ANNUAL REPORT

# 2019

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

Ole Gunnar Dahlhaug

# INTRODUCTION

***HydroCen has ramped up the activity level year by year since the start in 2017, and the centre has achieved many important results in 2019. The report describes some of these achievements, which are results from all participants in the centre stepping up to the challenge. The board and management group want to acknowledge the effort. Well done!***

HydroCen had a total of 42 directly funded and associated projects in 2019. This resulted in a high rate of scientific publication, many conference presentations and extensive student involvement. We are confident that the results will significantly impact the Norwegian hydropower sector in the time to come. The conclusion is simply - **2019 was a successful year in terms of hydropower science.**

The  HydroCen research is also profitable. This is shown in an evaluation performed by Impello, and companies that have implemented results. The main conclusion is -**Investing in research is profitable.**

In 2019, the Norwegian Research Council granted 55 million NOK to upgrade and refurbish HydroCen's laboratories.  The HydroCen laboratories  are a very important tool  for positioning Norwegian scientists at the forefront of the international hydropower research. This is an important step for strengthening the position of  hydropower in the efforts towards the green transition.

The launch of the project AlternaFuture project in 2019 was an important step towards bringing researchers from very different disciplines closely together to support the multi-disciplinary nature of HydroCen. It has shown the potential that lies in the borders between engineering and environmental disciplines, and the project shows that there is still major opportunity to develop hydropower - **Congratulations to the project team!**

HydroCen has been fortunate to have Hege Brende as its director the first four years of operation. We are grateful for the time, effort and contributions Hege has given all of us, and we recognize that HydroCen would not be the same without her. The communication between the researchers, professors, students and partners has become joyful. The visibility of hydropower both nationally and internationally has improved a lot. **Thank you, Hege!**

Liv Randi Hultgreen is the new director starting June 1st 2020, in the meantime Ole Gunnar Dahlhaug is acting director.

Looking ahead, HydroCen will have to add new projects to the portfolio. New project proposals will be initiated in order to utilize the research capacity in the coming four years of the centre.  Also, we need to start looking beyond the HydroCen period – this multidisciplinary team is viable and important far beyond 2024. We are confident that the challenges will be managed by the excellent HydroCen community.

On behalf of the management and board,

**Ole Gunnar Dahlhaug**



Hege Brende
Former Director
HydroCen

# PROUD OF HYDROCEN'S ACHIEVEMENTS

***2019 reinforced our ambition as a world-leading research centre and showed us that a lot of hard work has quickly gained impressive results.***

In this year's annual report you will gain insight into several of our main achievements for 2019. We have also continued our targeted work to secure international collaboration and position, both in Europe and globally.

I am very happy to oversee how our Joint Programme Hydropower in EERA has become operational and produced its first strategic research agenda. Amazing to see representatives from more than 14 countries and 28 institutions come together to found a common research agenda for hydropower in the future!

I am very proud that we could close a top-level agreement between the Norwegian Ministry of Petroleum and Energy and the US Department of Energy on hydropower research. I am impressed and humble for all the support I have experienced from both sides in order to make this come through!

In a rapidly changing clean energy transition, the need for innovation is crucial. It is assuring to see that our PhD candidates are able to focus both on academic production and innovation value. During 2019 we have received several new potential innovation results in several fields, both within technology and natural sciences.

It is also a fact that I myself took a difficult decision before Christmas in 2019. I accepted a new job offer and thus decided to leave HydroCen. It was a hard and heart-breaking decision since HydroCen and the hydropower sector have become an integral part of my professional life. But, sometimes it is good to move on although it hurts in the moment. I am also very aware that our centre and all it stands for is the result of a joint effort of many exceptional people. I am very sure that HydroCen will continue its successful journey!

So, lastly I will give my warmest appreciation and acknowledgements to my management team and all our scientists, my board, the members of our technical committees and our international relations. Special thanks to Energy21 and the Research Council of Norway and its excellent team who has facilitated and enabled our impressive portfolio on hydropower over the last years; from the establishment of the Norwegian Hydropower Centre to the realisation HydroCen FME.

A closing remark: I have worked with R&D in the hydropower industry for the last 12 years. It has been a blast! Clean energy is of outmost importance for us all, and I am extremely happy to have worked with the best people in a sector with a social impact and a valuable contribution to the future! I wish all of you, and HydroCen, all the best onwards!

**Hege Brende**
Former Director, HydroCen

Innovation inspired by nature: “Singing stay vanes” is a phenomena where a high frequency noise is created from unwanted vibrations in the stay vanes of hydropower turbines. These vibrations can cause fatigue of the blades and propagate in machinery and building stock and cause costly repairs or break downs in the hydropower plant. The current method for dealing with this phenomena can be ineffective, and unwanted vibrations sometimes still occur. Inspired by the silent flight of an owl, Pål-Tore Storli has designed a new type of trailing edge for such vanes that could prevent the problem. The new vanes are designed with a serrated edge like the feathers on an owl’s wing. Read more:
https://www.ntnu.edu/hydrocen/new-design-of-guide-vanes

*Photo: Bert de Tilly/CC BY-SA 3.0*

Hydro generators play a pivotal role in the production of electric power in Norway. High reliability of power supply depends on the synchronous generators. Online condition monitoring can provide a real-time assessment of the generator, and detect the gradual aggravating incipient fault in its initial stage before it results in costly damages. HydroCen researchers are working on a practical approach to diagnosing the faults in its early stages. They test their findings on a custom-made synchronous generator in National Smart Grid Laboratory.

*Photo: Juliet Landrø/HydroCen*



Hossein Ehya,
PhD-candidate
HydroCen

# FLEXIBLE HYDROPOWER PROVIDING VALUE TO RENEWABLE ENERGY INTEGRATION

***Flexibility resources are crucial for a secure and robust power system. As an increasing share of variable renewable energy sources (VRE) is integrated into electricity systems, the need for flexibility and energy storage also increases.***

-Hydropower is the largest source of renewable energy today. It can play an important role in integrating and balancing variable energy sources, says researcher Linn Emelie Schäffer.

Together with researcher Atle Harby she lead the work on the white paper from Annex IX, IEA Hydropower that describes the role of hydropower and the need for flexibility in the future electricity system.

Hydropower is a mature technology, but many older plants need upgrades and up-to-date modes of operation,
– In the report we've provided a high-level overview of key issues with the intent of identifying priority areas for further in-depth reviews and analyses, she says.

**The key topics discussed are:**
- Future energy systems with large shares of variable renewable energy sources
- The need for flexibility at time scales ranging from seconds to months
- The status and capabilities of hydropower to contribute to these needs
- The value of flexibility in the energy system

We also looked into the increasing importance of supplying the right capacity at the right time, and how the value of flexibility in the power system should be reflected in the marked, says Schäffer.

**The report also outlines the needs for further work:**
- Further assessment of technological, market, policy and regulatory requirements to ensure appropriate investments in the energy system.
- How to optimise market mechanisms to ensure sufficient flexibility at the right scale and the right time

The paper can be read and downloaded:
https://www.ieahydro.org/annex-ix-hydropower-services

Linn Emelie Schäffer

Atle Harby


Hydropower production and operation not only supplies Norway with green electricity, it also plays a crucial role during flood events. Flood dampening of hydropower reservoirs is important for flood protection.
We are using the hydrological model HYPE to predict waterflow in all Norwegian rivers and large reservoirs. In the model, we divide the Norwegian mainland into hydrological units and calculate river flow. This model can calculate the water-balance of almost 400 lakes and reservoirs in Norway.
Using different scenarios, we can simulate and assess how the operation of hydropower has had a positive impact on flood dampening in the past and for future climate scenarios.

On the map, lakes and reservoirs are in light blue and the green borders shows the model structure.



