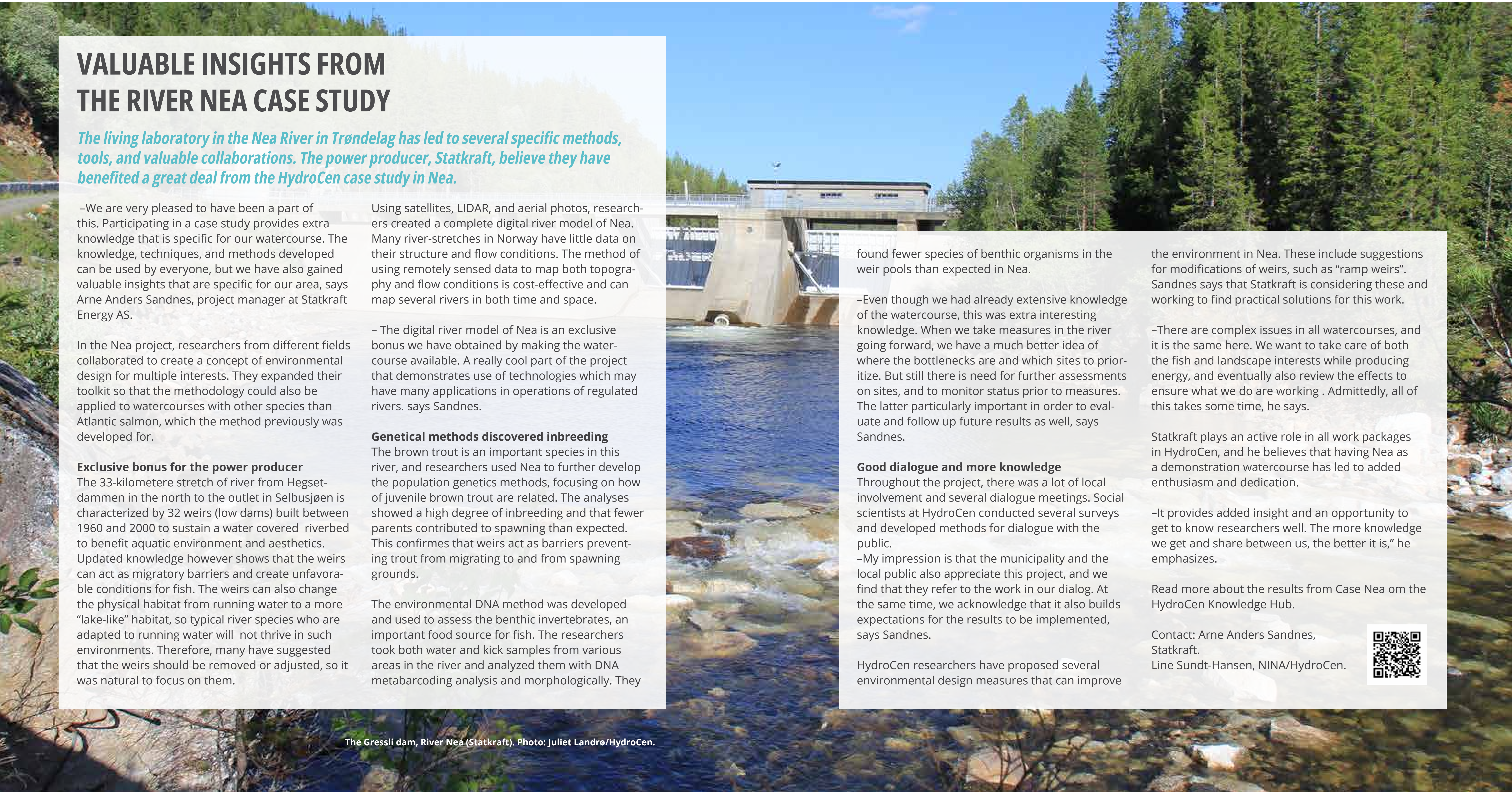
–There are complex issues in all watercourses, and it is the same here. We want to take care of both the fish and landscape interests while producing energy, and eventually also review the effects to ensure what we do are working . Admittedly, all of this takes some time, he says.

Statkraft plays an active role in all work packages in HydroCen, and he believes that having Nea as a demonstration watercourse has led to added enthusiasm and dedication.

–It provides added insight and an opportunity to get to know researchers well. The more knowledge we get and share between us, the better it is," he emphasizes.

Read more about the results from Case Nea om the HydroCen Knowledge Hub.

Contact: Arne Anders Sandnes, Statkraft.
Line Sundt-Hansen, NINA/HydroCen.



The Gressli dam, River Nea (Statkraft). Photo: Juliet Landrø/HydroCen.

POTENTIAL FOR UPGRADING AND EXPANDING NORWEGIAN HYDROPOWER (POTOUT)

Smarter use of Norwegian hydropower can save nature, ensure power supply, and increase profit.

In a study from HydroCen researchers recommend that industry and government focus on expanding storage capacity and the ability to rapidly deliver a large amount of electricity. This can maximize the amount of renewable energy with minimal impact on nature.

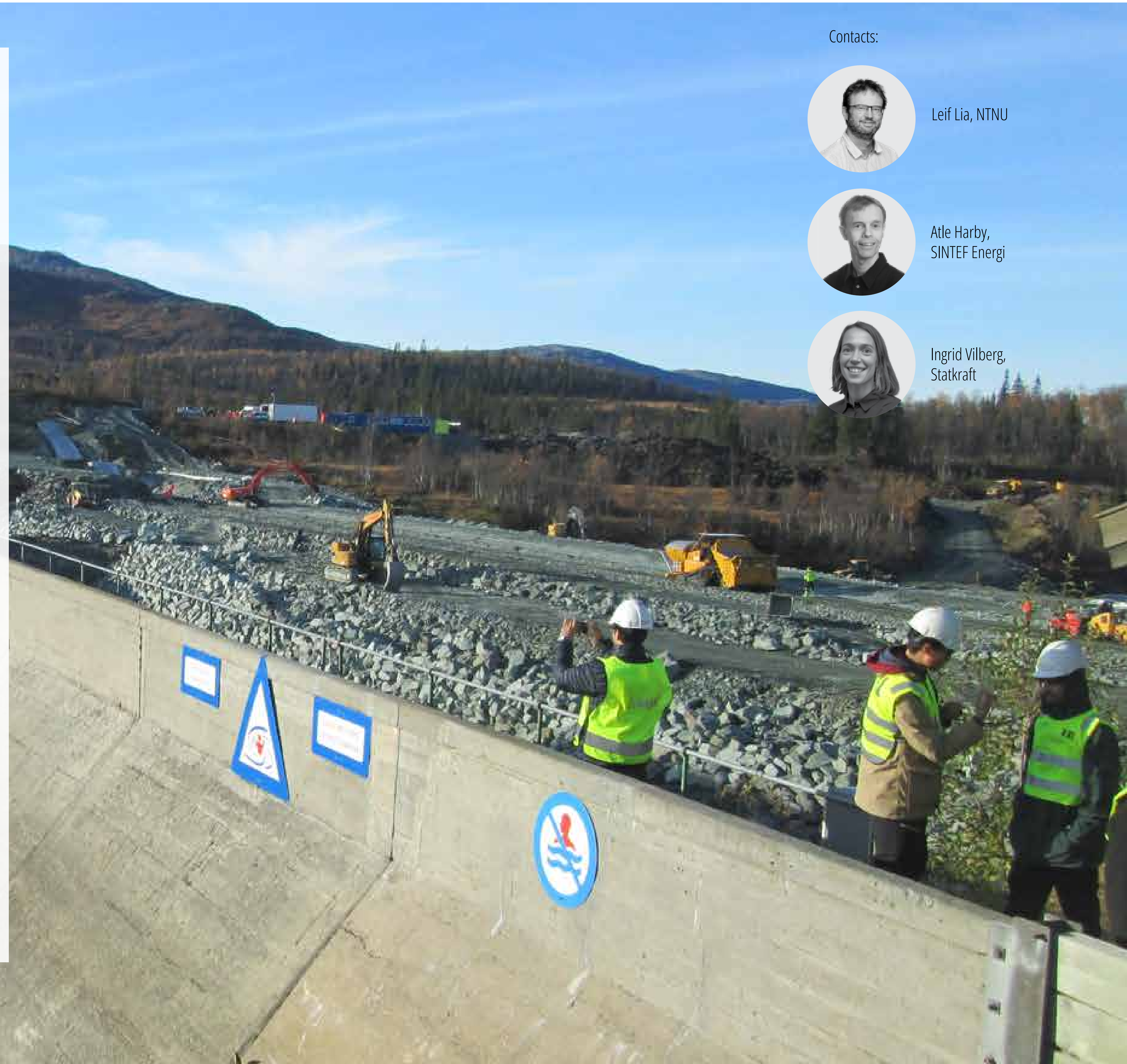
The study reveals significant potential to expand capacity (MegaWatt, MW) in already developed waterways. It could, for example, be possible to utilize more power from unregulated energy sources when if we were confident that hydropower can rapidly step-up production and provide energy when intermittent sources fail. The key lies in constructing new facilities alongside the already established ones. Water is typically released to sea, fjords, or large downstream reservoirs. According to the study, this paves the way for a more environmentally friendly operation. By adopting a more considerate operational pattern, existing power plants can improve the environment in previously regulated rivers.

Close cooperation with industry partners
The team collaborated closely with several power companies, delving into the intricacies of their opportunities and challenges concerning Upgrade/Expansion projects. This collaborative effort yielded invaluable insights, providing a foundation for compiling and calculating practical examples.

By simultaneously assessing environmental solutions when considering upgrading and expansion researchers found that a comprehensive solution with acceptable environmental consequences can be found. In some cases, they also found opportunities for improved environmental conditions compared to the current state of the rivers.

