ANNUAL REPORT

2022

HydroCen

NORWEGIAN RESEARCH CENTRE FOR HYDROPOWER TECHNOLOGY

FME

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

Liv Randi Hultgreen
Excecutive Director,
HydroCen

2022 – HYDROPOWER RESEARCH IS MORE RELEVANT THAN EVER

Through HydroCen's sixth year we have witnessed the rapid changing conditions for the energy supply system in Europe and the world. Together with challenging climate changes and the nature crisis, research on hydropower's role in the energy system is more relevant and widely discussed than ever before. We welcome the rising engagement and plan to spend the next two years to provide solutions. I hope you enjoy this report and join me in applauding our great staff of scientists!

In 2022 the hydropower industry has experienced how unforeseen major upheavals in Europe have influenced both energy markets and policies. The hydropower research community has received much more engagement from both industry and community on the development of hydropower's role in a future energy system with more wind and solar power. HydroCen has several projects that focus on this subject, from different scientific angles.

In 2022 we initiated 10 new projects, that focus on the implications of more dynamic operational modes for equipment, tunnels, dams, rivers, reservoirs, and fish. Most of these projects have a duration of two to three years. Five new PhDs & Postdocs started their research, in close cooperation with our user partners. 20 PhDs & Postdocs have been funded by HydroCen this year, and 26 Master students have completed their thesis'. The research activity has been high, with several successful field tests, resulting in high quality scientific publications and several conference presentations. Two PhDs completed and defended their thesis' in 2022, and both decided to continue their research in postdoctoral positions at NTNU after PhD completion.

In 2022 we have continued and expanded our international research cooperation. We are continuing our cooperation on projects in US, Canada, India, Nepal and Brazil, and have strengthened the cooperation with Sweden and Switzerland. Several researchers have visited us from Nepal, Switzerland and Germany through researcher mobility programs, hence growing the international cooperation with other world-leading research communities.

The HydroCen knowledge hub Kunnskapsbanken is now finding its form. Kunnskapsbanken is the place where all our research results are communicated, and it is continuously updated with new subjects and results, as research activities progress and bring forward new knowledge and results. We have also launched the concept "Researcher on demand", a service for our user partners, that allows the partner to book a researcher for a lecture on a chosen subject. During 2022 several research results have materialised; The research on fault detection in generators have matured further, towards implementation of solutions for machine detection and learning within predictive maintenance. Work on how to guide fish and eel around hydropower intakes has also provided valuable new solutions.

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

Ivar Arne Børset, Chairman of the Board

BRIEF FROM THE BOARD – 2022

Representing a broad part of Norwegian hydropower production and management, HydroCen's Board strongly supports and applauds the excellent scientific activities driven forward by HydroCen.

This year HydroCen has strengthened its focus on communication and dissemination of research results, to contribute to society's growing demand for fact and research-based information on hydropower's future possibilities. 2022 has been a volatile year, and the need for further development of our power system, involving a need for upgrading and possible expansion of hydropower, seems to be recognized by both governments, public management, the power industry and the public.

The need for innovation and fact-based decision making is high, and 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.

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.

We welcome the knowledge hub Kunnskapsbanken, where all research results from HydroCen continuously get added as they materialize. It is of great importance that all members of HydroCen will contribute to and benefit from more communication to be able to harvest the potential that lies in research results. To solve coming challenges in a more flexible power system, we need to pull together and find those solutions.

Ivar Arne Børset, on behalf of the Board

Photo: Juliet Landrø/HydroCen

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

Liv Randi Hultgreen
NTNU/Board
Secretary

MODEL TESTS AT VATTENFALL USING 3D PIV AND HIGH-SPEED CAMERAS

Researchers carried out experimental work at the Vattenfall laboratory in Älvkarleby in Sweden. PhD candidate Subhojit Kadia studied 3D flows and sediment movements in a sediment bypass tunnel model using 3D PIV (Particle image velocimetry) and high-speed cameras. 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.

Subhojit Kadia,
PhD candidate

Elena Pummer,
Associate Professor

Photos: Elena Pummer/NTNU

Halvor Kjærås
PhD candidate

HELPING EELS BYPASS HYDROPOWER

It has long been a problem in regulated river systems that eels swim into hydropower intakes and meet their death in the turbines.

In a new study from HydroCen, scientists tagged and tracked 90 eels to monitor their downstream migration in the river Ätran by Herting hydropower plant in Sweden.

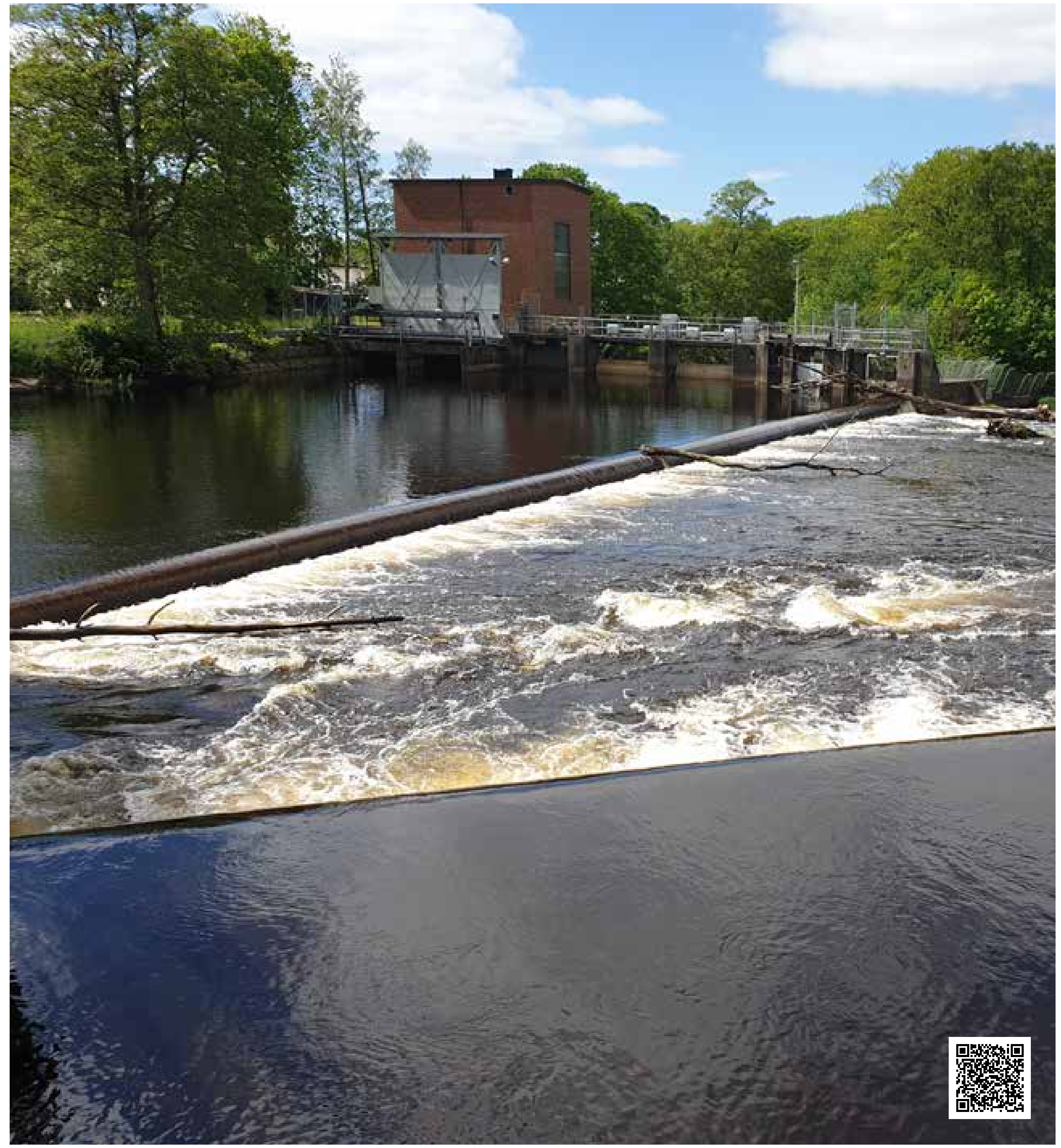
Contrary to previous beliefs eels swim both at the surface and along the riverbed. The water currents in the river affect their swimming behavior, and they move differently when swimming upstream, compared to downstream.

The river is divided in two before the intake, and the eels can either choose to swim towards the power plant intake or over some small weirs towards the natural river course.

Just under half of the tagged eels swam towards the intake where they encountered a guiding fence. Here the eels could choose to escape through openings at the surface or on the river bed. Almost one in three chose to swim through the upper opening, and two out of three through the lower.

None of the tagged eels ended up in the turbines on their way to the sea. The results from the study are important for finding solutions to make safe migratory routes for the eel past the hydropower plants on its way to the sea to spawn.

Photo: Erling Svendsen/Artsdatabanken.



Overflow weir and spillway for Herting hydropower plant in Sweden. Photo: Halvor Kjærås/NTNU.