Lennart Schönfelder,
researcher

Climate change and the resulting modified hydrology are likely to impose new strains on hydropower dams in the near future. Rockfill dams are vulnerable against extreme hydrological occurrences and they need to be protected against unanticipated leakage or overtopping events. To achieve this, components of the rockfill dam overtopping protection system such as riprap and dam toe are coupled with the dam structure. We are working to obtain a holistic evaluation of the behavior of rockfill dam structures subjected to extreme loading scenarios from both hydraulic and structural viewpoints. Research outcomes will lead to more effective design of these structures.

*Photos: Ganesh Ravindra*

Ganesh Ravindra,
PhD candidate



# FIELD WORK FOR FISH MIGRATION

Researchers are trying to find better ways to guide fish past hydropower plants during the spawning season. Different fish-species such as eel, trout and salmon have different strategies, and abilities, to get past the power intakes and many continue to end up in small pieces downstream after taking an unwanted trip through the power plant turbines.

In order to characterize the flow environment associated with such unwanted trips through the turbines, HydroCen is developing advanced numerical models that can simulate the different flow patterns around hydropower intakes. In 2019 Marcell Szabo-Meszaros, Lennart Schönfelder and Halvor Kjærås carried out various tests in the rivers by Hunderfossen (Norway) and Herting (Sweden) power plants to calibrate their computer models. Hopefully, this will lead to a better understanding of why fish swim into the intakes, and will help us develop and test new solutions to guide fish safely downstream.

*Photos: Lennart Schönfelder*

## *Can we do extreme upgrading of existing hydropower systems while improving environmental conditions?*

That has been one of the main questions in the project AlternaFuture.

– We've used this opportunity to force ourselves to think new, and without the limitations that exist in todays power system and reality, says project leader Kaspar Vereide.

A multidisciplinary team of experts on environmental research, hydrology, geology, engineering, market structures and the hydropower industry, have used the Mandal river system as a case study to discover different scenarios and research needs that can arise in the near future.

The project is carried out as a desk study with some field inspections, aiming to get an overview of challenges and needs for new research.

– We made different scenarios and put them together in various combinations of hydropower development and environmental projects, that should ultimately benefit nature, says Vereide.

**Can triple the installed capacity**
In one of the scenarios they found that it is possible to triple the installed capacity of the power system in the Mandal river, and at the same time improve the environmental conditions.

– It is not economically profitable today, but in the future it could be, says Vereide.

Other scenarios involve considerable flood control with a combination of flood power plants and pumped storage plants that together could reduce a damaging 200-year flood to a harmless 20-year flood.

**Strengthen multidisciplinary cooperation and future research projects**
Traditionally the hydropower system, and research, is segmented into specific areas, such as turbines, generator, environment and markets. HydroCen's goal is to look at the entire watercourse and power system as a whole, where everything connects to - and influences - everything else. This has also been one of the main issues in AlternaFuture, where they have found that the multidisciplinary approach triggered many new research issues and ideas.

– We have identified 18 possible research projects that we could look into, and have started one of them already, says Vereide.

*Photos: Kaspar Vereide*

# INTERNATIONAL INTEREST IN HYDROCEN

In 2019 the interest for HydroCen's research has expanded far beyond the Norwegian borders. There has been researcher-to-researcher cooperation, PhD- and researcher exchange and signing of several MoU's (Memorandum of Understanding) with universities and policy makers. We have also facilitated and participated in high-level political meetings and research cooperation with developing countries through NORAD and the World Bank.

**CANADA:**
Meetings with the HYCANOR-associates in the INTPART-research exchange programme.

**USA:**
Strategic cooperation with USDoE and several National Research Laboratories. MoU signed between USDoE and Norwegian Department of Energy in 2020.

**BRAZIL:**
Meetings with CEPEL (Electrical Energy Research Center) for possible cooperation on developing models for hydropower planning.

**SWEEDEN, ÄLVKARLEBY:**
Vattenfall became new partner i HydroCen, contributing with world class laboratories to study fish migration, dam-safety, turbines, generator operation and digitalisation tools.

**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.

**INDIA, 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.

**EU:**
Operation of Joint Programme Hydropower in EERA.

**SWITZERLAND:**
Researcher cooperation, and Scientific Committiee-member Prof Dr.Thomas Staubli.

**ALBANIA, MOGLICË:**
Lena Selen is investigating effects of swelling rock mass on stability and support in hydro-power tunnels.

**AUSTRALIA:**
Meetings and cooperation with Hydro Tasmania, and MOU with the state government of Tasmania.

# 55 MILLION NOK FOR RESEARCH INFRASTRUCTURE

**New research challenges and aging equipment in the laboratories has lead the Norwegian Research Council to grant HydroCen labs 55 million NOK to upgrade, refurbish and expand laboratories for hydropower research.**

– This will be a national revival of research-infrastructure that will contribute to position Norwegian scientists at the forefront of the international hydropower research, says project leader Ole Gunnar Dahlhaug.

The research infrastructure at the Waterpower Laboratory (established 1917) and the Hydraulic Laboratory (established 1958) at NTNU have played a major role in making Norway a world leading nation of hydropower technology. Today they are in dire need of upgrading. Without sufficient research facilities and the multi-disciplinary research groups at the Norwegian Research Centre for Hydropower Technology – HydroCen - the Norwegian hydropower industry cannot meet their future challenges of adapting an aging sector to future energy markets.

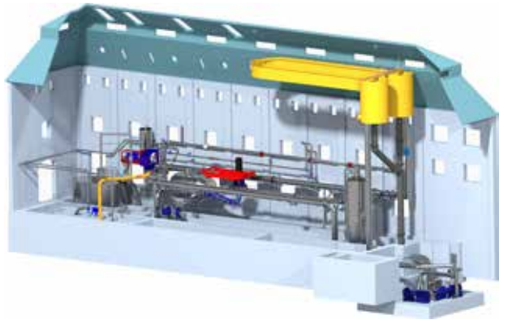
**Long term plan for massive upgrades**
First, the goal is to upgrade the Waterpower Laboratory and  Hydraulic Laboratory so researchers can find new solutions for flexible hydropower in a renewable energy system.

– Secondly, we wish to link these two laboratories with research infrastructure on smart grids, generators, geology and fish behaviour, says Dahlhaug.

In the application HydroCen showed the need for 199 million NOK over the next 8 years . The project is divided in 3 phases to achieve this. The first phase has s been granted 55 million NOK. The work for the first phase begins in 2020 and most of the new or refurbished infrastructure will be operational by 2023.
– New infrastructure in HydroCen laboratories will position Norwegian scientists at the forefront of the international hydropower research, says Dahlhaug.

**The Waterpower-, Smart Grid- and Material Testing laboratories**
Procurement, refurbishment and installation of new equipment to make the laboratories suitable for high quality research on hydropower technologies. Among other things, low-, and high pressure systems, generator multi-stress rig and virtual mechanical connection between the Waterpower laboratory and Smart Grid facility.

**The Hydrolic laboratory and Geology facility**
The upgrades will ensure a hydraulic laboratory with an infrastructure and instrumentation suited for the hydropower industry, to investigate and solve future societal water related challenges. New flumes, equipment for hydraulic measurement and model construction, new water circulation system and experimental equipment for testing rock stability are some of the measures that are planned. In the next phase, investments for equipment to study fish behavior will be initiated.





# INCREASED COMMITMENT TO INNOVATION

***As part of NTNU's increased focus on research-based innovation, Jonas Bergmann-Paulsen has joined the HydroCen team as "innovation manager", and will  work to ensure that our results also lead to value creation and social benefits.***


Several of HydroCen's research projects have now reached a level where piloting, prototyping and implementation are imminent, and Bergmann-Paulsen works closely together with HydroCen's "Innovation Forum". The group of experts from research and industry partners was formed at the end of 2019 and they work to ensure that research innovation is tested and adopted by the industry.