These are their recommendations for management and authorities:
- Provide good and predictable framework conditions for upgrade and expansion.
- Remove tax barriers for capacity expansion projects.
- Prioritize concession applications for projects with reservoir capacity and flexibility.
- Conduct thorough concession processes.
- Further develop the power system to avoid loss of flexibility.
- Innovate solutions for environmental solutions.

With a power market undergoing significant changes, it is essential to explore alternatives that have not been considered before and balance them against both new and known environmental solutions. The methodology used to identify new upgrade/expansion projects with environmental design involves defining the area, using an expert group to assess alternatives, arranging workshops between the expert group and power companies, and then using the card deck method:
- Map all possible power projects.
- Map all environmental and societal projects.
- Include new technical and environmental solutions in the assessment.
- Define goals/strategy and assemble cards.
- Report.



Contacts:

Leif Lia, NTNU

Atle Harby, SINTEF Energi

Ingrid Vilberg, Statkraft

MODELLING ENVIRONMENTAL CONSTRAINTS

It is difficult to include flow constraints that depend on reservoir storage in long-term hydro scheduling models. New research from HydroCen shows it can still be profitable to include these aspects in long-term models.

There are advantages both from an economic perspective and to better ensure that we can produce enough power during periods of high demand and low water availability.

In periods of spawning or specific use of a river system, such as fishing or boating in the river or reservoir, hydropower producers may have to comply to specific environmental restrictions such as water levels in the river or reservoir. These restrictions could potentially force power producers to run the power plant in a suboptimal way concerning power supply, storage protection, and profit.

It is possible to account for these restrictions in production planning by incorporating them into the optimization models used to plan hydropower plant operation. This way, it is possible to minimize the negative consequences of the production restrictions.

This is often done in models that plan production over short periods (weeks), as these models can handle this type of data. The difficulties arise when trying to incorporate these constraints into models that cover longer periods (months/years).

Taking a closer look at the complex models
HydroCen researcher Linn Emelie Schäffer from SINTEF Energy has therefore worked on modeling complex environmental restrictions that previously could not be included in existing production planning tools.

The aim is to better understand how they affect production patterns and the profitability of the power plant. She has also attempted to calculate profits by including the restrictions in planning models, or the cost of ignoring or simplifying these restrictions in strategic calculations.

In her PhD-work, she has examined a specific type of environmental restrictions, known as state-dependent environmental restrictions or soft reservoir restrictions. These restrictions are challenging as they change over time, depending on the amount of water in the reservoir, which again depends on the operational decisions of the power producer, as illustrated in the figure below. Another important aspect of the research has been assessing how the flexibility of power production in a limited area is affected by such constraints.

New models show effect
Through this work, two long term production planning models have been developed, where state-dependent environmental restrictions.

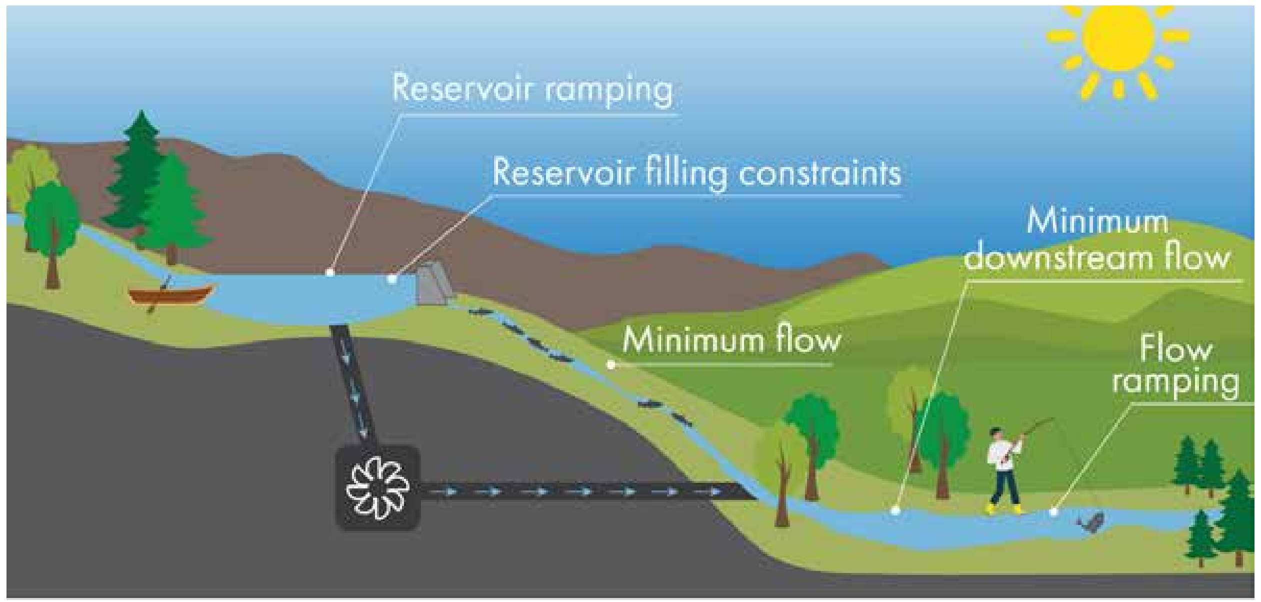
The first model is used to assess how much environmental restrictions affect the hydropower producer's profit and the significance of improved modeling of these restrictions in production planning. Results from the developed models demonstrate that planning for soft reservoir restrictions can be economically beneficial for the producer, especially during multiple high-price periods in spring/summer.

The second model is used to assess how environmental restrictions affect the flexibility of the hydropower production in a smaller, hydropower-dominated area. The results showed that different restrictions affect the system's ability to meet the demand for power and requirements for reserve capacity in the spring. In systems with limited flexibility, these restrictions could pose flexibility challenges during this period.

Enhanced knowledge and better planning
The research provides better knowledge of into how state-dependent environmental restrictions impact the value of water and indicate that under certain circumstances, there can be significant economic benefits for producers to plan for soft reservoir restrictions.

With significant changes in the power system due to a substantial influx of wind and solar power, there might be more high-price periods during restriction periods, which could be profitable for producers to consider in their production planning.

Contact: Linn Emelie Schäffer, SINTEF Energy.



llustration of different types of environmental constraints in a hydropower-regulated river from Schäffer's thesis 2023.

NEW MEASUREMENTS FOR FLEXIBLE TURBINE OPERATION

How can we calculate the cost of flexible operation and what is the remaining lifetime of my turbine?

These are the most frequently asked questions at the Waterpower Laboratory these days, and researchers are addressing the fatigue loads to find the answers.

The weakest part of the turbine is the turbine runner blades. So, this is what Johannes Kverno has focused on in his PhD-work through the HydroFlex project at the Waterpower Laboratory.

He added strain gauges on the runner blades of a laboratory scale Francis turbine, and did measurements while the turbine was running. At the Waterpower Laboratory, measurements with strain gauges in the runner has been a challenge for many years, and now we can proudly say that Johannes is the first one to achieve high quality measurements. His results show that the low turbine loads are the toughest ones apart from start-stop operation.

Now, NTNU are able to continue these types of measurements on more turbines to provide answers to the questions.

Contact:
Johannes Kverno

Johannes Kverno working on the Francis-model in the Waterpower laboratory, NTNU. Photo: Juliet Landrø/HydroCen.

CONVERTER FOR PUMPED STORAGE POWER PLANTS

A fast transition from power generation to pumping mode enables hydropower plants to better balance the energy from wind and solar power in the power grid. At HydroCen, researchers have discovered a solution to make pumped-storage power plants more flexible.

Today's pumped-storage plants are already very flexible in the sense that they can generate electricity during high demand and use energy to pump water back to   an upper reservoir during periods of low demand. However, they need to improve their ability to rapidly switch between pump and turbine modes to balance the non-regulated renewable sources like wind and solar energy.

The pumped-storage plants primarily operate at a constant speed, regardless of the amount of power to be generated or water being pumped into the reservoir. This limits its flexibility, especially during pumping.

As a result, variable-speed pumped-storage plants have emerged in the last decades. These plants use a frequency converter to regulate the speed of the generator and turbine. This allows for better regulation of the water being pumped, which is not efficiently achievable at a constant speed.

The system developed by researcher Raghbendra Tiwari makes the future pumped-storage plants even more flexible in the transition between turbine and pumping mode. With Tiwari's system the shift from power generation to pumping both simplifies and quickens. When working with the system, different types of frequency converters were evaluated and compared. Since these converters offer very high output power, selecting the most suitable technology for pumped-storage plants is very important.

Developing a control system for the converter
Tiwari has designed a control system to control the unit in both turbine and pump modes. The system is robust enough to handle power grid failures, so that the unit contributes to stability and recovery of the grid after faults.