NEW RESEARCH ON TURBINE EROSION BY SEDIMENTS

Nirmal Acharya
PhD Graduate

Globally, hydropower producers have a challenge when it comes to extensive erosion by sediments. When water and sediments enter tight spaces in the turbine, these spaces will expand and the leakage in the turbine increases. This means that you do not get to utilize the full power from the water, and thus produce less energy. Research on the flow pattern in the area between the stationary and the rotating parts of the turbine has resulted in better insight in how the placement of the turbine parts regarding each other affects the rate of erosion by sediments in the water. The results of the experiments showed that with increasing rotation speed, the wear on the metal increased. The position of the rotating and the stationary part in relation to each other had a lot to say. If the rotating part of the turbine was located higher than the stationary part, this would cause significantly more wear than if they were at the same height, or if the rotating part was lower than the stationary part. To take account for the erosion in this specific area of the turbine, the general erosion model was extended by including both the width and height difference between the stationary and rotating parts. In this way the model has become more specific, so that it becomes more accurate for the operation of Francis turbines in sediment loaded waters.

Photos: Ole Gunnar Dahlhaug/NTNU.

Photo: Juliet Landrø/HydroCen

METHOD FOR CALCULATION OF OPERATION RELATED COSTS

The components in hydropower plants are often designed for specific operational patterns or conditions. Production outside these specific operational patterns will often lead to increased stress on the power plant, resulting in more frequent repairs and replacements of parts, meaning significant expenses for the power producer.

In order to reduce these expenses, it is important to plan and weigh up how the current productional pattern and income affect the future expenses that the current operational pattern will cause for the facility.

The model is a continuation on a model for the cost of a start/stop of the hydropower unit, where the model includes both the duration of the stoppage as well as the plant's technical condition. The model can also be used to estimate the cost of "ramping", and the cost of operating the powerplant with loads the plant is not normally designed for (partial load and/or overload).

The results from the model should be included as input parameters to models or software that calculate the disposition of available water resources. It is therefore a good resource to be able to make better considered decisions related to production planning in various plants.

Arnt Ove Eggen
Researcher,
SINTEF Energy

Photo: Juliet Landrø/HydroCen

DEGAS LABORATORY EXPERIMENTS

Hydropower plants can cause air bubbles in the river, causing fish to die of “Gas Bubble Disease”, similar to diver’s disease for humans. Researchers have now tested new methods to reduce this problem. In the project DeGas we have built a test-rig in the Waterpower laboratory which is designed to test power ultrasound and initiate so-called “acoustic cavitation”.

That means that the air bubbles collapse when the ultrasound waves travel through the water. This method enhances the natural degassing process and lowers the air saturation level in the water. Researchers have also tested other parameters that affect the degassing process, such as sound intensity, gas saturation levels, and flow velocities.

COOPERATION WITH THE HYDROPOWER INDUSTRY

In 2022 several of our results have been tested and adopted by the hydropower industry. We have had fruitful meetings in the technical committees, many workshops and site visits. Here are a few examples:

Technical Committee meetings:
We have had two large meetings and workshops with around 100 of our partners. At these meetings experts from the hydropower industry meet with the researchers and each other to be updated on our results, give input on the research, to discuss implementation, and propose new research ideas.

Analysis of upgrade options in Røldal-Suldal (Lyse):
The power plants in Røldal-Suldal were built to supply Hydro's aluminum works on Karmøy, and are not adapted to a future power system with a greater need for flexibility in production. Lyse have operated the power plants since 2021. Personnel from HydroCen WP3, commissioned by Lyse, have carried out income analyses for a large number of expansion alternatives with alternative assumptions for inflow and market prices. The analyzes have been carried out with tools and methodology from focus areas in WP3. There are plans for further collaboration and analysis with even greater use of the latest tools from WP3.

ProdRisk-SHOP simulator: Hafslund Eco are among the power companies who are now planning to test and implement the simulator for revenue streams in future markets.

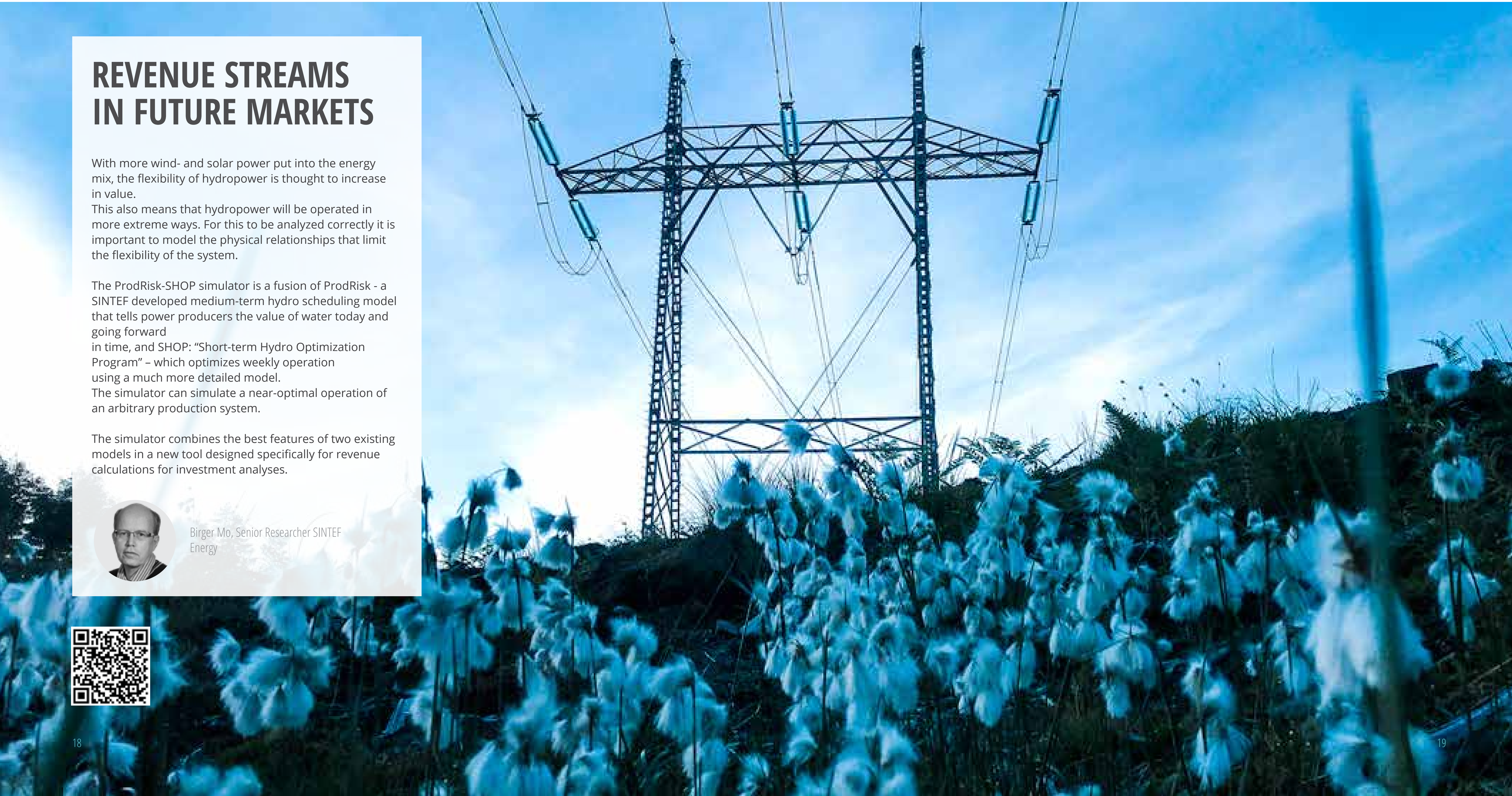
Measurements at Grunnåi power plant.
Skagerak Kraft has made unit two at Grunnåi Power Plant available for research activity. The aim is to further develop techniques to measure the efficiency of Pelton turbines. Today's standard for measurement can be problematic both for power producers and turbine suppliers who want to know how efficiently the turbine utilizes the water to produce energy. The method is based on temperature measurement and requires, among other things, a certain distance from the turbine. This is impossible to achieve in several Norwegian power plants due to the way the tunnels are constructed downstream from the turbine. In addition to this, heat from the rock mass can be transferred to cold water coming from reservoirs higher up in the mountains and affect the measurements.

Photo: Steis Mekaniske verksted

Researchers in HydroCen are therefore trying to develop a reliable method that can be used as an addition to the current standard when needed. This way both turbine suppliers and power producers can trust the measurements and be confident that the Pelton turbine is working as it should.

Fish fence at Laudal power plant:
The floating fish fence that has been tested at Laudal power plant in the Mandal river is a proved success for both fish migration and cooperation between researchers, power producer Å Energi (frm. Agder Energi) and local buisnesses such as Steis Mekaniske Verksted. After analyzing the data in 2022, researchers concluded that the guiding system effectively leads salmon smolts past the power intake. Other power producers are now considering to install similar systems and researchers are now working on guiding systems for more fish species.

Researcher on demand:
We have also established the concept "Researcher on demand" where we offer to visit our industry partners and present useful results and research from HydroCen.
Scan the QR-code for the list of topics to choose from – and the online application form.



REVENUE STREAMS IN FUTURE MARKETS

With more wind- and solar power put into the energy mix, the flexibility of hydropower is thought to increase in value.
This also means that hydropower will be operated in more extreme ways. For this to be analyzed correctly it is important to model the physical relationships that limit the flexibility of the system.