All projects and innovations are linked to the UN Sustainable Development goals to visualize the potential for value creation and the social benefits.

**Ready for full scale testing**
HydroCen aims to develop new research and enable hydropower to meet complex challenges and opportunities in a future renewable energy system and climate. To achieve this goal researchers work closely with the industry and across diciplines. Researchers at HydroCen are presently planning a full scale test with Agder Energi to test a new way of guiding fish past the power plant. Another project has investigated turbines suited for variable speed operation  and in our associated project FranSed, Indias largest hydropower supplier NHPC in considering a full scale test of a turbine that can handle the sedimented water of the Himalayas.

**The members of the Innovation Committee are:**
Jonas Bergmann-Paulsen (manager)
Frode Fossøy, NINA
Simen Vogt-Svendsen, Statkraft
Martin Holst, EDR
Inge Hovd Gangås, SINTEF
Gunnar Gran, Dynavec

# NEW IN HYDROCEN

**Mats Billstein - New partner**

PhD, R&D Manager
Hydro, Vattenfall AB

What is your assignment/ expertise/contribution in HydroCen?
*Vattenfalls contribution to HydroCen is field- and plant measurements and our laboratory facilities. We have world class facilities in many areas where HydroCen is active. To mention some of the facilities:*

- *A fish drome with flow capacity up to 2 m/s and 16 m3/s for experiments with fish and fish migration for environmental adaptation of hydro.*
- *An embankment dam (4 m high and 20 m wide) with well defined defects for a blinde test of geophysical measurements for improved dam safety.*
- *A turbine test rig for transient testing in order to increase the flexibility. Runner diameter up to 500 mm can be tested.*
- *A 4 m high vertical rotor rig for rotor dynamic experiments, vibrations, damping and validation of numerical codes for operation dependent fatigue.*
- *A rig for discharge and energy dissipation studies in scale 1:10 for improved dam safety.*
- *Game of Drones – a new test/research/education facility for digital inspections (drones, USV,ROV) for more efficient operation.*
- *Porjus U8/U9 - 2*10 MW (Kaplan and Francis) units for full scale R&D and education.*

What is your motivation to be a part of HydroCen?
*NTNU, NINA and SINTEF are a really strong research community. Together with Vattenfalls laboratory facilities and R&D competence HydroCen will be the strongest research community in Europe. Vattenfall and Norway share a lot of the challenges and possibilities in the Nordic region in comparison with the rest of Europe. Therefore, it is logical to join HydroCen in order to unify and speak with one voice.*

What are your expectations for HydroCen looking forward?
*In the short term, increase the exchange of R&D between Vattenfall, NTNU, NINA and SINTEF in generally all areas (dam safety and infrastructure, environment, turbines and generators, and flexible generation) and particularly in environmental design. In the long term, I expect HydroCen to deliver R&D-results to be implemented in the hydropower daily operation. It is only when results are implemented there will be an impact – and that is really important for Vattenfall.*



**Tonje Aronsen -
New in the management team**

Research Director
NINA

What is your assignment/ expertise/contribution in HydroCen?
*I represent NINA in the executive management team (EMT). My contribution in HydroCen is therefore mostly related to administrative and strategic tasks. I hope that I can contribute to good decision-making in the EMT, that this will benefit the researchers in HydroCen, the contribution HydroCen will make to the hydropower sector in general and specifically the mitigation of negative environmental effects of hydropower.*

What is your motivation to be a part of HydroCen?
*My motivation is to represent NINA as one of the research partners in the EMT, but also to emphasize the importance of the environmental and social sciences in HydroCen. The reports from IPCC — Intergovernmental Panel on Climate Change and IPBES - The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services stresses the need for a continued focus on the effects of climate change and human induced degradation of biodiversity and ecosystem functions. In addition, we need a better understanding of social acceptance in relation to hydropower.*

What are your expectations for HydroCen looking forward?
*This year (2020) will be an exciting year for HydroCen, we will have a new Centre Director, and it is time to identify important new research areas for HydroCen and hopefully initiate exciting new projects.*

**Hossein Ehya -
New PhD-candidate, HydroCen**

PhD-candidate HydroCen

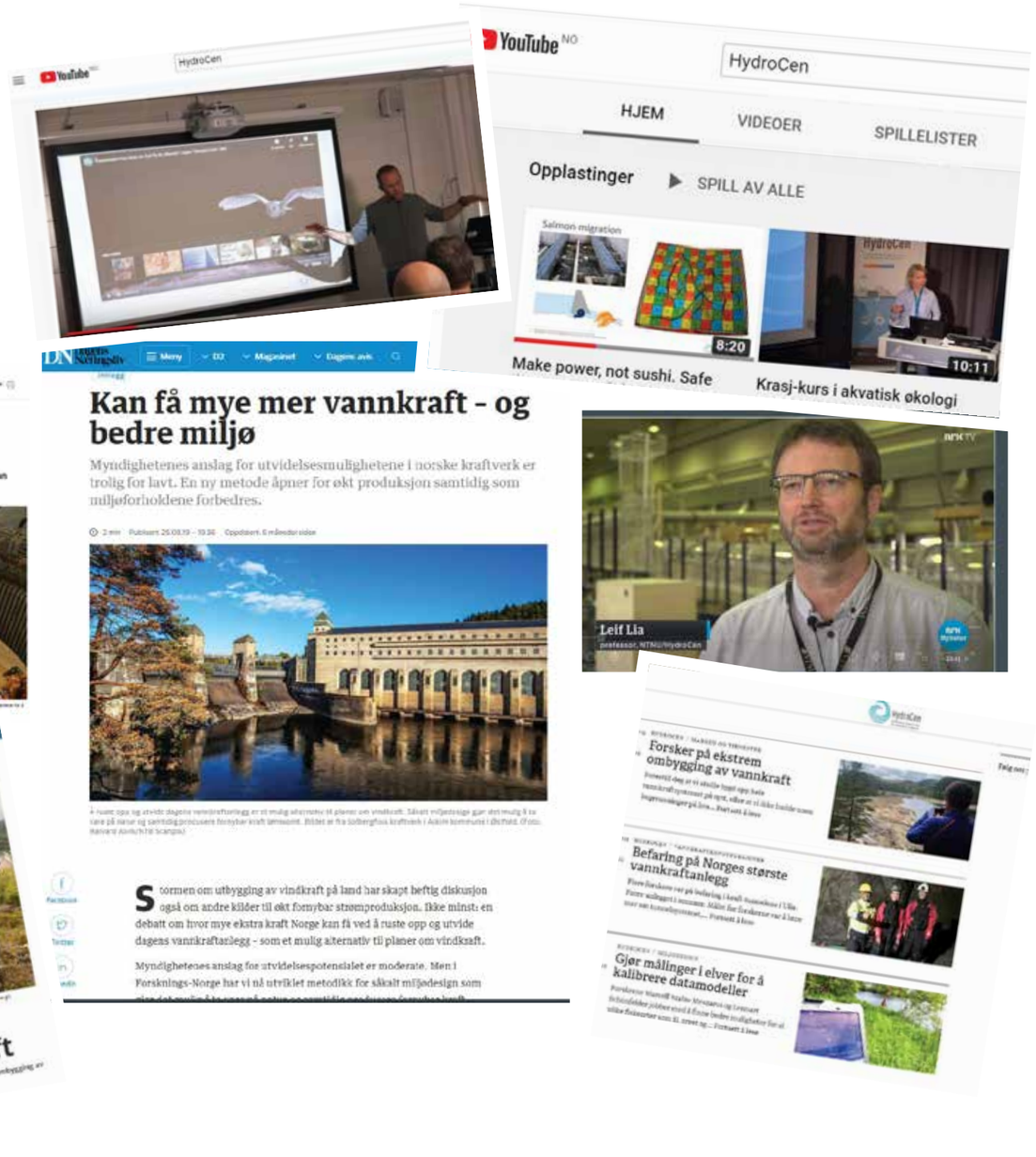
What is your assignment/ expertise/contribution in HydroCen?
*I am working on 'Electromagnetic Analysis and Fault Diagnosis of Synchronous Machines' at the Department of Electric Power Engineering. At the same time, I am also co-supervisor of master students who are also working on this project.*