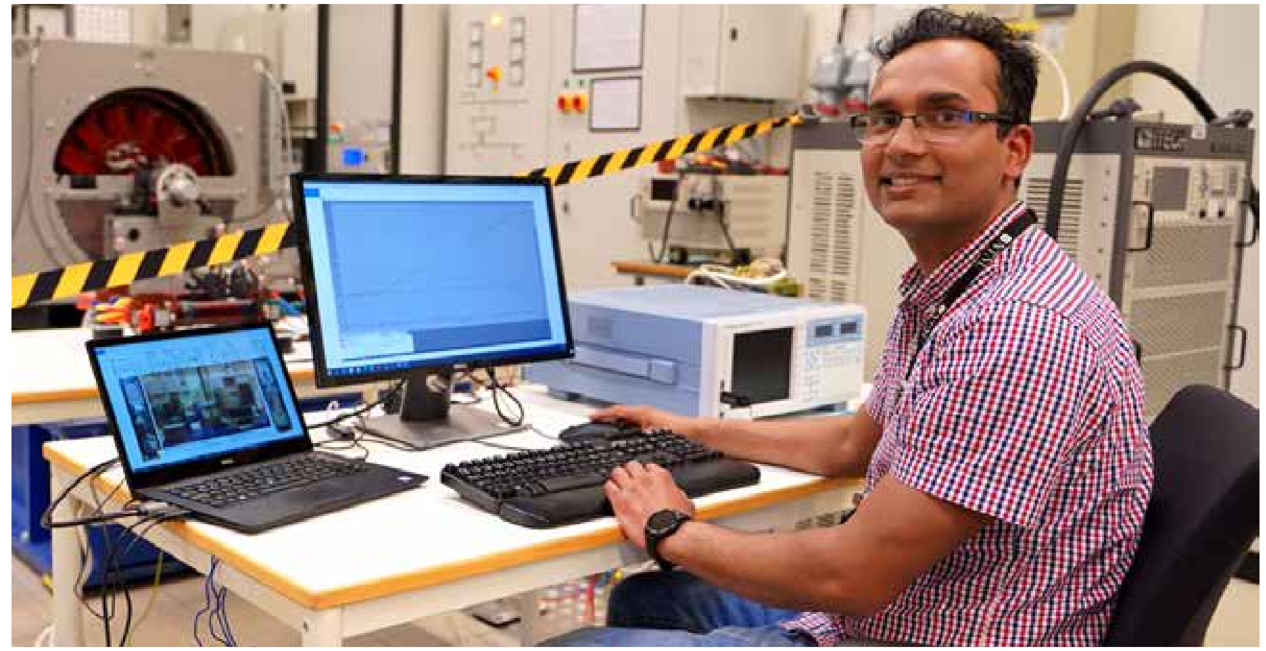
The control system is tested on a 100 kW generator in the SmartGrid laboratory at NTNU. A motor controlled by a separate frequency converter was used as a turbine. The generator was connected to its own frequency converter, which, in turn, is connected it to the power grid.

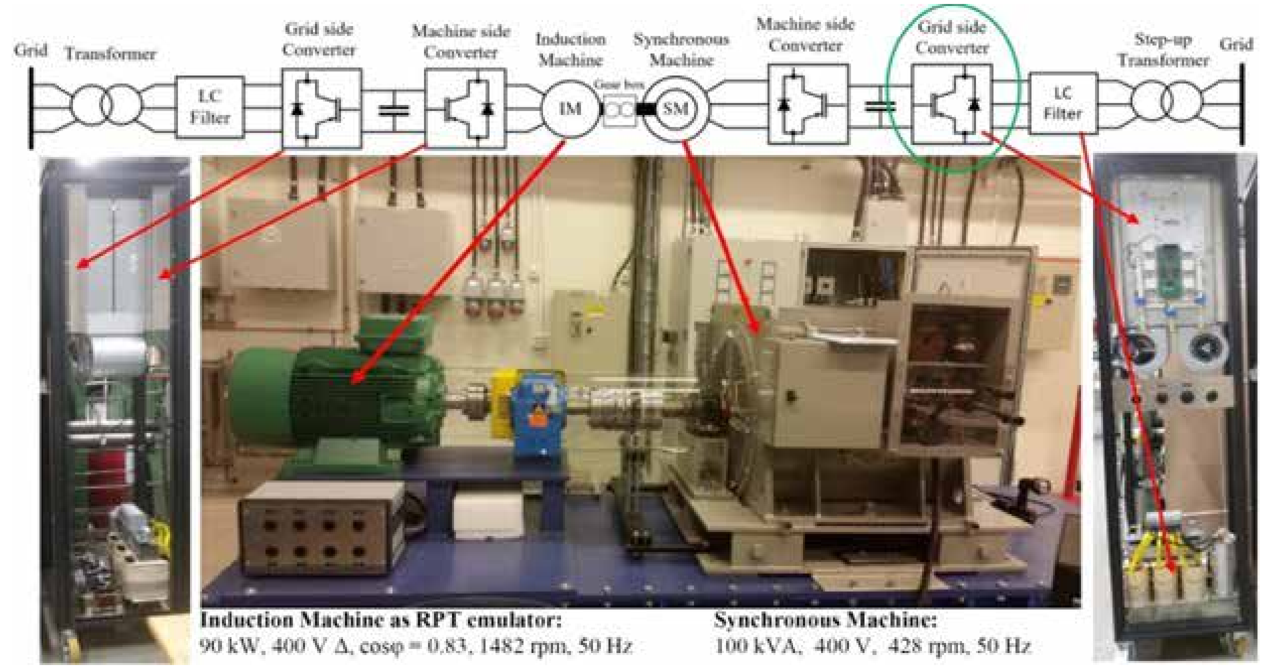
Enhanced flexibility and stability
The project's results are relevant for power plants intended to be re-built to pumped-storage or power plants seeking upgrades for variable-speed operation.

The smooth transition between turbine and pump mode puts less stress on the power grid and makes it better suited for utilizing renewable energy sources like solar and wind power. It also reduces turbine wear and tear during the shift from turbine to pump operation.

Since the control method has already been tested with a 100 kVA laboratory setup, it holds great potential for implementation in commercial pumped-storage plants.

Contact:
Raghbendra Tiwari, NTNU.


Raghbendra Tiwari working in the Smart Grid Laboratory at NTNU: Photo: Juliet Landrø/HydroCen.



The figure shows the laboratory setup of the system with a description of the various components. Photo: Raghbendra Tiwari, NTNU.

ULTRASOUND IN HYDROPOWER CAN SAVE FISH IN RIVERS

Shooting sound waves through water can eliminate gas bubbles that harm wild-life in rivers with power production. Researchers have explored various methods in the laboratory, and now they're ready to test the best one on a large scale in actual power plants.

The phenomenon of total dissolved gas (TDG) supersaturation occurs when air enters the tunnel in a power plant and is subsequently subjected to high pressure.

When released into the river, it is like popping a champagne cork, bubbles shoot into the river. This introduces so much air into the water that fish and other species can be harmed. In the worst case, they can suffer from lethal gas bubble disease — similar to human diver's sickness.

Currently, there are no requirements to monitor and limit total dissolved gas supersaturation downstream from power plants in Norway. However, studies have indicated that this problem might affect many more power plants than previously thought.

If future regulations demand addressing this issue, this solution could help power companies avoid costly shutdowns of power plants when the problem arises, while also improving the environment

The method is efficient and will likely have relatively low costs for installation, operation, and maintenance. Therefore, the researchers hope to receive funding from the Norwegian Research Council to test it in the rivers so the industry can adopt it shortly.

Contact:
Wolf Ludwig Kuhn, NINA

PhD-candidate Ludwig Kuhn working on the DeGas-flume in the Waterpower laboratory at NTNU. Photo: Juliet Landrø/HydroCen.

INTERNATIONAL INTEREST IN HYDROCEN

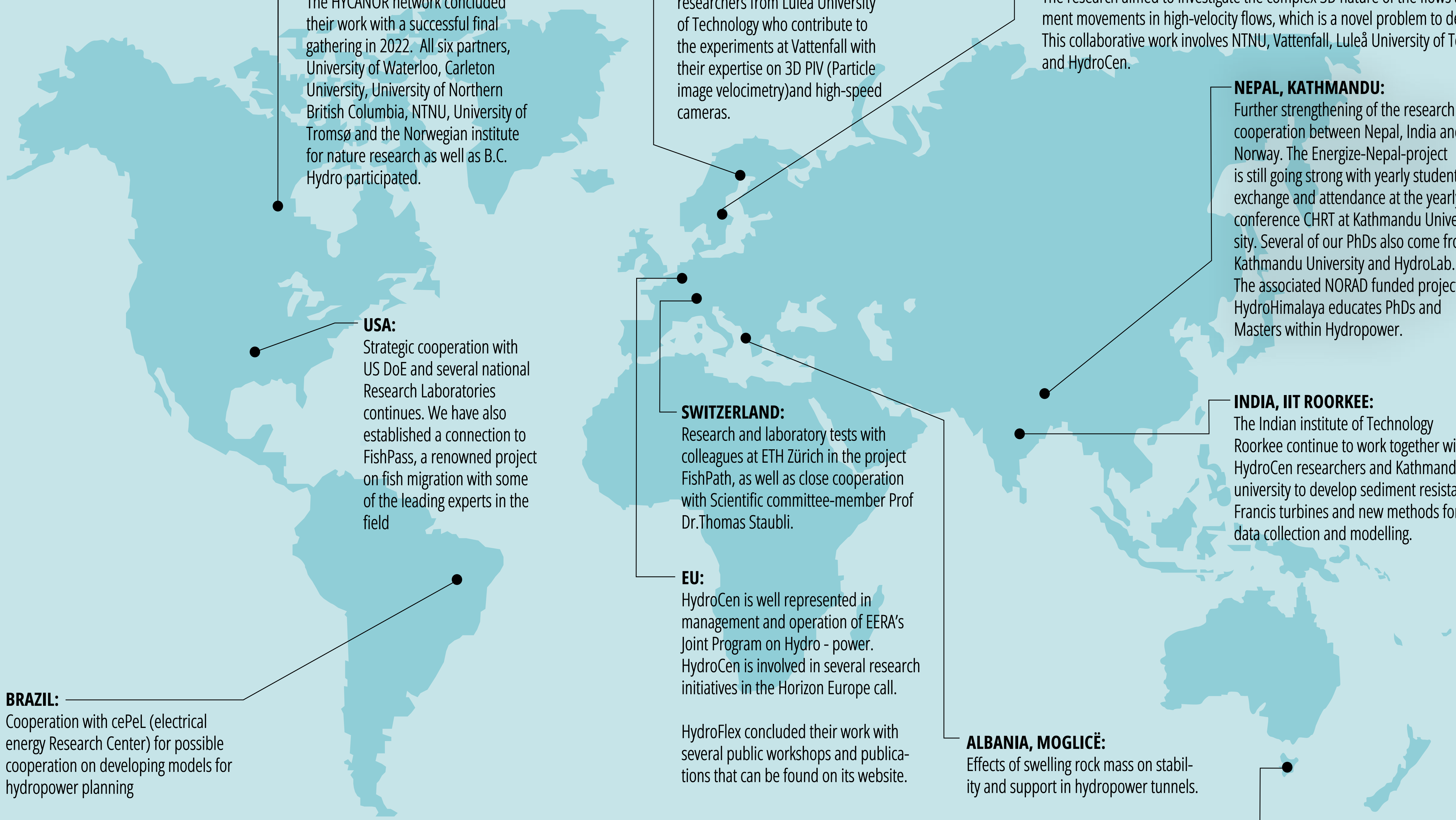
HydroCen researchers have sustained their partnerships with the international hydropower community throughout 2023. We have had research exchanges, workshops, webinars, and collaborated on scientific publications.