The ProdRisk-SHOP simulator is a fusion of ProdRisk - a SINTEF developed medium-term hydro scheduling model that tells power producers the value of water today and going forward
in time, and SHOP: "Short-term Hydro Optimization Program" – which optimizes weekly operation
using a much more detailed model.
The simulator can simulate a near-optimal operation of an arbitrary production system.

The simulator combines the best features of two existing models in a new tool designed specifically for revenue calculations for investment analyses.

Birger Mo, Senior Researcher SINTEF Energy

Photo: Sonja Kristina Norum Johansen.

USING ENVIRONMENTAL DNA TO DETERMINE HOW HYDROPOWER AFFECTS BIODIVERSITY IN RIVERS

Researchers from HydroCen took over 400 DNA samples from Norwegian rivers in 2022. The aim is to investigate how various forms of hydropower affect the species that live in the river, and ultimately help the hydropower industry produce more sustainable renewable energy.

As Norwegian rivers cascade through the landscape, a multitude of insects live their lives in these clear waters. Many are so small that you may never have considered their very existence, and some species are most likely to be discovered. How does hydropower impact them?
Nobody knows.

What we do know is that both EU rules and Norwegian laws require us to take care of them as part of natural biodiversity. If power companies show that they take this into account, they can also create an advantage in the so-called "EU taxonomy", the new system the EU has introduced for companies to document sustainability.

Environmental DNA revolutionizes mapping of species

Benthic fauna are small animals that live on the river bed. They are, among other things, food for larger species such as fish and birds. Without them we wouldn't have fish in our rivers. In the past, it has been almost impossible to monitor all of them because they are so tiny and hard to tell apart. But with new technology, scientists believe they can detect more species and distinguish them from each other.

- It is very likely that we will find species that have never been found in Norway before, says NINA-researcher Frode Fossøy.

He is one of the world's leading experts on environmental DNA (eDNA) and project manager in HydroCen. In collaboration with Hafslund Eco, Vattenfall, Å Energi and the Norwegian Environment Agency a multitude of rivers will be examined to find out if different forms of hydropower operation affect how many species live in the river.

With environmental DNA they can find hundreds of species using a small water sample.

Investigate developed and protected rivers

Hydropower accounts for 16 percent of the world's renewable energy production, and has the unique property that it can produce electricity exactly when it is needed, on the contrary to wind and solar power.The water stored in the huge reservoirs can be used at any time, which typically leads to low water in the river downstream of the dam when there is low demand for power, but quickly increases to high water flows when people need a lot of power.

Today, we know a lot about how changes in water flow affect salmon, and what we can do to improve the conditions for this one species, but we know little about how much these changes affect the biological diversity in the river.

- We will use environmental DNA to see if there is a difference between the species diversity in rivers with large flow changes and those with more regular flows, says Fossøy.

To assess the condition, they will compare with undeveloped, protected rivers in the vicinity.

This research is even more relevant recently due to the electricity price debates. Both the development of pumped storage production, the pumping of water back into reservoirs when the price is low, and development of protected rivers have been suggested in the energy debate.

- We don't know much about the total biodiversity in protected rivers, so it will also be very interesting to see if biodiversity there really is higher than in developed rivers, says Fossøy.

Climate change also affects rivers

It is not only hydropower that can affect biodiversity in watercourses. Climate change, pollution and several other factors cancontribute to decreasing the number of species in a watercourse. Until now it has been more or less impossible to map rivers at such a detailed level, because it has been too expensive and too difficult. This knowledge can be revolutionized with DNA. The same water sample can be used to find bacteria, algae, insects, crustaceans, fish and mammals.

- By using environmental DNA, we have a much better opportunity to get an overview of the species diversity in our rivers, at a much lower cost, says Fossøy.

Models of actual water flow

The flow of water in both regulated and non-regulated rivers varies greatly throughout the season and annually. The same type of regulation could also cause large differences in water flow in different rivers. Therefore, the researchers will use hydrological data in collaboration with experts from SINTEF to look at variation in the water flow the past three years.

- A lot of data is publicly available, but we will also get valuable contributions from our partners from the hydropower industry, says Fossøy.

The purpose of this modeling is to be able to link variation in water flow to biodiversity, both for different forms of regulation and for non-regulated rivers. This way, the researchers will be able to distinguish between the effect of different types of regulation and the effect of different forms of operation.

- We want to see how water flow alone affects species diversity in the rivers, so that we can help the hydropower industry to optimize operations in the most sustainable way possible, says Fossøy.

Frode Fossøy
Senior Researcher, NINA

PHD'S IN HYDROCEN

Nirmal Acharya

Doctoral thesis:

Erosion in Francis turbines due to geometrical positioning of runner and guide vanes

Through his work, Nirmal has looked at problems surrounding the wear and tear of turbine components due to sediments in the water. Through case studies and the use of numerical analyses, he has looked at how sediment-filled water moves through the turbine, and where and under which conditions the wear on the turbine components is most severe.

Hossein Ehya

Doctoral thesis:

A Novel Health Monitoring System for Synchronous Generators using Magnetic Signatures

In his doctoral work, Hossein has found a low cost and effective method to detect faults in electric machines in an early stage before they become critical!
The method involves measuring the machine's magnetic field to pick up irregularities that occurs before the accident itself. The method was developed for hydropower generators but has transfer value to other electric machines.

Håkon Sundt

Doctoral thesis:

Remotely sensed data for bathymetric mapping and ecohydraulics modelling in rivers

Through his PhD, Håkon Sundt has looked at the use of remote sensing as a source of information on bathymetry (topography in the water), seasonal mesohabitats for fish, scenarios for mitigation measures and strategies for environmental eDNA sampling.

Andreas Kleiven

Doctoral thesis:

Decision analytics in hydropower: Investment and operational planning under uncertainty

The rapid development towards a more sustainable power system gives rise to complex stochastic optimization problems for hydropower producers. In his thesis, Andreas Kleiven has worked on developing optimisation models and methods for sustainable investment and operation of hydropower plants.

Ana Silva, project leader, Norwegian institute of Nature research, NINA.

WILL GUIDE TIRED SALMON BACK TO SEA

Researchers are about to uncover the secret life of kelts in the river. These winter-survivors are important for securing the salmon population, and now researchers seek to help them pass obstacles in the river come spring.

– We know very little about what influences the swimming patterns of kelts, but we know that this is a very important life stage for salmon, says Kelt2SEA project manager Ana Silva.
Researchers have already made guiding solutions for salmon smolt. However, providing cost-effective downstream solutions for salmonid kelts is still one of the major remaining challenges when it comes to safe two-ways passage of migrating fish, particularly past hydropower installations in large river systems.

–The ultimate goal is to get the salmon safely past turbines and dams so they can reach the sea and survive for a new spawning season, says Silva.
Atlantic salmon kelts are adult salmon that have spawned in the river and stayed in the river over winter. Their downstream migration to the sea is in spring and they return as repeat spawners the following year.

Laboratory experiments with live fish
The interdisciplinary team of researchers and experts from several countries use the "Laxeleratorn" flume at Vattenfall's laboratory. They will measure the fish's response to different velocities and acceleration that commonly exist in the vicinity of a hydropower plant station.

Postdoctoral fellow Olivia Simmons will study the kelts' behaviour in the vicinity of different racks and bypass entrances.

Photo: Line Sundt-Hansen/NINA

– First, we will try to understand the behavior of the fish under various water conditions, says Olivia Simmons, who is a PhD-researcher in the project.
– Then we will study the kelts' behaviour in the vicinity of different racks and bypass entrances.

Will develop a model for power producers and management
The aim is that the results be used by power producers and authorities, both in Norway and internationally to ensure better two-way fish migration.
– Among other things, we will develop predictive models for kelts, that will then help us create new solutions to facilitate downstream migration of kelts, says Silva.
Previous research shows that for every extra day kelts are prevented from reaching the sea, it can lose as much as 4-5% of their remaining energy reserves.
– So, if we can help their migration, it will have a big impact on the salmon survival, says Silva.

NEW IN HYDROCEN

Subhojit Kadia, PhD

What is your assignment/expertise/ contribution in HydroCen?
Presently, I am investigating the flow and sediment movement characteristics in sediment bypass tunnels which are used to minimise sedimentation in hydropower/ multipurpose reservoirs. This objective lies within the scope and expertise of HydroCen.

What is your motivation to be a part of HydroCen?
HydroCen contributes to the research and development of renewable energy including hydropower which is my expertise and interest.

What are your expectations for HydroCen looking forward?
I expect HydroCen to continue to contribute toward the research on renewable energy development to support a sustainable power market for the generations to come.

Théo Dezert, Postdoctoral fellow

What is your assignment/expertise/ contribution in HydroCen?
My research focuses on the safety of embankment dams exposed to overtopping. I specifically build rockfill dam models in the laboratory to study failure mechanisms, riprap protection and breaching formulas validity.

What is your motivation to be a part of HydroCen?
I am pleased to be part of Hydrocen since my work goes hand in hand with previous work from PhD candidates HydroCen Priska Hiller, Ganesh Ravindra and Geir Helge Kiplesund. Working in the continuity of previous research allows us to go deeper in the understanding of riprap resistance against overtopping.