What is your motivation to be a part of HydroCen?
*HydroCen provides a chance to examine the theoretical founding in different laboratories and power plants not only in Norway, but also internationally due to HydroCen's vast collaboration with different research institutes, universities, and industry partners. Also, the multidisciplinary course that enables us to collaborate and learn from researchers with diverse backgrounds is a great achievement and advantage.*

What are your expectations for HydroCen looking forward?
*To support the project so the scientific outcomes could turn into a start-up company to be used in industries and bring funding back to HydroCen.*

## HYDROCEN IN THE MEDIA

In 2019 HydroCen had been featured in several media outlets, ranging from national tv, newspapers to local websites, and technical magazines. In total, HydroCen's research has been mentioned in more than 80 articles or broadcasts in the media. Researchers also participated in more than 25 popular science webinars.




## OUR OULETS

**Newsletter:**
Public newsletter, 4 publications, 204 subscribers and an opening ratio of 30-50%

**Blog:**
34 blog posts with information and news from Hydrocen in 2019, more than 13 000 visitors and 20 000 views.

**Vannposten:**
Weekly newsletter for researchers.
23 publications and 200 recipients.

**Website:**
Information and contact details for all projects and researchers in HydroCen. Publications and innovations are also accessible from www.hydrocen.com

**Webinar:**
#GodForskerMorgen by Multiconsult, and 19 webinars by HydroCen on YouTube.

## SOCIAL MEDIA

**Twitter:**
9 000 views per month and 474 followers.

9000

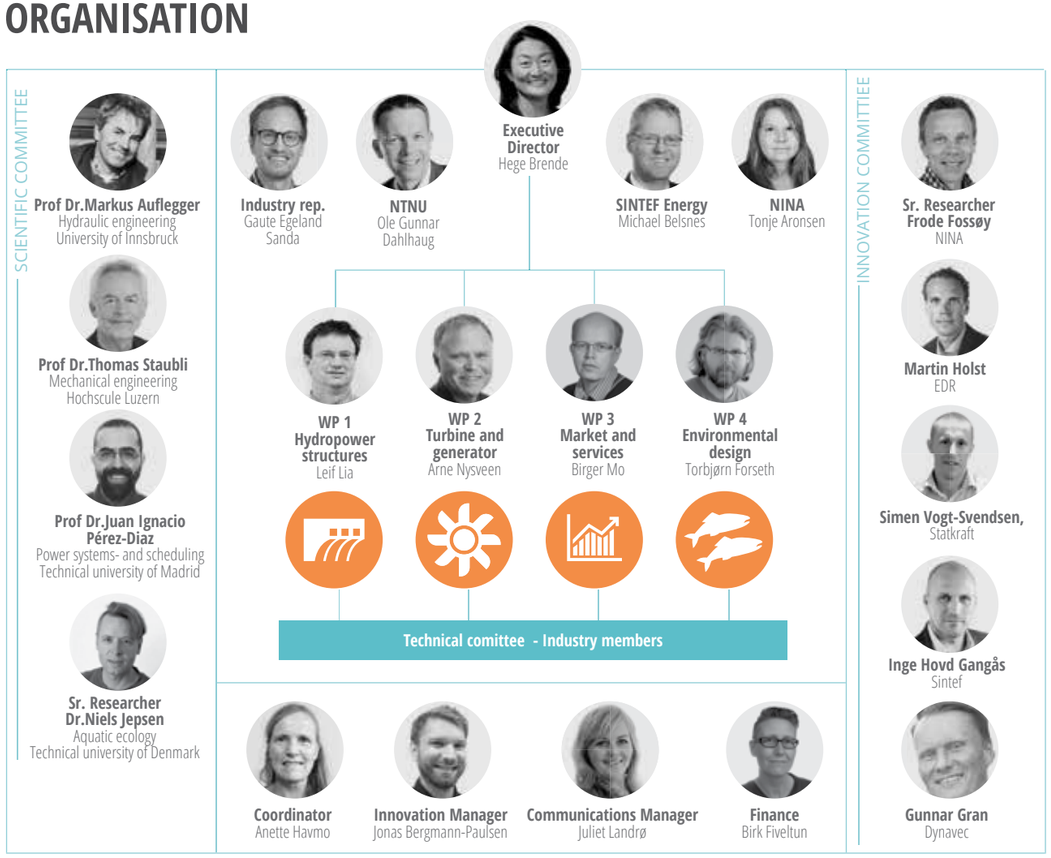
**Facebook:**
430 followers and increased activity

430

**LinkedIn:**
327 and increased activity

327 +

# ORGANISATION




| Board | | |
|---|---|---|
| Name | Institution | Function |
| Ivar Arne Børset | Statkraft | Chairman of the Board |
| Norunn Myklebust | NINA | Board member |
| Knut Samdal | SINTEF Energi | Board member |
| Eivind Heløe | EnergiNorge | Board member |
| Rune Flatby | NVE | Board member |
| Erik Skorve | BKK | Board member |
| Alf-Inge Berget | E-CO | Board member |
| Olav Bolland | NTNU | Board member |
| Ingeborg Palm Helland | NINA | Board member |
| Hege Brende | NTNU | Executive Director/ Board Secretary |

| | | |
|---|---|---|
| Name | Institution | Function |
| Anette Havmo | NTNU | Secretary |
| Harald Rikheim | Norwegian Research Council | Observer |
| Juliet Landrø | NINA | Observer/Head of communications |
| Jane Berit Solvi | Skagerak | 1. deputy board member |
| Tormod Eggan | TrønderEnergi | 2. deputy board member |
| Bjørn Honningsvåg | Lyse | 3. deputy board member |
| Lars Grøttå | NVE | Deputy board member |
| Terese Løvås | NTNU | Deputy board member |
| Petter Støa | Sintef Energi | Deputy board member |
| Jon Museth | NINA | Deputy board member |





| Executive Management Team and Admnistration | | |
|---|---|---|
| Name | Institution | Function |
| Hege Brende | NTNU | Executive director |
| Ole Gunnar Dahlhaug | NTNU | Member |
| Tonje Aronsen | NINA | Member |
| Michael Belsnes | SINTEF | Member |
| Gaute Egeland Sanda | Hydro | Member |