The international collaboration within HydroCen continues to be structured around five primary axes, facilitating the exchange of knowledge with relevant regions, research institutions, and active engagement in management and technological forums.

Among these axes, the Nordic and European regions represent the strongest focus, followed by an axis directed towards Asia, where significant hydropower development is underway.

Additionally, connections are established with America through a fourth axis, while the fifth axis emphasizes involvement in technological forums.

Over 60 international institutions maintain communication with HydroCen through these collaborative channels.



CANADA:
The HYCANOR network concluded their work with a successful final gathering in 2022. All six partners, University of Waterloo, Carleton University, University of Northern British Columbia, NTNU, University of Tromsø and the Norwegian institute for nature research as well as B.C. Hydro participated.

USA:
Strategic cooperation with US DoE and several national Research Laboratories continues. We have also established a connection to FishPass, a renowned project on fish migration with some of the leading experts in the field

BRAZIL:
Cooperation with cePeL (electrical energy Research Center) for possible cooperation on developing models for hydropower planning

Scientific publication with authors from Rio de Janeiro State University (Brazil) and Argonne National Laboratories (USA) on the topic “Hydropower scheduling toolchains”.

SWEDEN, LULEÅ:
Collaborations with the Swedish Centre for Sustainable Hydropower, SVC. As well as cooperation with researchers from Luleå University of Technology who contribute to the experiments at Vattenfall with their expertise on 3D PIV (Particle image velocimetry)and high-speed cameras.

SWEDEN, ÄLVKARLEBY:
Researchers from Kelt2Sea work on the “Laxeleratorn” flume where they measure the fish’s response to different velocities and acceleration that commonly exist in the vicinity of a hydropower plant station.
Researchers have also carried out experimental work at the Vattenfall laboratory in Älvkarleby.
The research aimed to investigate the complex 3D nature of the flows and sediment movements in high-velocity flows, which is a novel problem to deal with. This collaborative work involves NTNU, Vattenfall, Luleå University of Technology, and HydroCen.

SWITZERLAND:
Research and laboratory tests with colleagues at ETH Zürich in the project FishPath, as well as close cooperation with Scientific committee-member Prof Dr.Thomas Staubli.

EU:
HydroCen is well represented in management and operation of EERA’s Joint Program on Hydro - power. HydroCen is involved in several research initiatives in the Horizon Europe call.

HydroFlex concluded their work with several public workshops and publications that can be found on its website.

ALBANIA, MOGLICË:
Effects of swelling rock mass on stability and support in hydropower tunnels.

NEPAL, KATHMANDU:
Further strengthening of the research cooperation between Nepal, India and Norway. The Energize-Nepal-project is still going strong with yearly student exchange and attendance at the yearly conference CHRT at Kathmandu University. Several of our PhDs also come from Kathmandu University and HydroLab. The associated NORAD funded project HydroHimalaya educates PhDs and Masters within Hydropower.

INDIA, IIT ROORKEE:
The Indian institute of Technology Roorkee continue to work together with HydroCen researchers and Kathmandu university to develop sediment resistant Francis turbines and new methods for data collection and modelling.

AUSTRALIA:
Cooperation with Hydro Tasmania, and the state government of Tasmania.

HYDROCEN LABS

Upgrades and improvement of research infrastructure done through HydroCen Labs enable innovative research.

Through the Research Councils "National Initiative for Research Infrastructure" HydroCen labs was allocated 55 million NOK to ensure that the laboratories have the capability to meet the research challenges of the hydropower sector.

The infrastructure in the laboratories is available for researchers and partners in HydroCen, as well as student projects, to do applied and basic research based on challenges facing the hydropower industry today and in the future.

Here are some examples of the upgrades from phase one:

THE WATERPOWER LABORATORY

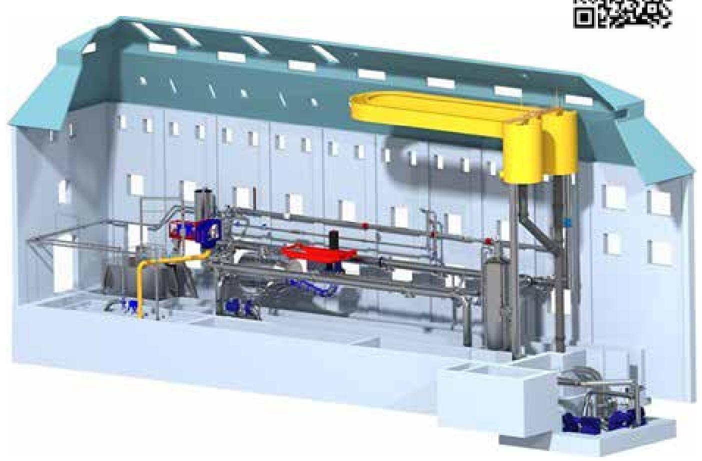
There has been an upgrade of the low-pressure experiment system his includes new valves for the piping system, upgrading existing pumps and pipes. The Francis turbine test-rig has been equipped with new generator, frequency converter, bearing block, and a high-quality torque meter.

The Francis turbine has been coupled with the SmartGrid Laboratory and its grid emulators. For example, this means that we can carry out research on the flexible operation of hydropower plants in connection to large wind farms.

The Pelton turbine test rig has been equipped with a new generator and frequency converter which provides better control of the Pelton turbine testing.

All electrical cabling for the operation of valves, generators, motors, and for all permanent installed instruments for the measurements of flow rate, pressure, level, torque, and temperature. We are sure that several kilometers of cables have been installed. The new infrastructure enables us to be better equipped to address today's and tomorrow's challenges within hydropower. It allows for research on material fatigue and analysis of turbine lifespan.

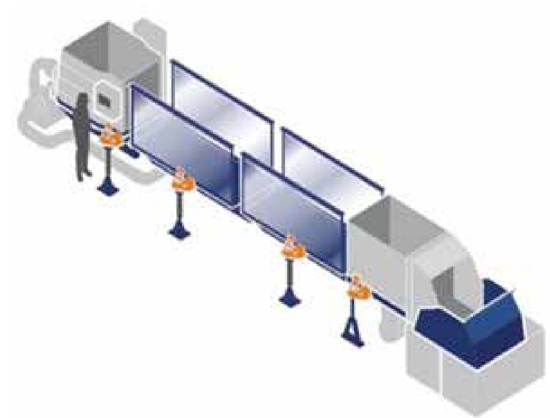
The utility of this type of research will be demonstrated through the extensive refurbishment that Norwegian hydropower is currently facing, but also because new turbines are experiencing more failures due to wear and tear.



HYDRAULIC LABORATORY

A new full pipe system and filter systems is implemented to enhance reliable delivery and water quality in the lab. This will improve the quality of optical measurements such as Particle Image Velocimetry (PIV) and Laser Doppler Velocimetry (LDV), as there will be fewer particles from rust and dust in the water. In addition, possible leakages and brake downs are avoided.

Two new experimental flumes for studies focused on flow fields, the effect of sediments, and research on hydraulic parameters and fish behavior are partly installed. This includes a 24-meter long and 2-meter-wide adjustable multipurpose flume intended for experiments with live fish. The mini-flume for educational purposes and prelimnary research has been in operation for two years. The total upgrade of the catchment area research field Sagelva has successfully fulfilled.



ENGINEERING GEOLOGY LABORATORY

The HydroCenLabs project has contributed to strengthen the Engineering Geology Laboratory located at the Department of Geoscience and Petroleum (IGP).

The development and upgrading mainly focused on the;

1) development of laboratory scale hydraulic jacking test rig,
2) development of cyclic oedometer test rig for the investigation of swelling of rocks, 3) upgrading electronic accessories for Tri-axial test machine. This development led to further enhancement of the state-of-art engineering geology laboratory.

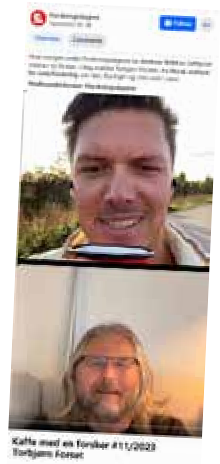
It is noted here that the newly developed equipment has many benefits:

- Simplifies and improves splitting tests at the laboratory as well as field samples.
- Provides safer and better determination of swelling properties, especially for swelling pressure of intact rocks in addition to powder.
- Expands the application area for existing triaxial equipment.

This upgrade is of significant importance for enhanced planning and design of Norwegian hydropower tunnels. The equipment will also be of great value for other types of projects within engineering geology, related to road and railway tunnels.

HYDROCEN IN THE MEDIA

In 2023, we have seen a growing interest in the topics of renewable energy and sustainable development, both in Norway and internationally. Several HydroCen researchers have contributed to increase knowledge in the public debate. They have participated in documentaries and feature stories abroad, and to more than 100 news articles in the media, as well as podcasts and research interviews. Our own blog and Knowledge Hub reach more than 4,000 people, and lectures and webinars on our YouTube channels had more than 3,400 views in 2023.