What are your expectations for HydroCen looking forward?
Looking forward, I am excited to keep on with the opportunity to meet many other young researchers working on complementary thematics like mine.

Birender Singh, Postdoctoral fellow

What is your assignment/expertise/ contribution in HydroCen?
The main objective of this research work is to investigate the Dielectric Condition Assessment of Back-up Hydro Generator Stator Bars using non-destructive methods. In this work, I have to conduct several tests to examine the remaining life of the generator bars and future planning for their maintenance. The non-destructive tests are as follows: Partial discharge measurement (online and offline mode), Tan delta measurement at different frequencies and voltages.

What is your motivation to be a part of HydroCen?
My background is from high voltage insulation design and assessment of the insulation remaining life, so I found HydroCen to be my best opportunity to be part of a centre for environmentally friendly research.

What are your expectations for HydroCen looking forward?
Currently I am working with hydrogenator stator bars condition monitoring, it would be excellent if I got the opportunity to interact with the industries/manufacturers of the hydrogenerators.

Jim Abregu, PhD

What is your assignment/expertise/ contribution in HydroCen?
I have worked in hydropower plants for 12 years, and now I have the assignment to research erosion in Pelton turbines with the new challenges that hydraulic turbines face with growing renewable energies and climate change.

What is your motivation to be a part of HydroCen?
Norway has a very important relation to the history of hydropower energy, and Hydrocen is now the research center for solutions to new challenges. Having the chance to contribute as part of HydroCen is a good motivation.

What are your expectations for HydroCen looking forward?
Its support to the project to find outcomes easy to massive and be used to increase the generation of clean energy.

NEW IN HYDROCEN

Michiel Desmedt, PhD

What is your assignment/expertise/ contribution in HydroCen?
I am developing the electromechanical part of a booster pump which can be retrofitted in existing power plants. Doing so could enable a hydropower plant to act as a pumped storage facility.

What is your motivation to be a part of HydroCen?
HydroCen approaches hydropower in a very multidisciplinary way, which I think is very important to actually see practical applications.

What are your expectations for Hydro-Cen looking forward?
HydroCen is providing support through facilities and funding, and has regular networking events within as well as outside HydroCen itself. I can only ask to keep up this good work!

Nils Solheim Smith, PhD

What is your assignment/expertise/ contribution in HydroCen?
I am a PhD candidate investigating measures to improve existing spillways for dams. We are hoping to find incremental increases in spillway capacities, ensuring that our dams and spillways continue to function safely into the future, without worsening conditions for migrating fish and minimising potential down time in energy production.

What is your motivation to be a part of HydroCen?
Already while doing my master's thesis, I was involved with HydroCen WP 1.2, working on embankment dams, ultimately leading to my first publication. I guess I am one of the last PhD candidates from HydroCen in its current configuration, so I am hoping to finish strong!

What are your expectations for HydroCen looking forward?
I greatly enjoy the interdisciplinary nature of HydroCen and I hope to learn more about the other sides of hydropower and the energy system!

Olivia Simmons, Postdoctoral fellow

What is your assignment/expertise/ contribution in HydroCen?
I started working as a Postdoctoral fellow at NINA in August 2022. My main tasks are working on KELT2SEA. As such, I am working on the collection and analysis of data from downstream migrating Atlantic salmon kelts, aiming to better understand how hydraulic conditions affect their swimming behaviour.

What is your motivation to be a part of HydroCen?
The work for KELT2SEA fits in really well with the objectives of WP4 in HydroCen. By better understanding how hydraulic conditions affect swimming behaviour, we can try to understand how kelts react to hydropower infrastructure, which alter the hydraulic conditions they experience as they migrate. Thus, working within HydroCen is very motivating.

What are your expectations for Hydro-Cen looking forward?
I expect that the results being generated from HydroCen projects will be really useful for developing knowledge to mitigate the impacts of hydropower on downstream migrating fish.

Gabriele Gaiti, PhD

What is your assignment/expertise/ contribution in HydroCen?
My assignment is to further investigate the behaviour of hydrodynamic damping on a circular blade cascade configuration. The goal is to understand the relation between Re and hydrodynamic damping for the specific configuration and compare the results with previous studies on simpler configurations.

What is your motivation to be a part of HydroCen?
HydroCen is a research center from which you get in touch with many interesting multidisciplinary projects and people from the hydropower research community, expand your network and be update on hydropower technologies.

What are your expectations for Hydro-Cen looking forward?
I hope the research center will be able to endure in the years to come and keep on linking and connecting the hydropower research community (but not only!).

TECHNICAL COMMITTEES 2022

NEW PROJECTS IN HYDROCEN

In 2022 we launched 13 new Open Calls- projects in HydroCen of various size and scope.

HYDROPOWER STRUCTURES

Improvement of the existing brook intake
The aim is to develop and verify a methodology for detecting and quantifying spill from brook intakes.
Project leader: Leif Lia, NTNU
Duration: Jan 2022 – Des 2023

InSpillyFish
The project will look into possibilities for increasing flood run capacity with better migration solutions for fish.
Project leader: Leif Lia, NTNU
Duration: 2022 – 2025

TURBINE AND GENERATORS

DigiSur
Developing an algorithm that will compare images of the turbine from several times in the erosion process, and thus estimate the condition.
Project leader: Nirmal Acharya
Duration: 2022 - 2024

MARKET AND SERVICES

HydroFai
Produce insights into how ZMC resources in the ongoing energy transition will impact future electricity markets and build competence on how a fair and inclusive market design for energy storage resources can look like.
Project leader: Michael Belsnes
Duration: 2022

MerUsikkerhet
The goal of this project is to significantly improve the uncertainty modelling used in the 2030 HydroCen data set and to calculate new price forecasts that incorporate the new uncertainty modelling.
Project leader: Birger Mo
Duration: 2022

Inflow Modelling
The results of this project will be a recommendation of an inflow model that is suitable for implementation in ProdRisk.
Project leader: Siri Mathisen
Duration: 2022

Photo: Sonja Kristina Norum Johansen/NINA

ENVIRONMENTAL DESIGN

KELT2SEA
The aim of this project is to expand the knowledge on kelts behaviour to hydraulic properties of the flow, in order to understand path choices that have been observed in previous projects (e.g. SafePass), and to develop predictive models for kelts.
Project leader: Ana T. Silva
Duration: May 2022 – Dec 2024

eDNA-SUSTAIN
Perform the first nation-wide analysis of biodiversity in relation to hydropower operation using eDNA and provide unique data for guiding future sustainable operation in face of the new EU-taxonomy.
Project leader: Frode Fossøy
Duration: 2022 - 2024

INTERDISCIPLINARY PROJECTS

TwinLab II
The main objective for TwinLab II is to include and demonstrate several user-cases in the digital workbench.
Project leader: Ingrid Vilberg
Duration: 2022

SusFlexMet
Developing a framework for systematic quantification of the regulation capabilities of hydropower in terms of a set of metrics and the trade-offs between them. The result will be an assessment system suitable for validating the capabilities of supplying flexibility in a sustainable way from individual hydropower watercourses. The metrics should be well-founded within their field while at the same time being understandable for non-experts.
Project leader: Ellen Krohn Aasgård (Maren Istad)
Duration: 2022 – 2023