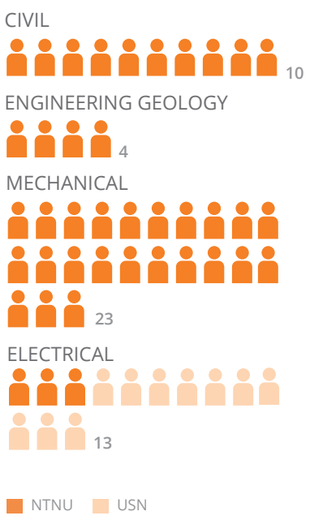
| | | |
|---|---|---|
| Name | Institution | Function |
| Sigve Næss | BKK | Member |
| Anette Havmo | NTNU | Secretary |
| Juliet Landrø | NTNU | Head of communications |
| Birk Fiveltun | NTNU | Finance |
| Jonas Bergmann-Paulsen | NTNU | Innovation Manager |

| Researchers | | |
|---|---|---|
| Name | Institution | Main research area |
| Arne Nysveen | NTNU | Turbine and generators |
| Bjørn Nilsen | NTNU | Hydropower structures |
| Bjørnar Svingen | NTNU | Turbine and generators |
| Elena Pummer | NTNU | Hydropower structures |
| Fjóla G. Sigtryggsdóttir | NTNU | Hydropower structures |
| Jonas Kristiansen Nøland | 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 |
| Leif Lia | NTNU | Hydropower structures |
| Magnus Korpås | NTNU | Market and services |
| Nils Reidar Bøe Olsen | NTNU | Hydropower structures |
| Nils Ruther | NTNU | Hydropower structures |
| Ole Gunnar Dahlhaug | NTNU | Turbine and generators |
| Peggy Zinke | NTNU | Environmental design |
| Pål-Tore Storli | NTNU | Turbine and generators |
| Roy Nilsen | NTNU | Turbine and generators |
| Siri Stokseth | NTNU | Hydropower structures |
| Stein-Erik Fleten | NTNU | Market and services |
| Tor Haakon Bakken | NTNU | Market and services |
| Torbjørn Nielsen | 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 |
| David Barton | NINA | Market and services |
| Frode Fossøy | NINA | Environmental design |
| Ingeborg Palm Helland | NINA | Environmental design |
| Ingebrigt Uglem | NINA | Environmental design |
| Karl Øystein Gjelland | NINA | Environmental design |
| Line Sundt-Hansen | NINA | Environmental design |
| Margrete Skår | NINA | Environmental design |
| Richard Hedger | NINA | Environmental design |
| Terje Bongard | NINA | Environmental design |
| Tonje Aronsen | NINA | Environmental design |
| Torbjørn Forseth | NINA | Environmental design |

| | | |
|---|---|---|
| Name | Institution | Main research area |
| Øystein Aas | NINA | Environmental design |
| Ana Adeva Bustos | SINTEF | Environmental design |
| Arild Helseth | SINTEF | Market and services |
| Arnt Ove Eggen | SINTEF | Market and services |
| Atle Harby | SINTEF | Environmental design |
| Atsede G. Endegnanew | SINTEF | Turbine and generators |
| 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 |
| Espen Eberg | SINTEF | Turbine and generators |
| Hans Ivar Skjelbred | SINTEF | Market and services |
| Hans Olaf Hågenvik | SINTEF | Market and services |
| Hans Petter Fjeldstad | SINTEF | Environmental design |
| Henrik Enoksen | SINTEF | Turbine and generators |
| Ingeborg Graabak | SINTEF | Market and services |
| Julie Charmasson | SINTEF | Hydropower structures |
| Jørn Foros | SINTEF | Turbine and generators |
| Karl Merz | SINTEF | Turbine and generators |
| Kjell Ljøkelsøy | SINTEF | Turbine and generators |
| Lennart Schönfelder | SINTEF | Market and services |
| Linn Emelie Schäffer | SINTEF | Market and services |
| Marcell Szabo-Meszaros | SINTEF | Environmental design |
| Maren Istad | SINTEF | Turbine and generators |
| Mari Haugen | SINTEF | Market and services |
| Michael Belsnes | SINTEF | Market and services |
| Olve Mo | SINTEF | Turbine and generators |
| Sverre Hvidsten | SINTEF | Turbine and generators |
| Tuan T. Nguyen | SINTEF | Turbine and generators |
| Thomas Welte | SINTEF | Market and services |
| Bernt Lie | USN | Turbine and generators |
| Gunne Hegglid | USN | Turbine and generators |
| Sailesh Chitrakar | KU | Turbine and generators |
| Ulrich Pulg | NORCE | Environmental design |
| Roger Olsson | NGI | Hydropower structures |
| Jochen Aberle | TU Braunschweig | Associated project |

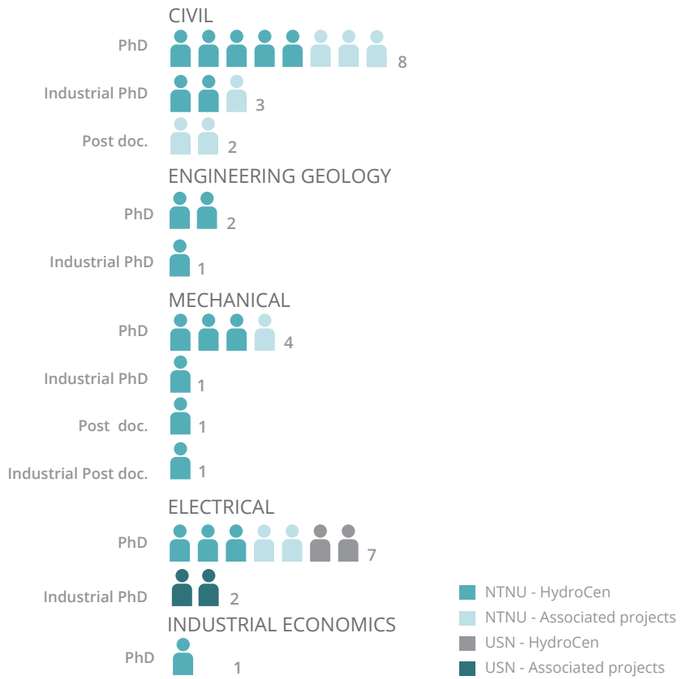
# MASTER STUDENTS

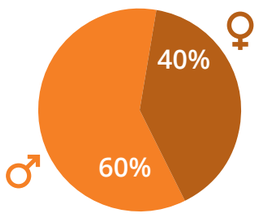
In 2019 we had a total of 50 master students at NTNU and The University of South-Eastern Norway (USN) within the field of hydropower. The distribution between the disciplines Civil, Mechanical, Electrical and and Engineering Geology is shown in the figure below.




# PHD AND POST DOCS.

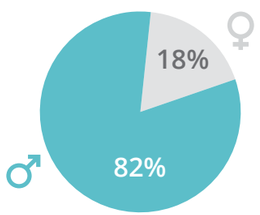
In 2019 a total of 33 PhD and Post doc. in HydroCen and HydroCen-associated projects. They worked within Civil, Mechanical, Electrical, Economy, and Engineering Geology.



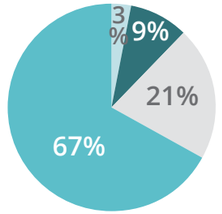

Gender distribution

Women
Men




Gender distribution

Women
Men




Distribution between PhD, Post doc. and industrial-PhD

Industrial PhD
PhD
Post doc.
Industrial Post doc.