OUR OULETS

Knowledge Hub / Kunnskapsbanken:
The HydroCen knowledge hub has expanded and now lists more than 50 pages in English and Norwegian describing the research results from HydroCen and putting them into a societal and practical context.

Newsblog:
18 news stories with information, news and research results from HydroCen in 2023.

Vannposten:
Weekly newsletter for researchers and partners. 17 publications and about 200 recipients.

Website:
Information and contact details for all projects and researchers in HydroCen. Publications and innovations are also listed on www.hydrocen.no

SOCIAL MEDIA

112

YouTube:
Presentations and webinars posted on our YouTube channel @HydroCenFME reach well beyond our 112 subscribers. The 12 presentations/webinars we posted in 2023 have about 3400 views.

550

X:
Share articles, news and follow public debate. This activity has decreased somewhat in 2023 due to societal events. We still have about 550 subscribers and reached about 500 people per month in 2023.

618

Facebook:
Sharing articles and news with our 618 followers. A monthly reach of about 2300.

1000

LinkedIn:
We have increased activity in this channel and see that our content gets a lot more attention here. We have passed 1000 followers and aim to continue to expand our outreach here.

PUBLIC OUTREACH

In 2023, we met our partners, management, interest groups, researchers and the public at a wide range of arenas. We have welcomed many esteemed visitors to our laboratories - ranging from eager first year students, to the Norwegian Minister of Energy Terje Aasland and Serbias president Aleksandar Vučić, as well as several busloads from Produksjonsteknisk konferanse. Several of our researcheres have also had the pleasure of visiting laboratories at Vattenfall R&D and the National Renewable Energy Laboratory in the United States.

We met school children and families during "Forsk-ningsdagene" and presented scientific results at vari-ous conferences. We have also visited several of our partners with our concept "Researcher-on-demand" with customized programs and presentations.

Our own Knowledge Hub (Kunnskapsbanken) has been updated with results from all work packages in both Norwegian and English. More than 500 unique visitors explore our results and publications each month. This work continues in 2024 and we aim for all our results to be presented here.


Visit from the Norwegian Minister of Energy, Terje Aasland.


Forsker on Demand at Hafslund Eco

BedPress at NTNU


Work shop with Swedish Centre for Sustainable Hydropower (SVC) and Vattenfall.


Delegation from Serbia in the Waterpower laboratory.

Our PhD's ready to welcome children and families during the national research days, Forskningsdagene.


Experimental flume at Älvkarleby, Vattenfall, Sweden.

All photos: Liv Randi Hultgreen and Juliet Landrø

Ivar Arne Børset, Chairman of the Board

BRIEF FROM THE BOARD – 2023

Representing a broad part of Norwegian hydropower production and management, HydroCen's Board applauds the convincing scientific research results from HydroCen and is happy to receive excellent communication and dissemination of these results.

HydroCen has delivered well on its priorities in 2023. Several large projects have reached their completion, and many of the new projects that were kicked off in 2021-2022 are completed with good results.

In a volatile world, the need for further development of our power system is ever increasing. This includes a need for upgrading and possible expansion of hydropower, which drives the need for fact-based decision making, innovation and implementation of updated knowledge through research and development. HydroCen and the research community answer to these needs by providing world class research and communicating this research to both industry and public management. HydroCen is a a hub for both executing research programs and coordinating new hydropower research initiatives by leading the Joint program for Hydropower in EERA, the European Energy Research organization.

The Board sees that the research activities planned at center startup in 2016 have proved relevant through these seven years and would like to applaud the foresight shown by the research community. Since 2020 HydroCen has kicked off several new projects with 1-3 year's duration, and these projects have proved to be a very good supplement to the original portfolio. They have allowed HydroCen to adjust according to new challenges in society and hydropower industry.

The knowledge hub Kunnskapsbanken, where all research results from HydroCen are continuously added as they materialize, has grown substantially throughout 2023. By using Kunnskapsbanken partners and the society in general can harvest the potential of these research results. It is crucial to feed society's growing demand for fact and research-based information on hydropower's future possibilities with relevant, reliable, and easily accessible information.

HydroCen is well managed, and scientific excellence is in focus, coupled with a strong ability to deliver and a high level of industry involvement. The Board appreciates the close cooperation and fruitful discussions with the management team, work package leaders, and members of HydroCen.

Ivar Arne Børset, Chairman of the Board

Representatives from the board and the management team of HydroCen in 2023.

Ivar Arne Børset
Statkraft

Eivind Heløe
Fornybar Norge
(fmr. Energi Norge)

Olav Bolland
NTNU

Ingeborg Palm
Helland
NINA

Knut Samdal
SINTEF

Erik Skorve
Eviny

Inga Katrine
Nordberg
NVE

Celine Setsaas
Hafslund Eco

Harald Rikheim
The Research
Council of Norway

Michel Bohnenblust,
The Research
Council of Norway

Liv Randi Hultgreen
NTNU/Board
Secretary

ORGANISATION

Board

Name	Institution	Function
Ivar Arne Børset	Statkraft	Chairman of the Board
Ingeborg Palm Helland	NINA	Board member
Knut Samdal	SINTEF	Board member
Eivind Heløe	Fornybar Norge	Board member
Inga Katrine Nordberg	NVE	Board member
Erik Skorve	Eviny	Board member
Celine Setsaas	Hafslund Eco	Board member
Olav Bolland	NTNU	Board member
Liv Randi Hultgreen	NTNU	Executive Director/Board Secretary
Michel Bohnenblust	Norwegian Research Council	Observer

Name	Institution	Function
Harald Rikheim	Norwegian Research Council	Observer
Juliet Landrø	NINA	Observer
Berit Garberg Hagen	NTNU	Coordinator
Lars Grøttå	NVE	Deputy board member
Ole-Morten Midtgård	NTNU	Deputy board member
Petter Støa	Sintef Energi	Deputy board member
Norunn Myklebust	NINA	Deputy board member
Jane Berit Solvi	Skagerak	1. deputy board member
Tormod Eggan	TrønderEnergi	2. deputy board member
Bjørn Honningsvåg	Lyse	3. deputy board member

Executive Management Team and Admnistration

Name	Institution	Function
Liv Randi Hultgreen	NTNU	Executive Director/Board Secretary
Leif Lia	NTNU	Member (spring)
Ole Gunnar Dahlhaug	NTNU	Member (autumn)
Tonje Aronsen	NINA	Member
Michael Belsnes	SINTEF	Member
Sigve Næss	Eviny	Member

Name	Institution	Function
Berit Garberg Hagen	NTNU	Coordinator
Juliet Landrø	NINA	Communications officer
Birk Fiveltun	NTNU	Finance officer
Jonas Bergmann-Paulsen	NTNU	Innovation Manager
Silje Margrethe Nessjø Larsen	NINA	HydroCen knowledge hub

Researchers

Name	Institution	Main research area
Andreas Kleiven	NTNU	Market and services
Arne Nysveen	NTNU	Turbine and generators
Birender Singh	NTNU	Turbine and generators
Bjørn Nilsen	NTNU	Hydropower structures
Bjørnar Svingen	NTNU	Turbine and generators
Chirag Trivedi	NTNU	Turbine and generators
Dadi Ram Dahal	NTNU	Turbine and generators
Diwash Lal Maskey	NTNU	Hydropower structures
Elena Pummer	NTNU	Hydropower structures
Fjóla G. Sigtryggsdóttir	NTNU	Hydropower structures
Frank Mauseth	NTNU	Turbine and generators
Gabriele Gaiti	NTNU	Turbine and generators
Geir Helge Kiplesund	NTNU	Hydropower structures
Halvor Kjærås	NTNU	Hydropower structures
Helene Dagsvik	NTNU	Turbine and generators
Hossein Ehya	NTNU	Turbine and generators
Ishwar Joshi	NTNU	Hydropower structures
Jan Rhebrina	NTNU	Hydropower structures
Jim Abregu	NTNU	Turbine and generators

Researchers

Name	Institution	Main research area
Johannes Opedal Kverno	NTNU	Turbine and generators
Kaspar Vereide	NTNU	Hydropower structures
Kjetil Uhlen	NTNU	Turbine and generators
Knut Alfredsen	NTNU	Environmental design
Krishna Panthi	NTNU	Hydropower structures
Kristian Sagmo	NTNU	Turbine and generators
Leif Lia	NTNU	Hydropower structures
Linn Emelie Schäffer	NTNU	Market and services
Mamata Rijal	NTNU	Turbine and generators
Magnus Korpås	NTNU	Market and services
Michiel Desmedt	NTNU	Turbine and generators
Nirmal Acharya	NTNU	Turbine and generators
Ola Haugen Havrevoll	NTNU	Hydropower structures
Ole Gunnar Dahlhaug	NTNU	Turbine and generators
Pål Keim Olsen	NTNU	Turbine and generators
Pål-Tore Storli	NTNU	Turbine and generators
Raghbendra Tiwari	NTNU	Market and services
Roy Nilsen	NTNU	Turbine and generators
Stein-Erik Fleten	NTNU	Market and services