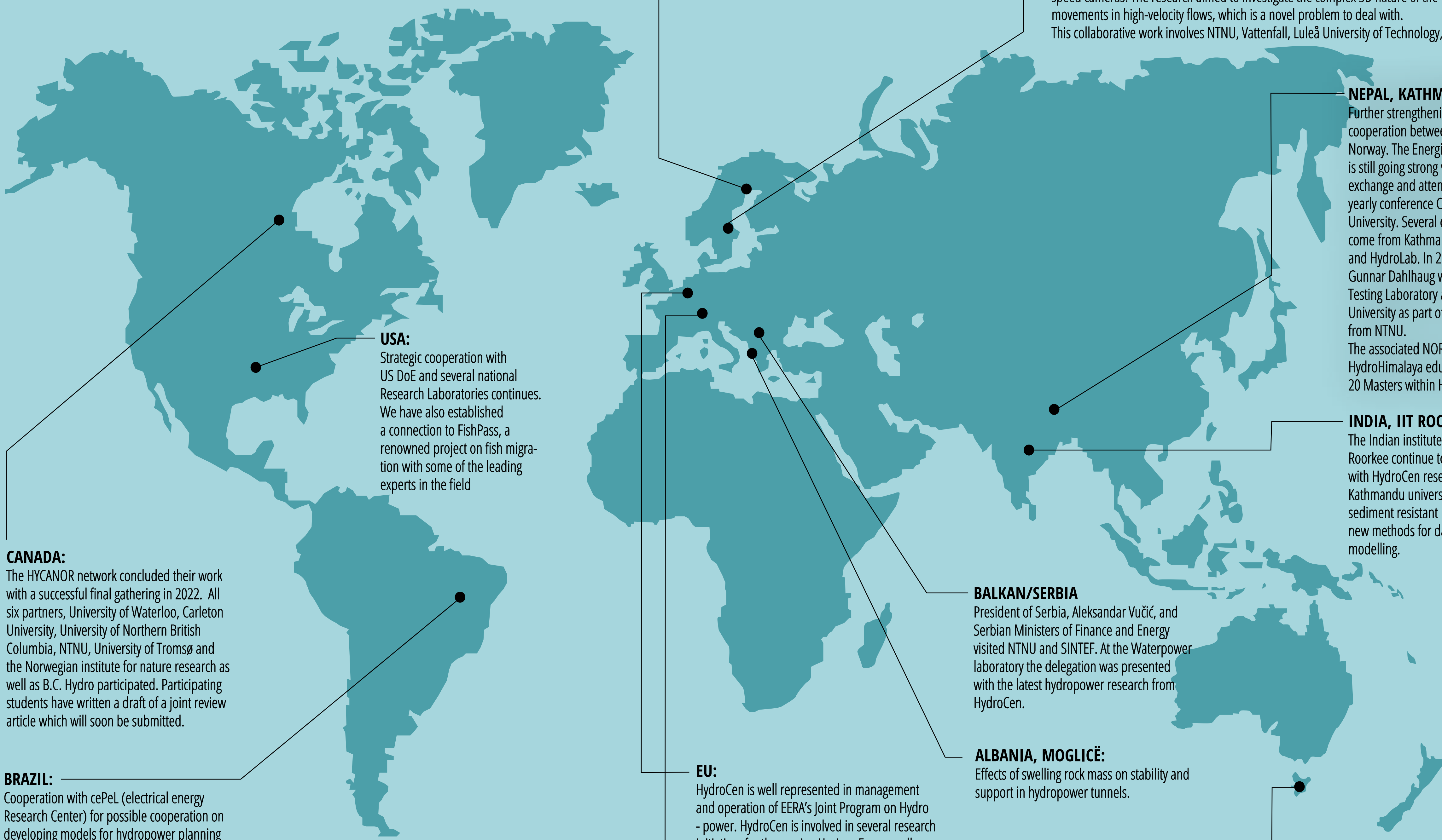
Climate project
The project will map and prepare a larger climate project with hydropower producers' perspective and challenges.
Project leader: Tor Haakon Bakken
Duration: 2022 – 2023

GridVille
GridVille is a student driven project with its origin from "Engineers without borders".
Project leader: Ole Gunnar Dahlhaug
Duration: 2022

Interdisciplinary groups
The project will follow up the work in the interdisciplinary groups.
Project leader: Liv Randi Hultgreen
Duration: Jan 2022 – Dec 2022

INTERNATIONAL INTEREST IN HYDROCEN

HydroCen researchers have continued the collaboration with our international partners in 2022. Through research exchange, workshops, webinars and scientific articles HydroCen has reached across the world. The international collaboration in HydroCen is organized along five main axes, ensuring knowledge transfer to/from relevant regions, excellent research groups and participation in technological fora. The two strongest axes are geographically focused towards the Nordic and European regions, the third axis is towards Asia where large-scale development of hydropower is ongoing. The fourth axis to America and the fifth axis is towards the participation in technological fora. More than 60 international institutions are in contact with HydroCen through these axes.



SWEDEN, LULEÅ:
Researchers from Luleå University of Technology contribute to the experiments at Vattenfall with their expertise on using high resolution 3D PIV (Particle image velocimetry) and high-speed cameras in research.

SWEDEN, ÄLVKARLEBY:
Several researchers did experiments in the laboratories of our partner Vattenfall. 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.
PhD candidate Subhojit Kadia, who is working with Associate Prof. Elena Pummer, carried out experimental work at the Vattenfall laboratory in Älvkarleby. He studied 3D flows and sediment movements in a sediment bypass tunnel model using 3D PIV (Particle image velocimetry) and high-speed cameras. 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.

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. In 2022 Professor Ole Gunnar Dahlhaug works at the Turbine Testing Laboratory at Kathmandu University as part of his sabbatical year from NTNU.
The associated NORAD funded project HydroHimalaya educates 10 PhDs and 20 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.

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

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. Participating students have written a draft of a joint review article which will soon be submitted.

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

Writing a scientific article together with authors from Rio de Janeiro State University (Brazil) and Argonne National Laboratories (USA) on the topic "Hydropower scheduling toolchains".

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

BALKAN/SERBIA
President of Serbia, Aleksandar Vučić, and Serbian Ministers of Finance and Energy visited NTNU and SINTEF. At the Waterpower laboratory the delegation was presented with the latest hydropower research from HydroCen.

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

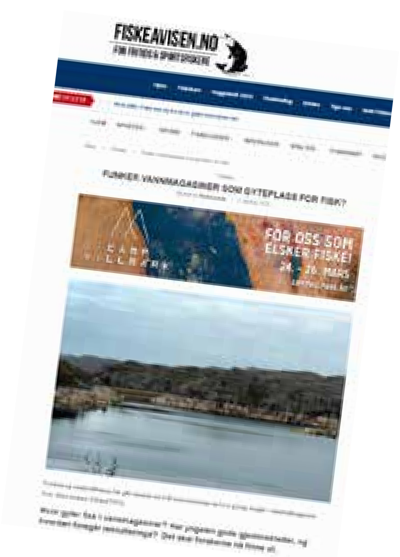
EU:
HydroCen is well represented in management and operation of EERA's Joint Program on Hydro - power. HydroCen is involved in several research initiatives for the coming Horizon Europe call.

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

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

HYDROCEN IN THE MEDIA

In 2022 HydroCen researchers have been featured in various media outlets. They have participated in news articles, radio and tv pieces both nationally and locally.
HydroCen has been mentioned over 110 times in many traditional media outlets. We have also actively used social media platforms to promote HydroCen research and produced 15 news pieces on our website.
Many of these stories have been republished in technical magazines.



OUR OULETS

Knowledge Hub / Kunnskapsbanken:
The new HydroCen knowledge hub has listed more than 30 new pages in English and Norwegian describing the research results from HydroCen and putting them into a societal and practical context.

Newsblog:
15 news stories with information, news and research results from HydroCen in 2022, and an increasing number of followers. These posts have had more than 5000 views.

Vannposten:
Weekly newsletter for researchers and partners. 15 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

Webinar:
More than 17 webinars posted on HydroCens YouTube-channel and others. Approx. 2600 views in 2022.

SOCIAL MEDIA

555

Twitter:
Sharing news and articles, and following the public debate. 555 followers and a monthly reach of about 1500.

600

Facebook:
Sharing articles and news with our 600 followers. A monthly reach of about 2000.

666

LinkedIn:
666 followers and aiming to increase activity

KUNNSKAPSBANKEN

During the past year the knowledge-hub for hydropower has been launched in both Norwegian and English. The goal of the knowledge-hub is to make the knowledge from the research in HydroCen available for partners and society. This is to ensure that the results can be used directly by the hydropower industry or in further research and thereby to ensure value creation and societal benefit.

The knowledge-hub will continuously collect, popularise and present the results from HydroCen and put them into the broader context until the end of the center period in 2024.

To make the results from the science from HydroCen even more available and easy to use, the plan for the coming year is to further communicate them through the use of different dissemination platforms, such as handbooks, fact sheets and webinars.

GUIDING FENCE FOR FISH
Solutions for fish migration

LIFETIME OF TURBINES IN SEDIMENT-CONTAINING WATER
Optimizing design for Francis turbines

MODEL FOR OPERATION PATTERN-RELATED COSTS
How to lessen operational costs

OPTIMAL CONTROL FOR VARIABLE SPEED
Use of virtual inertia

PRICE FORCAST FOR ELECTRICITY
Open and accessible price forcast for electricity

RAPID STEP-RATE TEST (RSRT)
Measuring rock stress in hydropower tunnels

REMOTE SENSING IN RIVER MAPPING
LIDAR, aerial photography, drones and satellite images

SIMULATING PARTICLE MOVEMENTS IN RIBBED SAND TRAPS
Method to find the optimal design of ribbed sand traps

SIMULATOR FOR OPERATIONAL COSTS
ProdRisk-SHOP simulator

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 (fmr. Energi 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

Name	Institution	Function
Harald Rikheim	NRC	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 Administration

Name	Institution	Function
Liv Randi Hultgreen	NTNU	Executive Director/Board Secretary
Ole Gunnar Dahlhaug	NTNU	Member
Tonje Aronsen	NINA	Member
Michael Belsnes	SINTEF	Member
Sigve Næss	Eviny	Member
Leif Lia	NTNU	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 N. 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
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
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
Magnus Korpås	NTNU	Market and services
Michiel Desmedt	NTNU	Turbine and generators
Nils Reidar Bøe Olsen	NTNU	Hydropower structures
Nils Ruther	NTNU	Hydropower structures
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

Researchers

Name	Institution	Main research area
Raghbendra Tiwari	NTNU	Market and services
Roy Nilsen	NTNU	Turbine and generators
Stein-Erik Fleten	NTNU	Market and services
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
Ana Teixeira da Silva	NINA	Environmental design
Anders Foldvik	NINA	Hydropower structures
Audun Ruud	NINA	Environmental design
Berit Köhler	NINA	Environmental design
Bjørn Winther Solemslie	NINA	Turbine and generators
Eli Kvingedal	NINA	Environmental design
Finn Økland	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
Richard Hedger	NINA	Environmental design
Rolf Sivertsgård	NINA	Environmental design
Tonje Aronsen	NINA	Environmental design
Torbjørn Forseth	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
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