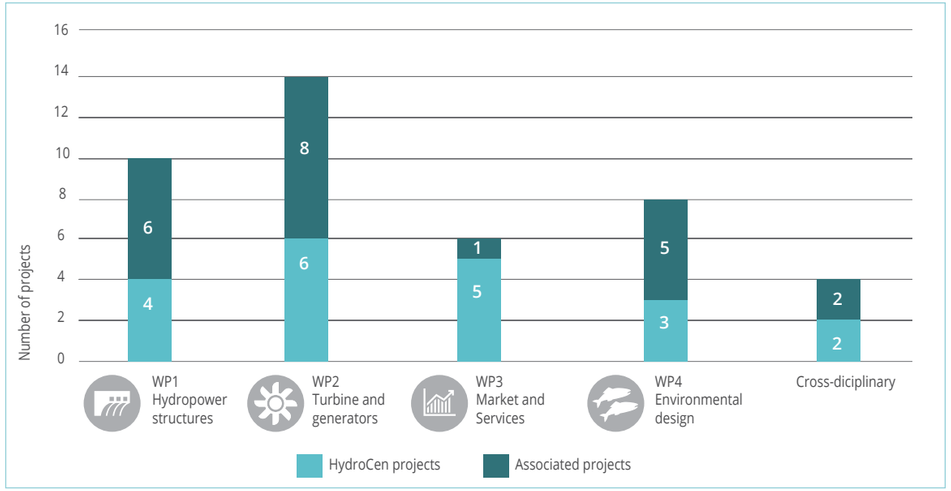


**PhD and Post doc. in HydroCen, active in 2019**

| Name | PhD Post doc. | Gender | Nationality | Topic | Period |
|---|---|---|---|---|---|
| Igor Iliev | PhD | M | Mecedonian | Design of a high-head Francis turbine for variable speed configurations | 2016-2019 |
| Helene Dagsvik | PhD | F | Norwegian | Reversible Pump-Turbines in Existing Power Plants | 2017-2020 |
| Kristian Sagmo | PhD RSO | M | Norwegian | Flow manipulation for improved operation of hydraulic turbines | 2017-2020 |
| Celine Faudot | Post doc. | F | French | Fatigue Loads on Turbines attached to a Conduit System | 2017-2020 |
| Ganesh Ravindra | PhD | M | Indian | Embankment dam safety under extreme loading conditions | 2017-2020 |
| Livia Pitorac | PhD | F | Romanian | Upgrading of hydropower plants to pumped storage plants: reconstruction and improvements of the tunnel system | 2017-2020 |
| Håkon Sundt | PhD | M | Norwegian | Environmental design for multiple interests under future flexible hydropower operation | 2017-2020 |
| Andreas Kleiven | PhD | M | Norwegian | Investment Decisions in Upgrading and Refurbishment of Hydropower Plants | 2017-2020 |
| Ola Haugen Havrevoll | PhD RSO | M | Norwegian | Rock traps in pumped storage and peaking power plants | 2017-2021 |
| Bibek Neupane | PhD | M | Nepalese | Long-term impact on unlined tunnels of hydropower projects due to frequent start stop sequences | 2017-2021 |
| Lena Selen | PhD | F | Norwegian | Effects of swelling rock and swelling clay in water tunnels | 2017-2021 |
| Henki Ødegaard | PhD RSO | M | Norwegian | Optimization of test methods and design of transition zones in unlined pressure tunnels | 2017-2021 |
| Raghbendra Tiwari | PhD RSO | M | Nepalese | Frequency converter solutions and control methods for variable speed operation of pump storage plant | 2018-2020 |
| Bjørn Solemslie | Post doc. RSO | M | Norwegian | Resonance and pressure pulsations in High Head Francis Runner | 2018-2020 |
| Tor Inge Reigstad | PhD RSO | M | Norwegian | Grid Integration of Variable Speed Hydro Power Plant | 2018-2021 |
| Hossein Ehya | PhD | M | Iranian | Electromagnetic Analysis and Online Fault detection of Hydropower Generators | 2018-2021 |
| Nirmal Acharya | PhD | M | Nepalese | Design of a Francis turbine that accomodates high sediment concentration | 2018-2021 |
| Diwash Lal Maskey | PhD | M | Nepalese | Sediment handling at the intake of the hydropower plants: A toolbox for decision making | 2018-2021 |
| Shohreh Monshizadeh | PhD | F | Iranian | The Flexible Hydro Power Unit | 2018-2021 |
| Halvor Kjærås | PhD RSO | M | Norwegian | Modeling of fish guidance by floating devices | 2018-2022 |
| Geir Helge Kiplesund | PhD | M | Norwegian | Damsikkerhet og bruddutvikling i fyllingsdammer | 2019-2022 |

# PROJECTS OVERVIEW 2019

A total of 42 projects related to hydropower were ongoing in 2019. 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 and surge chambers | Bjørn Nilsen | Hydropower structures |
| 1.2 Dam construction and dam saftey | Fjola G. Sigtryggsdottir | Hydropower structures |
| 1.3 Sediment handling | Nils Rüther | Hydropower structures |
| 1.4 Fish friendly hydropower intakes | Leif Lia | Hydropower structures |
| 2.1 Variable speed operation | Arne Nysveen | 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 | Thomas Welte | Turbine and generators |
| 2.5 Flexible Hydropower Unit | Kjetil Uhlen | Turbine and generators |
| 2.6 New Design of Guide Vanes | Pål-Tore Storli | Turbine and generators |
| 3.1 Future market structures and prices | Birger Mo | Market and services |
| 3.2 Remaining useful life, failure probability | Arnt Ove Eggen | Market and services |
| 3.3 Optimal hydro design in the future power system | 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 Governance and social acceptance | Audun Ruud | Environmental design |
| 4.2 Fish migration | Ana da Silva/ Torbjørn Forseth | Environmental design |
| 4.3 Multiple interests under future flexible hydropower operation | Atle Harby | Environmental design |
| AlternaFuture | Kaspar Vereide | AlternaFuture |
| Francis turbine for sediment laden waters (FranSed) | Ole Gunnar Dahlhaug | Direct Project |



| Associated Projects | | | | |
|---|---|---|---|---|
| Project name | Project leader | Field of study | Type | Project owner |
| HiFrancis FSI Toolkit | Martin Holst | Hydropower Structures | IPN | EDRMedeso |
| DIRT-X | Nils Rüther | Market and services | | |
| HydroCen Labs | Ole Gunnar Dahlhaug | Environmental Design | | |
| EnergizeNepal | Nawaraj Sanjel | Environmental Design | MFA | Kathmandu University |
| FIThydro | Peter Rutschmann | Turbine and generators | EU H2020 | Koordinator Technical University of Munich, Germany |
| Elvemuslingens miljøkrav | Bjørn M. Larsen | Hydropower Structures | Government | NINA |
| HYCANOR | Ingeborg Palm Helland | Turbine and generators | INTPART | NINA |
| HYPOS - Hydropower Suite | Nils Rüther | Turbine and generators | | |
| JP hydropower/ EERA | Sara Heidenreich | Cross-disciplinary | | |
| LiTRo | Morten Kjeldsen | Hydropower Structures | | |
| HydroFLEX | Ole Gunnar Dahlhaug | Turbine and generators | EU H2020 | NTNU |
| Fancis -99 | Chirag Trivedi | Environmental Design | Intern | NTNU |
| SediPASS | Nils Rüther | Turbine and generators | KPN | NTNU (NVKS) |
| TunnelRoughness | Jochen Aberle | Cross-disciplinary | KPN | NTNU (NVKS) |
| HydroStator | Arne Nysveen | Hydropower Structures | KPN | NTNU (NVKS) |
| HiFrancis | Ole Gunnar Dahlhaug | Environmental Design | KPN | NTNU (NVKS) |
| MonitorX | Maren Istad | Hydropower Structures | | |
| Levetidsberegning for Francis | Petter Østby | Turbine and generators | IPN | EnergiNorge |
| PRIBAS | Arild Helseth | Hydropower Structures | KPN | SINTEF Energi |
| Fleksibel Sandfang (FlexS) | Kaspar Vereide | Turbine and generators | Industry | Sira Kvina Kraftselskap |
| Miljødesignhåndbok for ørret i magasin | Ingeborg Palm Helland | Turbine and generators | Government | Miljødirektoratet |
| HyMo | Atle Harby | Environmental design | Government | Miljødirektoratet |

# FINANCIAL STATEMENT HYDROCEN 2019

| | | | All figures in 1000 NOK |
|---|---|---|---|
| **Funding** | **Funding** | **In-kind** | **Total** |
| The Research Council of Norway | 36,469 | | 36,469 |
| Industry partners | 9,401 | 4,421 | 13,822 |
| Research partners | | 18,967 | 18,967 |
| Total funding 2018 | 45,870 | 23,388 | 69,258 |
| **Revenue 2019** | **Funding** | **In-kind** | **Total** |
| Sintef Energi | 14,853 | 5,365 | 20,218 |
| NINA | 6,904 | 3,493 | 10,397 |
| NGI | | 689 | 689 |
| USN | 1095 | 138 | 1,233 |
| KU | 270 | | 270 |
| NTNU | 22,748 | 9,282 | 32,030 |
| Industry in-kind | | 4,421 | 4,421 |
| **Total Costs 2018** | **45,870** | **23,388** | **69,258** |

# PUBLICATIONS

HydroCen researchers have contributed to 177 scientific publications in 2019. As well as presenting their findings as papers at a large number of conferences for researchers and hydropower industry, they have also published 25 Level 1 and 2 papers.