Researchers		
Name	Institution	Main research area
Subhojit Kadia	NTNU	Hydropower structures
Theo Dezert	NTNU	Hydropower structures
Tor Haakon Bakken	NTNU	Market and services
Torbjørn Nielsen	NTNU	Turbine and generators
Wolf Ludwig Kuhn	NTNU	Turbine and generators
Asli Bor Turkben	NTNU	Hydropower structures
Anders Foldvik	NINA	Hydropower structures
Bjørn Winther Solemslie	NINA	Turbine and generators
Ana Teixeira da Silva	NINA	Environmental design
Audun Ruud	NINA	Environmental design
Berit Köhler	NINA	Environmental design
Eli Kvingedal	NINA	Environmental design
Frode Fossøy	NINA	Environmental design
Henrik Baktoft	NINA	Environmental design
Ingebrigt Uglem	NINA	Environmental design
Ingerid Julie Hagen	NINA	Environmental design
Jon Museth	NINA	Environmental design
Karl Øystein Gjelland	NINA	Environmental design
Line Sundt-Hansen	NINA	Environmental design
Magni Kyrkjeeide	NINA	Environmental design
Marie-Pierre Gosselin	NINA	Environmental design
Markus Majaneva	NINA	Environmental design
Olivia Simmons	NINA	Environmental design
Oddgeir Andersen	NINA	Environmental design
Richard Hedger	NINA	Environmental design
Rolf Sivertsgård	NINA	Environmental design
Tonje Aronsen	NINA	Environmental design
Torbjørn Forseth	NINA	Environmental design
Bjørn Larsen	NINA	Environmental design
Grete Robertsen	NINA	Environmental design
Hege Brandsegg	NINA	Environmental design
Ingeborg Helland	NINA	Environmental design
Ida Andersskog	NINA	Environmental design
Jens Åström	NINA	Environmental design
Knut Eikland	NINA	Environmental design
Kristine Bjørnås	NINA	Environmental design
Merete Spets	NINA	Environmental design
Narve Opsahl	NINA	Environmental design
Ola Ugedal	NINA	Environmental design
Sebastian Wacker	NINA	Environmental design
Vebjørn Opsanger	NINA	Environmental design
Ana Adeva Bustos	SINTEF	Market and services
Arild Helseth	SINTEF	Market and services
Arnt Ove Eggen	SINTEF	Market and services
Atle Harby	SINTEF	Environmental design
Bendik Torp Hansen	SINTEF	Hydropower structures
Birger Mo	SINTEF	Market and services

Researchers		
Name	Institution	Main research area
Christian Øyn Naversen	SINTEF	Market and services
Eivind Solvang	SINTEF	Turbine and generators
Emre Kantar	SINTEF	Turbine and generators
Espen Eberg	SINTEF	Turbine and generators
Gunnar Berg	SINTEF	Turbine and generators
Hans Ivar Skjelbred	SINTEF	Market and services
Håkon Sundt	SINTEF	Environmental design
Igor Iliev	SINTEF	Turbine and generators
Ingeborg Graabak	SINTEF	Market and services
Ingrid vilberg	SINTEF	Market and services
Kjell Ljøkelsøy	SINTEF	Turbine and generators
Marcell Szabo-Meszaros	SINTEF	Environmental design
Maren Istad	SINTEF	Turbine and generators
Mari Haugen	SINTEF	Market and services
Mauro Carolli	SINTEF	Environmental design
Michael Belsnes	SINTEF	Market and services
Olve Mo	SINTEF	Turbine and generators
Siri Mathisen	SINTEF	Market and services
Stefan Rex	SINTEF	Market and services
Sverre Hvidsten	SINTEF	Turbine and generators
Tor Inge Reigstad	SINTEF	Turbine and generators
Tuan T. Nguyen	SINTEF	Turbine and generators
Bjørnar Fjelldal	SINTEF	Market and services
Dimitri Pinel	SINTEF	Market and services
Håkon Toftaker	SINTEF	Market and services
Jiehong Kong	SINTEF	Market and services
Kjartan Hovde	SINTEF	Market and services
Kyriaki Tselika	SINTEF	Market and services
Linn Emelie Schäffer	SINTEF	Turbine and generators
Ove Wolfgang	SINTEF	Market and services
Per Aaslid	SINTEF	Market and services
Sigurd Jakobsen	SINTEF	Market and services
David Florian Vetsch	ETH	Environmental design
Robert Boes	ETH	Environmental design
Sebastian Stranzl	NORCE	Environmental design
Ulrich Pulg	NORCE	Environmental design
Armin Peters	FishConsulting GmbH	Environmental design
Biraj Singh Thapa	KU	Turbine and generators
Bholo Thapa	KU	Turbine and generators
Sailesh Chitrakar	KU	Turbine and generators
Saroj Gautam	KU	Turbine and generators
Dadiram Dahal	KU	Turbine and generators
Rabina Awal	KU	Turbine and generators
Prajwal Sapkota	KU	Turbine and generators
Hari Neopane	KU	Turbine and generators
Ashim Joshi	KU	Turbine and generators

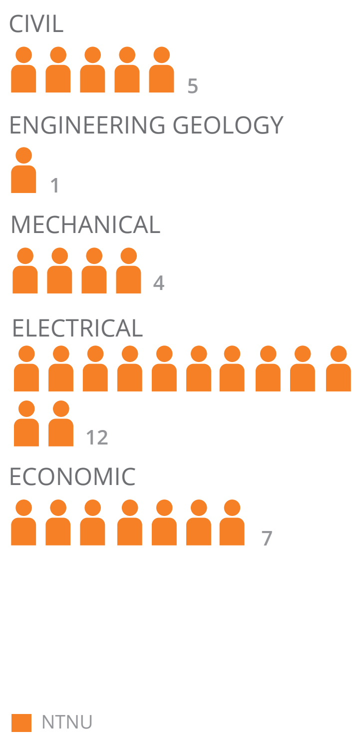
FINANCIAL STATEMENT HYDROCEN 2023

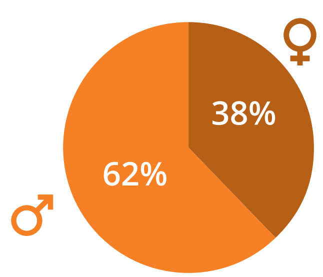
			All figures in 1000 NOK
Funding 2023	**Funding**	**In-kind**	**Total**
The Research Council of Norway	19 747		19 747
Industry partners	9 422	6 787	16 209
Research partners		5 540	5 540
Total funding 2023	**29 169**	**12 327**	**41 496**
Revenue 2023	**Funding**	**In-kind**	**Total**
SINTEF	7 220	2 626	9 846
NINA	7 458	1 577	9 035
NTNU	14 378	1 328	15 706
USN			
NGI			
KU	113	9	122
Open Calls			
Industry in-kind		6 787	6 787
Total Costs 2023	**29 169**	**12 327**	**41 496**

This new model of the hydropower system allows for physical and enthusiastic dissemination both at events and conferences as well as for visitors at the Waterpower laboratory

MASTER STUDENTS

In 2023 we had a total of 29 master students at NTNU within the field of hydropower. The distribution between the disciplines civil, engineering geology, mechanical and electrical is shown in the figure below.



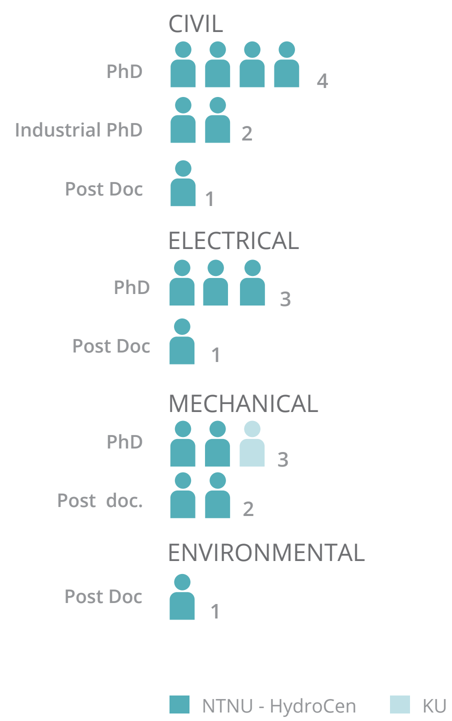


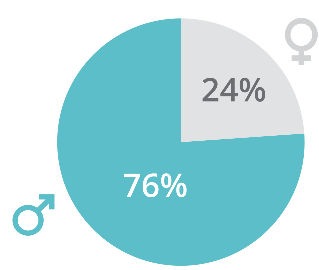
Gender distribution

Women
Men

PHDS AND POSTDOCTORAL FELLOWS

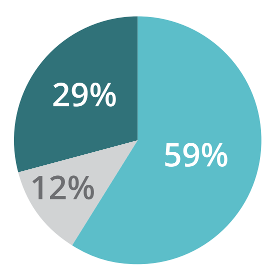
In 2023 a total of 17 PhD and Post docs were in HydroCen. They worked within Civil, Engineering geology, Mechanical, Electrial and Environmental.





Gender distribution

Women
Men



Distribution between PhD, Post doc. and industrial PhD and post doc

Industrial PhD
PhD
Post doc.