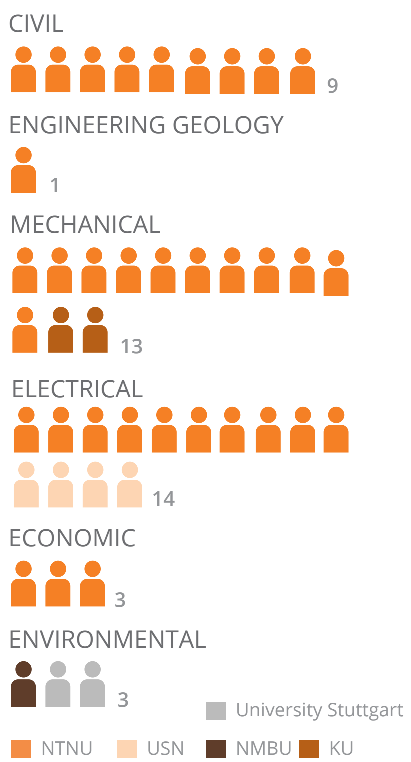
Researchers

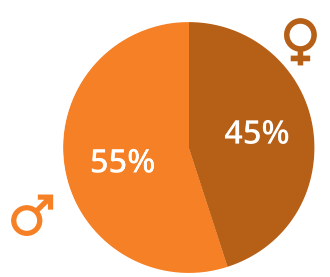
Name	Institution	Main research area
Gunnar Berg	SINTEF	Turbine and generators
Hans Ivar Skjelbred	SINTEF	Market and services
Hans Olaf Hågenvik	SINTEF	Market and services
Henrik Enoksen	SINTEF	Turbine and generators
Håkon Sundt	SINTEF	Environmental design
Igor Iliev	SINTEF	Turbine and generators
Ingeborg Graabak	SINTEF	Market and services
Ingrid vilberg	SINTEF	Market and services
Jørn Foros	SINTEF	Turbine and generators
Karl Merz	SINTEF	Turbine and generators
Kjell Ljøkelsøy	SINTEF	Turbine and generators
Lennart Schönfelder	SINTEF	Market and services
Marcell Szabo-Meszaros	SINTEF	Environmental design
Maren Istad	SINTEF	Turbine and generators
Mari Haugen	SINTEF	Market and services
Mauro Carolli	SINTEF	Environmental design
Sverre Hvidsten	SINTEF	Turbine and generators
Michael Belsnes	SINTEF	Market and services
Olve Mo	SINTEF	Turbine and generators
Siri Mathisen	SINTEF	Market and services
Stefan Rex	SINTEF	Market and services
Tor Inge Reigstad	SINTEF	Turbine and generators
Tuan T. Nguyen	SINTEF	Turbine and generators
Roger Olsson	NGI	Hydropower structures
David Florian Vetsch	ETH	Environmental design
Robert Boes	ETH	Environmental design
Sebastian Stranzl	NORCE	Environmental design
Ulich Pulg	NORCE	Environmental design
Armin Peters	FishConsulting GmbH	Environmental design
Biraj Singh Thapa	Kathmandu University (KU)	Turbine and generator
Bholo Thapa	KU	Turbine and generator
Sailesh Chitrakar	KU	Turbine and generator
Saroj Gautam	KU	Turbine and generator
Dadiram Dahal	KU	Turbine and generator
Rabina Awal	KU	Turbine and generator
Prajwal Sapkota	KU	Turbine and generator
Hari Prasad Neopane	KU	Turbine and generator
Ashim Joshi	KU	Turbine and generator
Mamata Rijal	KU	Turbine and generator

Photo: Juliet Landrø/HydroCen

MASTER STUDENTS

In 2022 we had a total of 43 master students at NTNU and The University of South-Eastern Norway (USN) within the field of hydropower. The distribution between the disciplines civil, engineering geology, mechanical and electrical is shown in the figure below.

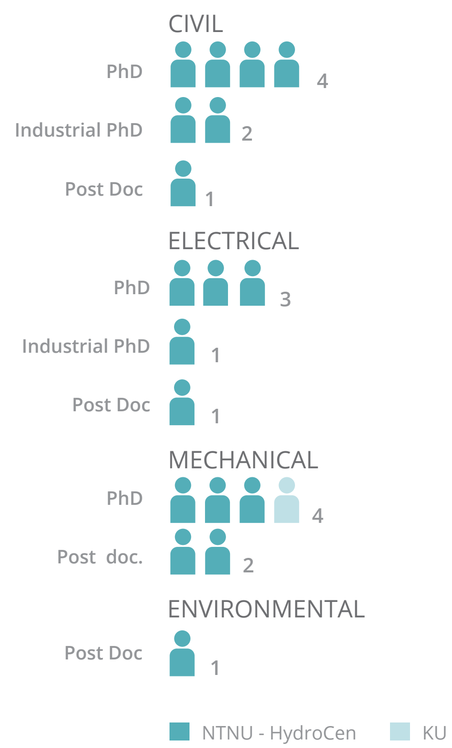


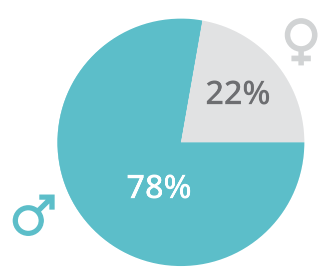


Gender distribution

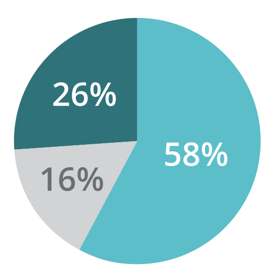
PHDS AND POSTDOCTORAL FELLOWS

In 2022 a total of 19 PhD and Post docs were in HydroCen. They worked within Civil, Engineering geology, Mechanical, Electrial and Environmental.





Gender distribution



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

PhD and Post doc. funded by HydroCen, active in 2022

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: Breaching 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
Hossein Ehya	PhD	Male	Iranian	Condition Monitoring of Synchronous Generators	2018-2022	Electrical
Ishwar Joshi	PhD	Male	Nepalese	Numerical Simulation of Sediment Transport in Rivers and Reservoirs	2021-2024	Civil
Jim Abregu	PhD	Male	Peruvian	Erosion on Pelton turbines	2022-2025	Mechanical
Kristian Sagmo	Post doc.	Male	Norwegian	Design and testing of axial turbine blade-stage for damping measurements 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	PhD	Male	Nepalese	Design of a Francis turbine that accomodates high sediment concentration	2018-2022	Mechanical
Nils Solheim Smith	PhD	Male	Danish	Incremental increases in spillway capacities	2021-2024	Civil
Ola Haugen Havrevoll	PhD	Male	Norwegian	Rock traps in pumped storage and peaking power plants	2017-2022	Civil
Olivia Simmons	Post doc.	Female	Canadian	Fish migration	2022-2024	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	Riprap structures for dam toe protection and dam breaching calculations in rock fill dams	2021-2023	Civil

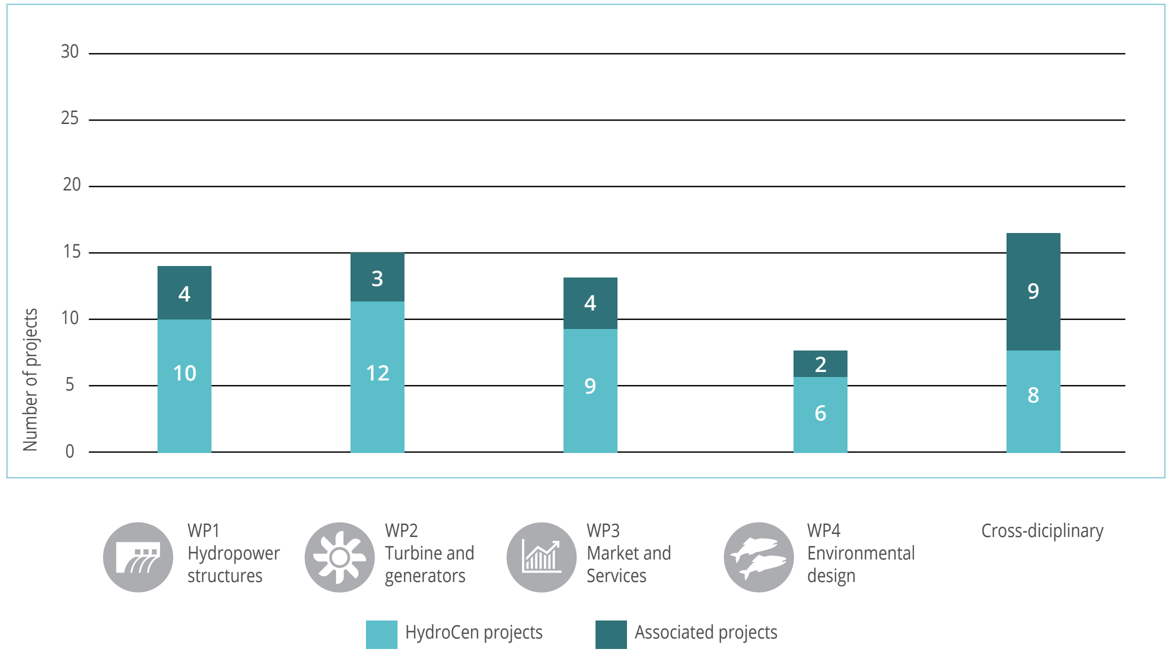
FINANCIAL STATEMENT HYDROCEN 2022

All figures in 1000 NOK

Funding 2022	**Funding**	**In-kind**	**Total**
The Research Council of Norway	24 271		24 271
Industry partners	9 662	6 030	15 692
Research partners		10 942	10 942
Total funding 2022	**33 933**	**16 972**	**50 905**
Revenue 2022	**Funding**	**In-kind**	**Total**
SINTEF	11 297	4 445	15 742
NINA	5 843	2 358	8,201
NTNU	15 581	4 119	19,700
USN	0	0	0
NGI	694		694
KU	518	20	538
Industry in-kind		6 030	6,030
Total Costs 2022	**33 933**	**16 972**	**50,905**

PROJECT OVERVIEW 2022

A total of 67 projects related to hydropower were ongoing in 2022. 22 of these are associated projects within hydropower where HydroCen's researchers are involved.