## Level 2 papers

1. Basnet, Chhatra Bahadur; Panthi, Krishna Kanta.
   Evaluation on the Minimum Principal Stress State and Potential Hydraulic Jacking from the Shotcrete-Lined Pressure Tunnel: A Case from Nepal. Rock Mechanics and Rock Engineering 2019 ;Volume 52.(7) pp. 2377-2399
   NTNU

2. Fleten, Stein-Erik; Mauritzen, Johannes; Ullrich, Carl J..
   The other renewable: Hydropower upgrades and renewable portfolio standards. Energy Journal 2018 ;Volume 39.(2) pp. 197-217
   BI NTNU

3. Panthi, Krishna Kanta; Shrestha, Pawan Kumar.
   Estimating Tunnel Strain in the Weak and Schistose Rock Mass Influenced by Stress Anisotropy: An Evaluation Based on Three Tunnel Cases from Nepal. Rock Mechanics and Rock Engineering 2018 ;Volume 51.(6) pp. 1823-1838
   NTNU

4. Selen, Lena; Panthi, Krishna Kanta; Vistnes, Gunnar.
   An analysis on the slaking and disintegration extent of weak rock mass of the water tunnels for hydropower project using modified slake durability test. Bulletin of Engineering Geology and the Environment 2020
   NTNU

5. Sigtryggsdottir, Fjola Gudrun; Snæbjörnsson, Jonas Thor; Grande, Lars Olav.
   Statistical model for dam-settlement prediction and structural-health assessment. Journal of Geotechnical and Geoenvironmental Engineering 2018 ;Volum 144.(9)
   NTNU UIS

6. Silva, Ana T.; Bærum, Kim Magnus; Hedger, Richard David; Baktoft, Henrik; Fjeldstad, Hans-Petter; Gjelland, Karl Øystein; Økland, Finn; Forseth, Torbjørn.
   The effects of hydrodynamics on the three-dimensional downstream migratory movement of Atlantic salmon. Science of the Total Environment 2019 ;Volume 705.
   ENERGISINT NINA

7. Sundt-Hansen, Line Elisabeth Breivik; Hedger, Richard David; Ugedal, Ola; Diserud, Ola Håvard; Finstad, Anders Gravbrøt; Sauterleute, Julian Friedrich; Tøfte, Lena S; Alfredsen, Knut; Forseth, Torbjørn.
   Modelling climate change effects on Atlantic salmon: Implications for mitigation in regulated rivers. Science of the Total Environment 2018 ;Volume 631-632. pp. 1005-1017
   ENERGISINT NINA NTNU

8. Trivedi, Chirag; Agnalt, Einar; Dahlhaug, Ole Gunnar.
   Experimental investigation of a Francis turbine during exigent ramping and transition into total load rejection. Journal of Hydraulic Engineering 2018 ;Volume 144.(6)
   NTNU

## Level 1 papers published in 2019

1. Acharya, Nirmal; Trivedi, Chirag; Wahl, Nina Marie; Gautam, S; Chitrakar, Sailesh; Dahlhaug, Ole Gunnar.
   Numerical study of sediment erosion in guide vanes of a high head Francis turbine. Journal of Physics: Conference Series 2019 ;Volume 1266.(012004)
   NTNU

2. Agnalt, Einar; Iliev, Igor; Solemslie, Bjørn Winther; Dahlhaug, Ole Gunnar.
   On the Rotor Stator Interaction Effects of Low Specific Speed Francis Turbines. International Journal of Rotating Machinery 2019 ;Volume 2019.
   NTNU

3. Chitrakar, Sailesh; Neopane, Hari Prasad; Dahlhaug, Ole Gunnar.
   The numerical and experimental investigation of erosion induced leakage flow through guide vanes of Francis turbine. IOP Conference Series: Earth and Environmental Science (EES) 2019 ;Volume 240.(7)
   NTNU

4. Hiriyanna Rao Ravindra, Ganesh; Sigtryggsdottir, Fjola Gudrun; Asbølmo, Malin Fossum; Lia, Leif.
   Toe support conditions for placed ripraps on rockfill dams –A field survey. Vann 2019 ;Volume 54.(3) pp. 185-199
   NTNU

5. Hiriyanna Rao Ravindra, Ganesh; Sigtryggsdottir, Fjola Gudrun; Høydal, Øyvind Armand.
   Non-linear flow through rockfill embankments. Journal of Applied Water Engineering and Research 2019 ;Volume 7.(4) pp. 247-262
   NGI NTNU

6. Iliev, Igor; Trivedi, Chirag; Agnalt, Einar; Dahlhaug, Ole Gunnar.
   Variable-speed operation and pressure pulsations in a Francis turbine and a pump-turbine. IOP Conference Series: Earth and Environmental Science (EES) 2019 ;Volume 240.
   NTNU

7. Iliev, Igor; Trivedi, Chirag; Dahlhaug, Ole Gunnar.
   Variable-speed operation of Francis turbines: A review of the perspectives and challenges. Renewable & Sustainable Energy Reviews 2019 ;Volume 103. pp. 109-121
   NTNU

8. Monshizadeh, Shohreh; Hegglid, Gunne John; Hagen, Svein Thore.
   Comparison of Intelligent Algorithms with FACTS Devices for Minimization of Total Power Losses. Advances in Intelligent Systems and Computing 2019 ;Volume 926. pp. 120-131
   USN

9. Monshizadeh, Shohreh; Hegglid, Gunne John; Hagen, Svein Thore.
   Solving optimal power dispatch using artificial algorithm for Nordic 44 network. Journal of High Speed Networks 2019 ;Volume 25.(3) pp. 301-310
   USN

10. Nordvik, Andreas; Iliev, Igor; Trivedi, Chirag; Dahlhaug, Ole Gunnar.
    Numerical prediction of hill charts of Francis turbines. Journal of Physics: Conference Series 2019 ;Volume 1266.(1) pp. 1-10
    NTNU

11. Panthi, Krishna Kanta; Basnet, Chhatra Bahadur.
    Evaluation of earthquake impact on magnitude of the minimum principal stress along a shotcrete lined pressure tunnel in Nepal. Journal of Rock Mechanics and Geotechnical Engineering 2019 ;Volume 11.(5) pp. 920-934
    NTNU

12. Sagmo, Kristian Forfot; Storli, Pål-Tore Selbo.
    A test of the v 2-f k-epsilon turbulence model for the prediction of vortex shedding in the Francis-99 hydrofoil test case. Journal of Physics: Conference Series 2019 ;Volume 1296.(1)
    NTNU

13. Sagmo, Kristian Forfot; Tengs, Erik Os; Bergan, Carl Werdelin; Storli, Pål-Tore Selbo.
    PIV measurements and CFD simulations of a hydrofoil at lock-in. IOP Conference Series: Earth and Environmental Science (EES) 2019 ;Volume 240.
    NTNU

14. Sigtryggsdottir, Fjola Gudrun; Snæbjörnsson, Jonas Thor.
    Geological challenges and geohazard monitoring of a mega engineering hydropower project in Iceland. Engineering Geology 2019 ;Volume 259.
    NTNU UIS

15. Tengs, Erik Os; Einzinger, Johannes; Storli, Pål-Tore Selbo.
    Two-way coupled simulation of the Francis-99 hydrofoil using model order reduction. Journal of Physics: Conference Series 2019 ;Volume 1296.(1)
    NTNU

16. Tengs, Erik Os; Fevåg, Live Salvesen; Storli, Pål-Tore Selbo.
    Francis-99: Coupled simulation of the resonance effects in runner channels. Journal of Physics: Conference Series 2019 ;Volume 1296.(1) pp. 1-16
    NTNU

17. Volent, Eirik; Dahlhaug, Ole Gunnar; Tengs, Erik Os.
    Study of flow structure in erosion prone complex geometries. IOP Conference Series: Earth and Environmental Science (EES) 2019 ;Volume 240. pp. 1-9
    NTNU

The “holy grail” of fish migration has been the question of what determines the fish’s movements in the water. New cross-disciplinary research, sound tags, remote sensing and 3D-technology have shown that salmon smolt don’t just go with the flow. These findings will make us more able to prevent fish from losing their lives in hydropower plants.