PhD and Post doc. funded by HydroCen, active in 2023

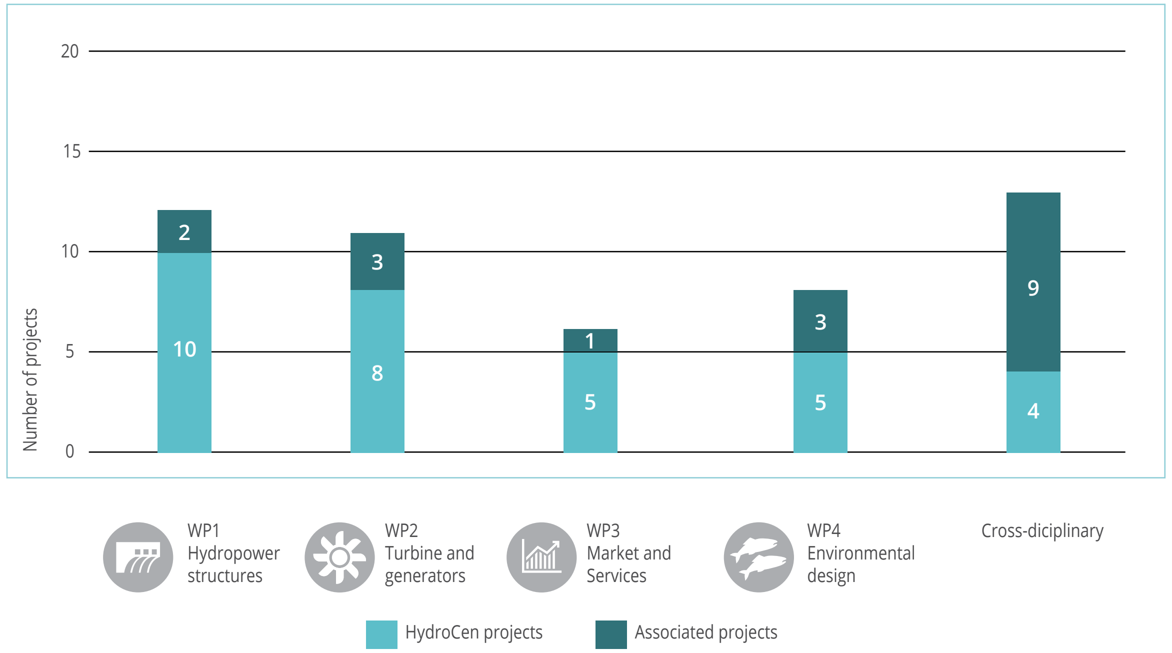
Name	PhD Post doc.	Gender	Nationality	Topic	Period	Department
Birender Singh	PD	Male	Indian	Dielectric Condition Assessment of Back-up Hydro Generator Stator Bars	2021-2023	Electrical
Diwash Lal Maskey	PhD	Male	Nepalese	"Sediment handling at the intake of the hydropower plants: A toolbox for decision making"	2018-2023	Civil
Geir Helge Kiplesund	PhD	Male	Norwegian	Embankment dam safety under extreme loading conditions: Bre-aching of embankment dams	2019-2023	Civil
Halvor Kjærås	PhD	Male	Norwegian	Modeling of fish guidance by floating devices	2018-2023	Civil
Helene Dagsvik	PhD	Female	Norwegian	Reversible Pump-Turbines in Existing Power Plants	2017-2023	Mechanical
Ishwar Joshi	PhD	Male	Indian	Numerical Simulation of Sediment Transport in Rivers and Reservoirs	2021-2024	Civil
Jim Abregu	PhD	Male	Peruvian	Sediment erosion on Pelton turbines	2022-2025	Mechanical
Kristian Sagmo	Post doc.	Male	Norwegian	Design and testing of axial turbine blade-stage for damping measure-ments connected to complex mode shapes	2021-2023	Mechanical
Linn Emelie Schäffer	PhD	Female	Norwegian	Modelling of Environmental Constraints for Hydropower Optimization Problems	2020-2023	Electrical
Mamata Rijal	PhD	Female	Nepalese	Optimization of Variable Speed Francis Turbines for Sediment Laden Projects	2022-2025	Mechanical
Michiel Desmedt	PhD	Male	Dutch	FEA analysis of a novel single stator-dual rotor machine topology	2021-2024	Electrical
Nirmal Acharya	Post doc.	Male	Nepalese	Experimental work on model Pelton turbines	2022-2024	Mechanical
Nils Solheim Smith	PhD	Male	Norwegian	Inkrementell økning av flomløpskapasitet.	2021-2024	Civil
Ola Haugen Havrevoll	PhD	Male	Norwegian	Rock traps in pumped storage and peaking power plants	2017-2023	Civil
Olivia Simmons	Post doc.	Female		Fiskevandring av vinterstøing	2022-2023	Environmental
Raghbendra Tiwari	PhD	Male	Nepalese	Frequency converter solutions and control methods for variable speed operation of pump storage plant	2018-2023	Electrical
Theo Dezert	Post doc.	Male	French	Plastring av damtå og bruddforløp i fyllingsdammer	2021-2023	Civil

PhD student working on projects in the centre with financial support from other sources

Name		"Sex M/F"	Nationality	Topic	Period	Funding
Gabriele Gaiti	PhD	M	Italian	Fluid structure interaction in hydraulic turbine	2021-2024	NTNU
Jan Hrebrina	PhD	M	Czech	Boulder transport and design of structural flood mitigation measures in high mountain regions	2022-2025	NTNU
Johannes Kverno	PhD	M	Norwegian	Design of a Francis turbine for many start-stop cycles per day and high ramping	2019- 2023	EU H2020
Subhojit Kadia	PhD	M	Indian	Secondary currents, turbulent flow characteristics, and bed shear stress variations and impact on sediment transport in supercritical narrow channel flows.	2020-2024	IBM
Dadiram Dahal	PhD	M	Nepalese	Study of boundary layer and its interaction with vibrating blade	2023-2025	NTNU
Ludwig Kuhn	PhD	M	German	Degassing of air-supersaturated water by use of power ultrasound	2020-2023	NTNU

PROJECT OVERVIEW 2023

A total of 57 projects related to hydropower were ongoing in 2023. 15 of these are associated projects within hydropower where HydroCen's researchers are involved.



HydroCen Projects			
Project name		Project leader	Field of study
1.1	Tunnels, penstocks, surge chambers	Krishna Panthi	Hydropower structures
1.2	Dam construction and dam safety	Fjola G. Sigtryggsdottir	Hydropower structures
1.3	Sediment handling	Elena Pummer	Hydropower structures
1.4	Fish friendly hydropower intakes	Leif Lia	Hydropower structures
2.1	Variable Speed Operation	Chirag Trivedi	Turbine and generators
2.3	Pump turbines in existing power plants	Pål-Tore Storli	Turbine and generators
2.4	Turbine and Generator Lifetime	Arne Nysveen	Turbine and generators
3.3	Optimal hydro design in future power systems	Birger Mo	Market and services
3.4	Environmental constraints and uncertainties – impact on revenues	Arild Helseth	Market and services
3.5	Water resources assessment tool	Ana Adeva Bustos	Market and services
4.1	Implementing and founding environmental design solutions (EDS)	Berit Köhler	Environmental design
4.3	Environmental design	Atle Harby	Environmental design

PROJECTS OVERVIEW 2023

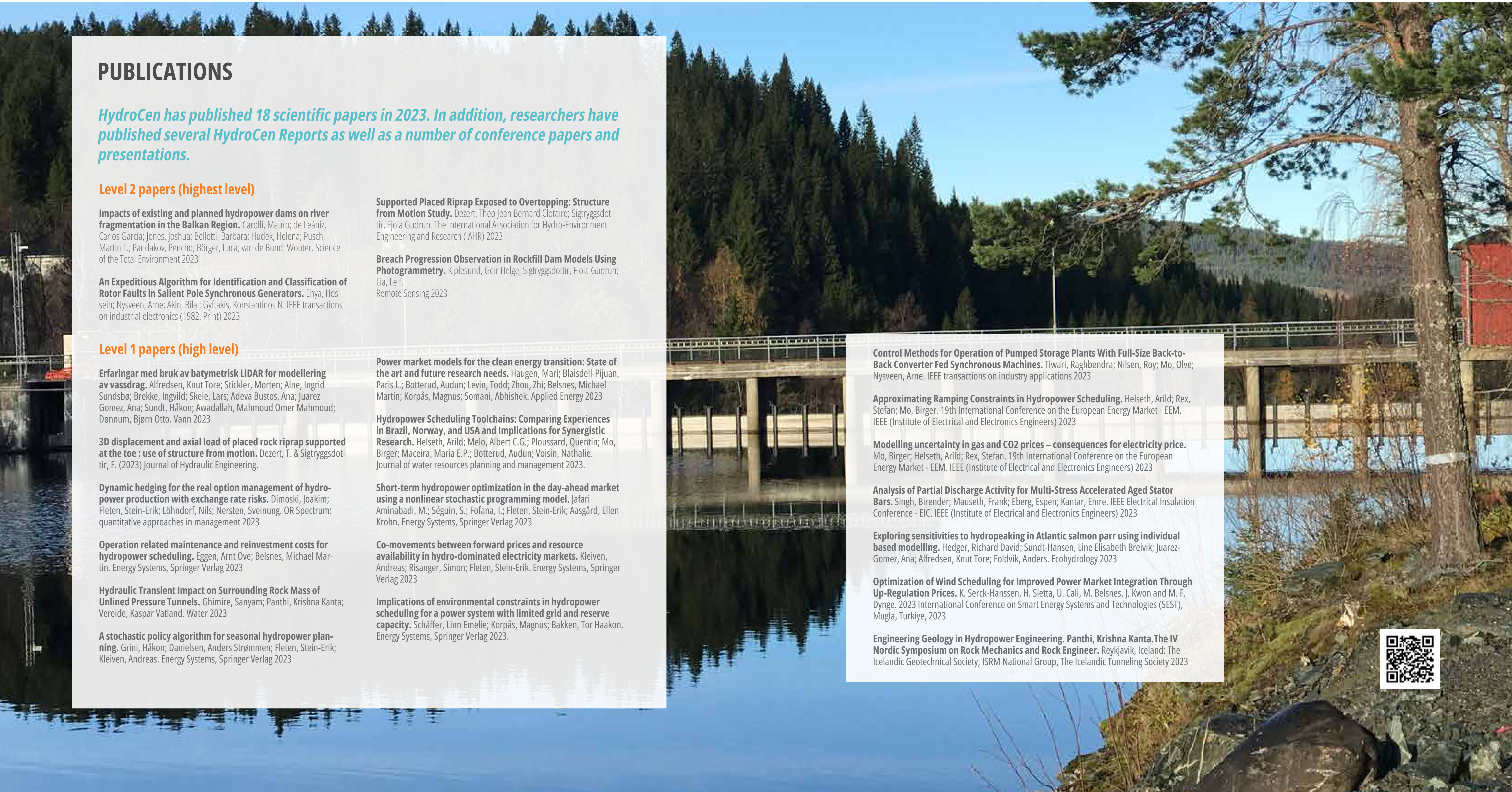
Ongoing HydroCen projects (Open Calls)			
Project name		Project leader	Field of study
5.1.2	Breaching of rockfill dams with core	Fjola G. Sigtryggsdottir	Hydropower Structures
5.1.4	Rock support dimensioning	Krishna Panthi	Hydropower Structures
5.1.8	Forprosjekt: Effektiv funksjonsforbedring av eksisterende bekkeinntak	Leif Lia	Hydropower Structures
5.1.9	InSpillyFish - Øking av flomløpskapasitet med betre vandringsløysingar for fisk	Leif Lia	Hydropower Structures
5.1.10	Hydraulic impact pressure	Krishna Panthi	Hydropower Structures
5.1.11	Fleksible sandfang 3.0	Kaspar Vereide	Hydropower Structures
5.2.6	Peltonturbin Prototyp virkningsgradsmålinger	Bjørn Winther Solemslie	Turbine and generators
5.2.9	SediRes	Sailesh Chitrakar	Turbine and generators
5.2.11	DigiSur	Nirmal Acharya	Turbine and generators
5.2.12	Numerical modeling cracked blade	Igor iliev	Turbine and generators
5.2.13	Fluid Structure Interaction	Chirag Trivedi	Turbine and generators
5.3.7	HydroFy - fair og inkluderende markeder med vannkraft	Michael Belsnes	Market and services
5.3.8	MerUsikkerhet - Markedspriser med forbedret beskrivelse av usikkerhet	Birger Mo	Market and services
5.4.10	Kelt2Sea	Ana da Silva	Environmental Design
5.4.11	eDNA-Sustain	Frode Fossøy	Environmental Design
5.4.12	e-DNA Sampler	Bjørn Winther Solemslie	Environmental Design
5.5.8	Kunnskapsbanken	Jonas Bergmann-Paulsen	Cross-disciplinary
5.5.10	TwinLab II – Accelerating Digitalization of Hydropower Research	Ingrid Vilberg	Cross-disciplinary
5.5.11	Måltall for bærekraftig fleksibilitet fra vannkraft (SusFlexMet)	Siri Mathisen	Cross-disciplinary
5.5.12	Klimaprosjekt	Tor Haakon Bakken	Cross-disciplinary