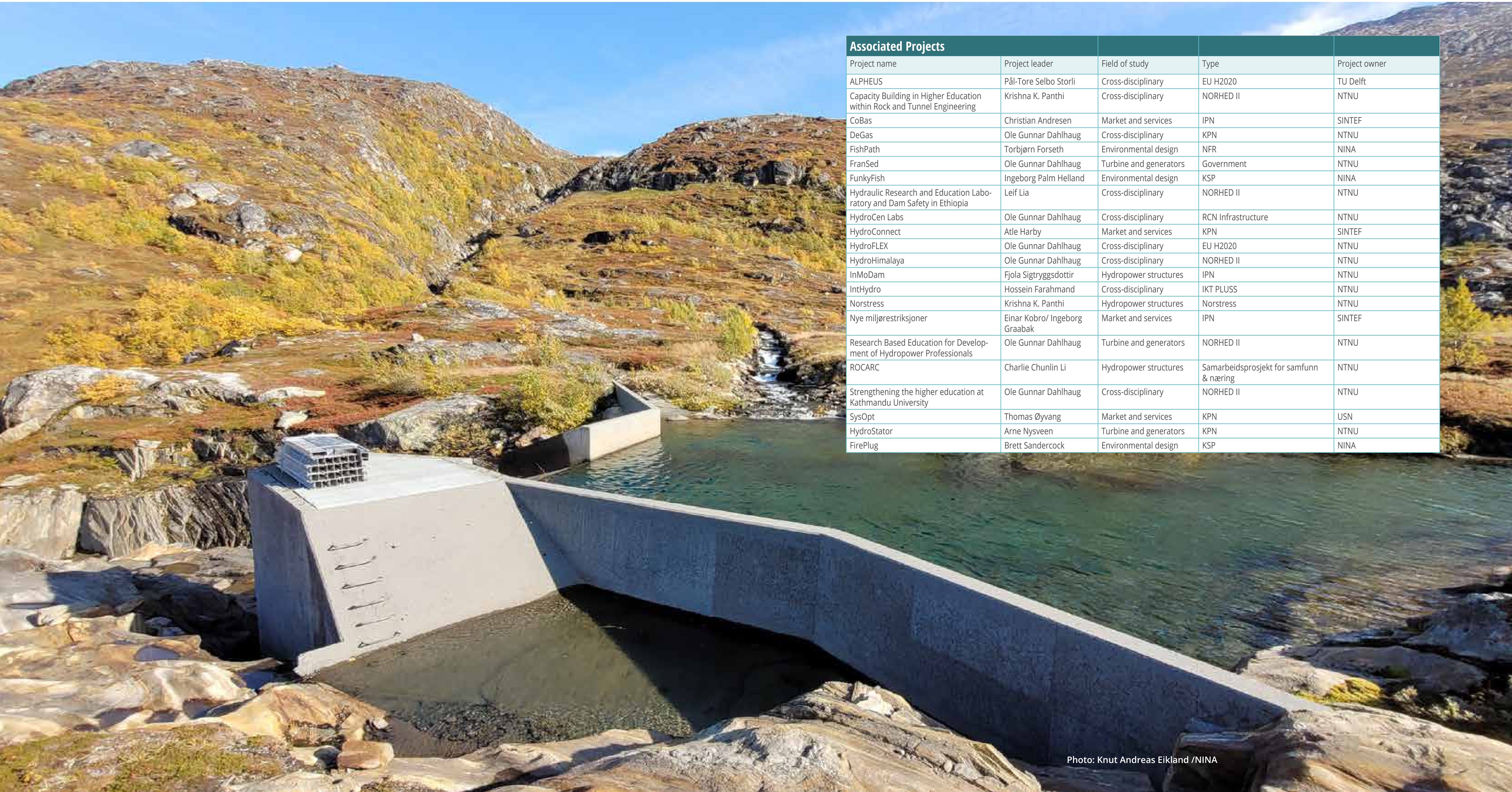
HydroCen Projects

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/Nils Rüther	Hydropower structures
1.4	Fish friendly hydropower intakes	Leif Lia	Hydropower structures
2.1	Variable Speed Operation	Olve Mo	Turbine and generators
2.2	Fatigue loads on turbines	Torbjørn Nielsen	Turbine and generators
2.3	Pump turbines in existing power plants	Pål-Tore Storli	Turbine and generators
2.4	Turbine and Generator Lifetime	Maren Istad	Turbine and generators
3.2	Remaining useful life, failure probability	Arnt Ove Eggen	Market and services
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	Lennart Schönfelder	Market and services
4.1	Implementing and founding environmental design solutions (EDS)	Berit Köhler	Environmental design
4.3	Environmental design	Atle Harby	Environmental design

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
5.1.3	Mesmerise	Elena Pummer/Nils Rüther	Hydropower Structures
5.1.4	Rock support dimensioning	Krishna Panthi	Hydropower Structures
5.1.6	Utvidelse av flomløp	Leif Lia	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
5.2.2	Francis Turbiner	Ole Gunnar Dahlhaug	Turbine and generators
5.2.3	Trykkpulsasjoner	Pål-Tore Storli	Turbine and generators
5.2.5	Asset Life	Eivind Solvang	Turbine and generators
5.2.6	Peltonturbin Prototyp virkningsgradsmålinger	Bjørn Winther Solemslie	Turbine and generators
5.2.7	Måling, beregning og modellering av dynamikk og dynamisk belastning i vannkraftsystemer.	Tor Inge Reigstad	Turbine and generators
5.2.8	Identifisering av sprekkdannelser i løpehjul	Ole Gunnar Dahlhaug	Turbine and generators
5.2.9	SediRes	Sailesh Chitrakar	Turbine and generators
5.2.10	HiFlex - HydroStator II	Espen Eberg	Turbine and generators
5.3.2	Priser og modelleringsutfordringer i et 100% fornybart kraftsystem	Birger Mo	Market and services
5.3.3	Environmental measures impact on hydro power system (FlexMet)	Arild Helseth	Market and services
5.3.4	Electricity Market Models for the Future Power Grid: A US-European Review	Michael Belsnes	Market and services
5.3.6	Toolchains	Arild Helseth	Market and services
5.4.3	Dynamisk minstevannføring i et miljødesign perspektiv	Line Sundt-Hansen	Environmental Design
5.4.5	Artsmangfold i magasiner	Markus Majaneva	Environmental Design
5.4.9	Guiding Fence Evaluation	Torbjørn Forseth	Environmental Design
5.5.2	Valueflex	Michael Belsnes	Cross-disciplinary
5.5.5	PotOUT: Potensiale for opprusting og utvidelse av vannkraft med miljødesign	Atle Harby og Ingrid Vilberg	Cross-disciplinary
5.5.6	TwinLab – Digital Twin Laboratory for Hydropower	Ingrid Vilberg	Cross-disciplinary
5.5.8	Kunnskapsbanken	Jonas Bergmann-Paulsen	Cross-disciplinary
5.5.9	Environ Hy-Flex	Atle Harby	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	Michael Belsnes	Cross-disciplinary
5.5.12	Klimaprosjekt	Tor Haakon Bakken	Cross-disciplinary

PROJECTS OVERVIEW 2022



Associated Projects

Project name	Project leader	Field of study	Type	Project owner
ALPHEUS	Pål-Tore Selbo Storli	Cross-disciplinary	EU H2020	TU Delft
Capacity Building in Higher Education within Rock and Tunnel Engineering	Krishna K. Panthi	Cross-disciplinary	NORHED II	NTNU
CoBas	Christian Andresen	Market and services	IPN	SINTEF
DeGas	Ole Gunnar Dahlhaug	Cross-disciplinary	KPN	NTNU
FishPath	Torbjørn Forseth	Environmental design	NFR	NINA
FranSed	Ole Gunnar Dahlhaug	Turbine and generators	Government	NTNU
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
HydroFLEX	Ole Gunnar Dahlhaug	Cross-disciplinary	EU H2020	NTNU
HydroHimalaya	Ole Gunnar Dahlhaug	Cross-disciplinary	NORHED II	NTNU
InMoDam	Fjola Sigtryggsdottir	Hydropower structures	IPN	NTNU
IntHydro	Hossein Farahmand	Cross-disciplinary	IKT PLUSS	NTNU
Norstress	Krishna K. Panthi	Hydropower structures	Norstress	NTNU
Nye miljørestriksjoner	Einar Kobro/ Ingeborg Graabak	Market and services	IPN	SINTEF
Research Based Education for Development of Hydropower Professionals	Ole Gunnar Dahlhaug	Turbine and generators	NORHED II	NTNU
ROCARC	Charlie Chunlin Li	Hydropower structures	Samarbeidsprosjekt for samfunn & næring	NTNU
Strengthening the higher education at Kathmandu University	Ole Gunnar Dahlhaug	Cross-disciplinary	NORHED II	NTNU
SysOpt	Thomas Øyvang	Market and services	KPN	USN
HydroStator	Arne Nysveen	Turbine and generators	KPN	NTNU
FirePlug	Brett Sandercock	Environmental design	KSP	NINA