Read more: https://blogg.forskning.no/blogg-villaksbloggen

*(Photo: Henrik Baktoft/DTU AQUA)*

Silva, Ana T.; Bærum, Kim Magnus; Hedger, Richard David; Baktoft, Henrik; Fjeldstad, Hans-Petter; Gjelland,
Karl Øystein; Økland, Finn; Forseth, Torbjørn. The effects of hydrodynamics on the three-dimensional
downstream migratory movement of Atlantic salmon. Science of the Total Environment 2019 ;Volume 705.
ENERGISINT NINA



Ana Teixeira Da Silva,
Researcher

# TECHNICAL COMMITTEES 2019

| Work Package 1<br>Hydropower stuctures | Work Package 2<br>Turbine and generator | Work Package 3<br>Market and services | Work Package 4<br>Environmental design |
|---|---|---|---|
| WP Leader: Leif Lia, NTNU | WP Leader: Arne Nysveen, NTNU | WP Leader: Birger Mo, SINTEF | WP Leader: Torbjørn Forseth, NINA |
| Anne Marit Ruud, Statkraft | Arne Nysveen, NTNU | Andreas Kleiven, SINTEF | Ana Adeva-Bustos, SINTEF |
| Bendik Hansen, SINTEF | Arne Småbrekke, BKK Produksjon | Andreas Sylte, Statkraft | Ana Silva, NINA |
| Bibek Neupane, NTNU | Bernt Lie, USN | Arild Helseth, SINTEF | Arne Anders Sandnes, Statkraft |
| Bjørn Nilsen, NTNU | Carl Andreas Veie, NVE | Arnt Ove Eggen, SINTEF | Atle Harby, SINTEF |
| Diwash Lal Maskey, NTNU | Carl-Maikel Högström, Vattenfall | Atle Frøland, Tafjord Kraftproduksjon AS | Berit Koehler, NINA |
| Eirik Leknes, Hydro Energi | Celine Faudot, NTNU | Bendik Hansen, SINTEF | Bjørn Otto Dønnum, E-CO |
| Erlend Bårgard, Sognekraft AS | Egil Skåre, Dynavec | Birger Mo, SINTEF | David Aldvén, Vattenfall |
| Fjola Gudrun Sigtryggsdottir, NTNU | Einar Kobro, Energi Norge | Bjørn Austrud, Agder Energi | Eilif Brodtkorb, NVE |
| Ganesh Ravindra, NTNU | Espen Eberg, SINTEF | Eirik Veirød, NVE | Eirik Bjørkhaug, NVE |
| Halvor Kjærås, NTNU | Gunne Hegglid, USN | Frode Vassenden, TrønderEnergi | Erling Otterlei, SKL AS |
| Hanne Nøvik, Multiconsult | Hossein Ehya, NTNU | Hans Olaf Hågenvik, SINTEF | Geir Taugbøl, Energi Norge |
| Helge Martinsen,<br>Glitre Energi Produksjon AS | Igor Iliev, NTNU | Hans Ole Riddervold, Norsk Hydro | Hans-Petter Fjeldstad, SINTEF |
| Henki Ødegaard, NTNU | Ingunn Granstrøm, Skagerak Kraft | Jonas Funkquist, Vattenfall | Håkon Sundt, NTNU |
| Kaspar Vereide, Sira-Kvina kraftselskap | Jan Petter Haugli,Statkraft | Kjetil Midthun, BKK | Jo H. Halleraker, Miljødirektoratet |
| Krishna Kanta Panthi, NTNU | Jens Österud, Vattenfall | Kristin Nilssen, Hydro Energi AS | Knut Alfredsen, NTNU |
| Leif Lia, NTNU | Jonas Nøland, NTNU | Lennart Schönfelder, SINTEF | Line Sundt-Hansen, NINA |
| Lena Selen, NTNU | Jørgen Ramdal, Statkraft | Linn Emelie Schäffer, SINTEF | Marcell Szabo-Meszaros, SINTEF |
| Livia Pitorac, NTNU | Jørn Foros, SINTEF | Magnus Brostrup Landstad,<br>Lyse Produksjon AS | Mari Roald Bern, Statkraft |
| Magne Skog, Agder Energi | Kjell Sivertsen, Rainpower | Martin Hjelmeland, Lyse Produksjon As | Nils Henrik Johnson, TrønderEnergi |
| Magne Wraa, Skagerak Kraft | Kjetil Uhlen, NTNU | Michael Belsnes, SINTEF | Patrik Andreasson, Vattenfall |
| Morten Skoglund, NVE | Kristian Sagmo, NTNU | Ragne Hildrum, Statkraft | Per Ivar Bergan, Sweco |
| Nirmal Acharya, NTNU | Lars Lone, Hydro Energi AS | Sigurd Hofsmo Jacobsen, SINTEF | Roy M. Langåker, Miljødirektoratet |
| Oddmund Brevik, E-CO Energi | Line Drange Ruud, Glitre Energi | Tor Haakon Bakken, NTNU | Sissel H Mykletun, BKK Produksjon |
| Ola Haugen Havrevoll, NTNU | Linn Saarinen, Vattenfall | Tor Halvor Bolkesjø, E-CO Energi | Stein Øvstebø, Hydro Energi AS |
| Patrik Andreasson, Vattenfall | Maren Istad, SINTEF | | Svein Haugland, Agder Energi |
| Per Vidar Halsnes, BKK Produksjon | Martin Aasved Holst, EDR Medeso | | Torbjorn Forseth, NINA |
| Siri Stokseth, Statkraft | Mats Billstein, Vattenfall | | Trond Erik Børresen, Lyse Produksjon |
| Tom Jacobsen, SediCon | Nils Ruther, NTNU | | Trond Taugbøl, Eidsiva Vannkraft |
| Øyvind Pedersen, Multiconsult | Olve Mo, SINTEF | | Åsmund Hasaas, Skagerak Kraft |
| | Pål Glimen, NTNU | | |
| | Pål-Tore Storli, NTNU | | |
| | Raghbendra Tiwari , NTNU | | |
| | Stig Falling, Tafjord Kraftproduksjon | | |
| | Sverre Knutsen, E-CO Energi | | |
| | Thomas Øyvang, USN | | |
| | Tor Inge Reigstad, NTNU | | |
| | Torbjørn Kristian Nielsen, NTNU | | |
| | Tore-Johan Flåm, NTE | | |
| | Tormod Kleppa, Eidsiva Vannkraft AS | | |
| | Vidar Nylund, Eidsiva Vannkraft AS | | |
| | Øystein Gjerde, Voith Hydro | | |
| | Øyvind Linnebo, ABB AS | | |



# PARTNER OVERVIEW

Forskningspartnere

Partnere fra bransje og forvaltning

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