Associated Projects				
Project name	Project leader	Field of study	Type	Project owner
Capacity Building in Higher Education within Rock and Tunnel Engineering	Krishna K. Panthi	Cross-disciplinary	NORHED II	NTNU
DeGas	Ole Gunnar Dahlhaug	Cross-disciplinary	KPN	NTNU
EnergizeNepal	Ole Gunnar Dahlhaug	Cross-disciplinary	NORAD	NTNU
FirePlug	Brett Sandercock	Environmental design	KSP	NINA
FishPath	Torbjørn Forseth	Environmental design	NFR	NINA
FunkyFish	Ingeborg Palm Helland	Environmental design	KSP	NINA
Hydraulic Research and Education Laboratory and Dam Safety in Ethiopia	Leif Lia	Cross-disciplinary	NORHED II	NTNU
HydroCen Labs	Ole Gunnar Dahlhaug	Cross-disciplinary	RCN Infrastructure	NTNU
HydroConnect	Atle Harby	Market and services	KPN	SINTEF
HydroHimalaya	Ole Gunnar Dahlhaug	Cross-disciplinary	NORHED II	NTNU
InMoDam	Fjola Sigtryggsdottir	Hydropower structures	IPN	NTNU
Norstress	Krishna K. Panthi	Hydropower structures	Norstress	NTNU
SysOpt	Thomas Øyvang	Cross-disciplinary	KPN	USN

PROJECT OVERVIEW 2023

Flomløp ved Midtbotnavatnet. Photo: Leif Lia/NTNU

PUBLICATIONS



PUBLICATIONS

HydroCen has published 18 scientific papers in 2023. In addition, researchers have published several HydroCen Reports as well as a number of conference papers and presentations.

Level 2 papers (highest level)

Impacts of existing and planned hydropower dams on river fragmentation in the Balkan Region. Carolli, Mauro; de Leániz, Carlos Garcia; Jones, Joshua; Belletti, Barbara; Hudek, Helena; Pusch, Martin T.; Pandakov, Pencho; Börger, Luca; van de Bund, Wouter. Science of the Total Environment 2023

An Expeditious Algorithm for Identification and Classification of Rotor Faults in Salient Pole Synchronous Generators. Ehya, Hossein; Nysveen, Arne; Akin, Bilal; Gyftakis, Konstantinos N. IEEE transactions on industrial electronics (1982. Print) 2023

Supported Placed Riprap Exposed to Overtopping: Structure from Motion Study. Dezert, Theo Jean Bernard Clotaire; Sigtryggsdottir, Fjola Gudrun. The International Association for Hydro-Environment Engineering and Research (IAHR) 2023

Breach Progression Observation in Rockfill Dam Models Using Photogrammetry. Kiplesund, Geir Helge; Sigtryggsdottir, Fjola Gudrun; Lia, Leif.
Remote Sensing 2023

Level 1 papers (high level)

Erfaringar med bruk av batymetrisk LiDAR for modellering av vassdrag. Alfredsen, Knut Tore; Stickler, Morten; Alne, Ingrid Sundsbø; Brekke, Ingvild; Skeie, Lars; Adeva Bustos, Ana; Juarez Gomez, Ana; Sundt, Håkon; Awadallah, Mahmoud Omer Mahmoud; Dønnum, Bjørn Otto. Vann 2023

3D displacement and axial load of placed rock riprap supported at the toe : use of structure from motion. Dezert, T. & Sigtryggsdottir, F. (2023) Journal of Hydraulic Engineering.

Dynamic hedging for the real option management of hydropower production with exchange rate risks. Dimoski, Joakim; Fleten, Stein-Erik; Löhndorf, Nils; Nersten, Sveinung. OR Spectrum: quantitative approaches in management 2023

Operation related maintenance and reinvestment costs for hydropower scheduling. Eggen, Arnt Ove; Belsnes, Michael Martin. Energy Systems, Springer Verlag 2023

Hydraulic Transient Impact on Surrounding Rock Mass of Unlined Pressure Tunnels. Ghimire, Sanyam; Panthi, Krishna Kanta; Vereide, Kaspar Vatland. Water 2023

A stochastic policy algorithm for seasonal hydropower planning. Grini, Håkon; Danielsen, Anders Strømmen; Fleten, Stein-Erik; Kleiven, Andreas. Energy Systems, Springer Verlag 2023

Power market models for the clean energy transition: State of the art and future research needs. Haugen, Mari; Blaisdell-Pijuan, Paris L.; Botterud, Audun; Levin, Todd; Zhou, Zhi; Belsnes, Michael Martin; Korpås, Magnus; Somani, Abhishek. Applied Energy 2023

Hydropower Scheduling Toolchains: Comparing Experiences in Brazil, Norway, and USA and Implications for Synergistic Research. Helseth, Arild; Melo, Albert C.G.; Ploussard, Quentin; Mo, Birger; Maceira, Maria E.P.; Botterud, Audun; Voisin, Nathalie. Journal of water resources planning and management 2023.

Short-term hydropower optimization in the day-ahead market using a nonlinear stochastic programming model. Jafari Aminabadi, M.; Séguin, S.; Fofana, I.; Fleten, Stein-Erik; Aasgård, Ellen Krohn. Energy Systems, Springer Verlag 2023

Co-movements between forward prices and resource availability in hydro-dominated electricity markets. Kleiven, Andreas; Risanger, Simon; Fleten, Stein-Erik. Energy Systems, Springer Verlag 2023

Implications of environmental constraints in hydropower scheduling for a power system with limited grid and reserve capacity. Schäffer, Linn Emelie; Korpås, Magnus; Bakken, Tor Haakon. Energy Systems, Springer Verlag 2023.

Control Methods for Operation of Pumped Storage Plants With Full-Size Back-to-Back Converter Fed Synchronous Machines. Tiwari, Raghbendra; Nilsen, Roy; Mo, Olve; Nysveen, Arne. IEEE transactions on industry applications 2023

Approximating Ramping Constraints in Hydropower Scheduling. Helseth, Arild; Rex, Stefan; Mo, Birger. 19th International Conference on the European Energy Market - EEM. IEEE (Institute of Electrical and Electronics Engineers) 2023

Modelling uncertainty in gas and CO2 prices – consequences for electricity price. Mo, Birger; Helseth, Arild; Rex, Stefan. 19th International Conference on the European Energy Market - EEM. IEEE (Institute of Electrical and Electronics Engineers) 2023

Analysis of Partial Discharge Activity for Multi-Stress Accelerated Aged Stator Bars. Singh, Birender; Mauseth, Frank; Eberg, Espen; Kantar, Emre. IEEE Electrical Insulation Conference - EIC. IEEE (Institute of Electrical and Electronics Engineers) 2023

Exploring sensitivities to hydropeaking in Atlantic salmon parr using individual based modelling. Hedger, Richard David; Sundt-Hansen, Line Elisabeth Breivik; Juarez-Gomez, Ana; Alfredsen, Knut Tore; Foldvik, Anders. Ecohydrology 2023

Optimization of Wind Scheduling for Improved Power Market Integration Through Up-Regulation Prices. K. Serck-Hanssen, H. Sletta, U. Cali, M. Belsnes, J. Kwon and M. F. Dynge. 2023 International Conference on Smart Energy Systems and Technologies (SEST), Mugla, Turkiye, 2023

Engineering Geology in Hydropower Engineering. Panthi, Krishna Kanta.The IV Nordic Symposium on Rock Mechanics and Rock Engineer. Reykjavik, Iceland: The Icelandic Geotechnical Society, ISRM National Group, The Icelandic Tunneling Society 2023

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