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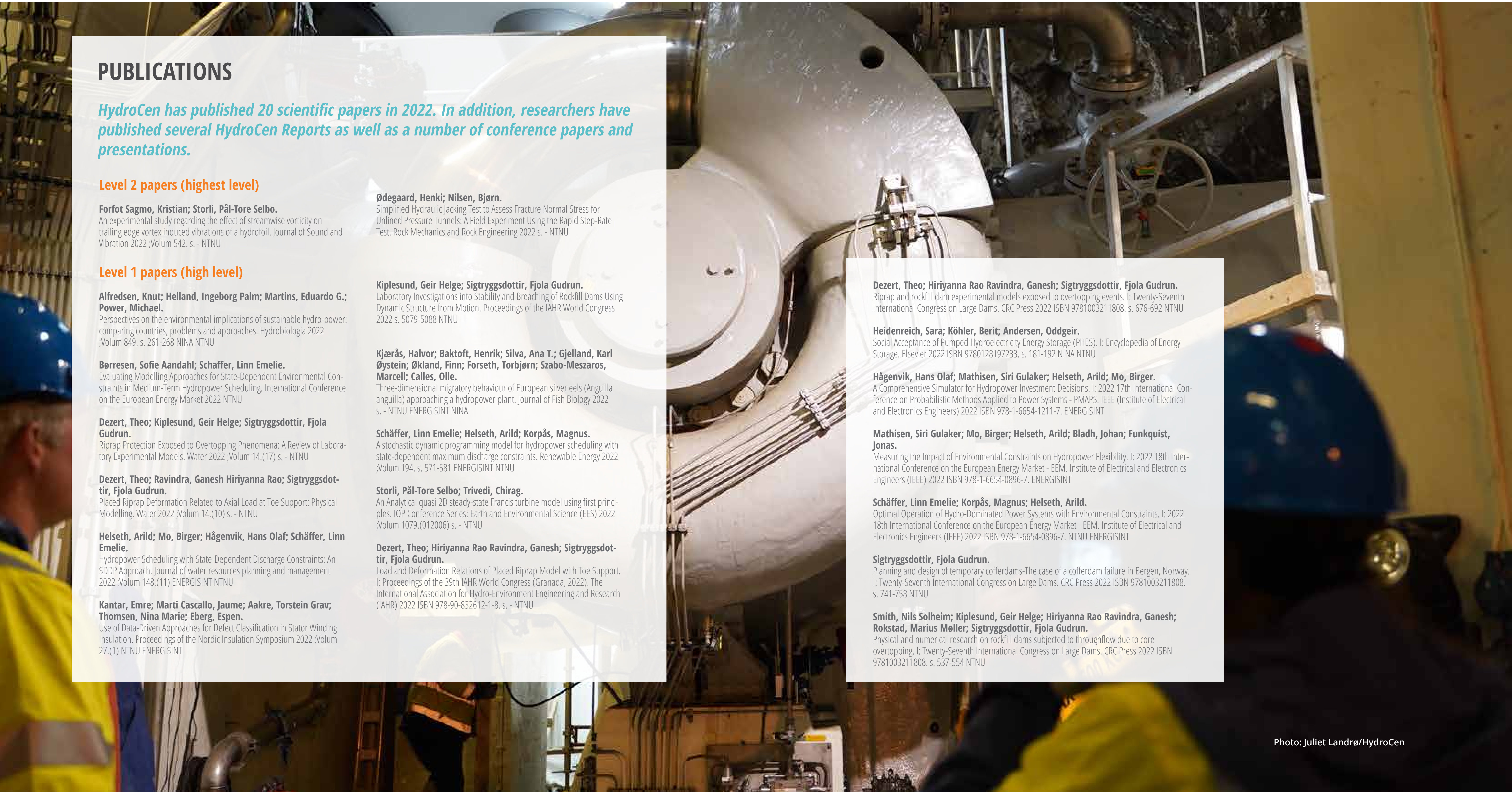
PUBLICATIONS



PUBLICATIONS

HydroCen has published 20 scientific papers in 2022. In addition, researchers have published several HydroCen Reports as well as a number of conference papers and presentations.

Level 2 papers (highest level)

Forfot Sagmo, Kristian; Storli, Pål-Tore Selbo.
An experimental study regarding the effect of streamwise vorticity on trailing edge vortex induced vibrations of a hydrofoil. Journal of Sound and Vibration 2022 ;Volum 542. s. - NTNU

Ødegaard, Henki; Nilsen, Bjørn.
Simplified Hydraulic Jacking Test to Assess Fracture Normal Stress for Unlined Pressure Tunnels: A Field Experiment Using the Rapid Step-Rate Test. Rock Mechanics and Rock Engineering 2022 s. - NTNU

Level 1 papers (high level)

Alfredsen, Knut; Helland, Ingeborg Palm; Martins, Eduardo G.; Power, Michael.
Perspectives on the environmental implications of sustainable hydro-power: comparing countries, problems and approaches. Hydrobiologia 2022 ;Volum 849. s. 261-268 NINA NTNU

Børresen, Sofie Aandahl; Schaffer, Linn Emelie.
Evaluating Modelling Approaches for State-Dependent Environmental Constraints in Medium-Term Hydropower Scheduling. International Conference on the European Energy Market 2022 NTNU

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Riprap Protection Exposed to Overtopping Phenomena: A Review of Laboratory Experimental Models. Water 2022 ;Volum 14.(17) s. - NTNU

Dezert, Theo; Ravindra, Ganesh Hiriyanna Rao; Sigtryggsdottir, Fjola Gudrun.
Placed Riprap Deformation Related to Axial Load at Toe Support: Physical Modelling. Water 2022 ;Volum 14.(10) s. - NTNU

Helseth, Arild; Mo, Birger; Hågenvik, Hans Olaf; Schäffer, Linn Emelie.
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Three-dimensional migratory behaviour of European silver eels (Anguilla anguilla) approaching a hydropower plant. Journal of Fish Biology 2022 s. - NTNU ENERGISINT NINA

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A stochastic dynamic programming model for hydropower scheduling with state-dependent maximum discharge constraints. Renewable Energy 2022 ;Volum 194. s. 571-581 ENERGISINT NTNU

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An Analytical quasi 2D steady-state Francis turbine model using first principles. IOP Conference Series: Earth and Environmental Science (EES) 2022 ;Volum 1079.(012006) s. - NTNU

Dezert, Theo; Hiriyanna Rao Ravindra, Ganesh; Sigtryggsdottir, Fjola Gudrun.
Load and Deformation Relations of Placed Riprap Model with Toe Support. I: Proceedings of the 39th IAHR World Congress (Granada, 2022). The International Association for Hydro-Environment Engineering and Research (IAHR) 2022 ISBN 978-90-832612-1-8. s. - NTNU

Dezert, Theo; Hiriyanna Rao Ravindra, Ganesh; Sigtryggsdottir, Fjola Gudrun.
Riprap and rockfill dam experimental models exposed to overtopping events. I: Twenty-Seventh International Congress on Large Dams. CRC Press 2022 ISBN 9781003211808. s. 676-692 NTNU

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A Comprehensive Simulator for Hydropower Investment Decisions. I: 2022 17th International Conference on Probabilistic Methods Applied to Power Systems - PMAPS. IEEE (Institute of Electrical and Electronics Engineers) 2022 ISBN 978-1-6654-1211-7. ENERGISINT

Mathisen, Siri Gulaker; Mo, Birger; Helseth, Arild; Bladh, Johan; Funkquist, Jonas.
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Optimal Operation of Hydro-Dominated Power Systems with Environmental Constraints. I: 2022 18th International Conference on the European Energy Market - EEM. Institute of Electrical and Electronics Engineers (IEEE) 2022 ISBN 978-1-6654-0896-7. NTNU ENERGISINT

Sigtryggsdottir, Fjola Gudrun.
Planning and design of temporary cofferdams-The case of a cofferdam failure in Bergen, Norway. I: Twenty-Seventh International Congress on Large Dams. CRC Press 2022 ISBN 9781003211808. s. 741-758 NTNU

Smith, Nils Solheim; Kiplesund, Geir Helge; Hiriyanna Rao Ravindra, Ganesh; Rokstad, Marius Møller; Sigtryggsdottir, Fjola Gudrun.
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Photo: Juliet Landrø/HydroCen

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