HydroCen
NORWEGIAN RESEARCH CENTRE FOR HYDRO POWER TECHNOLOGY

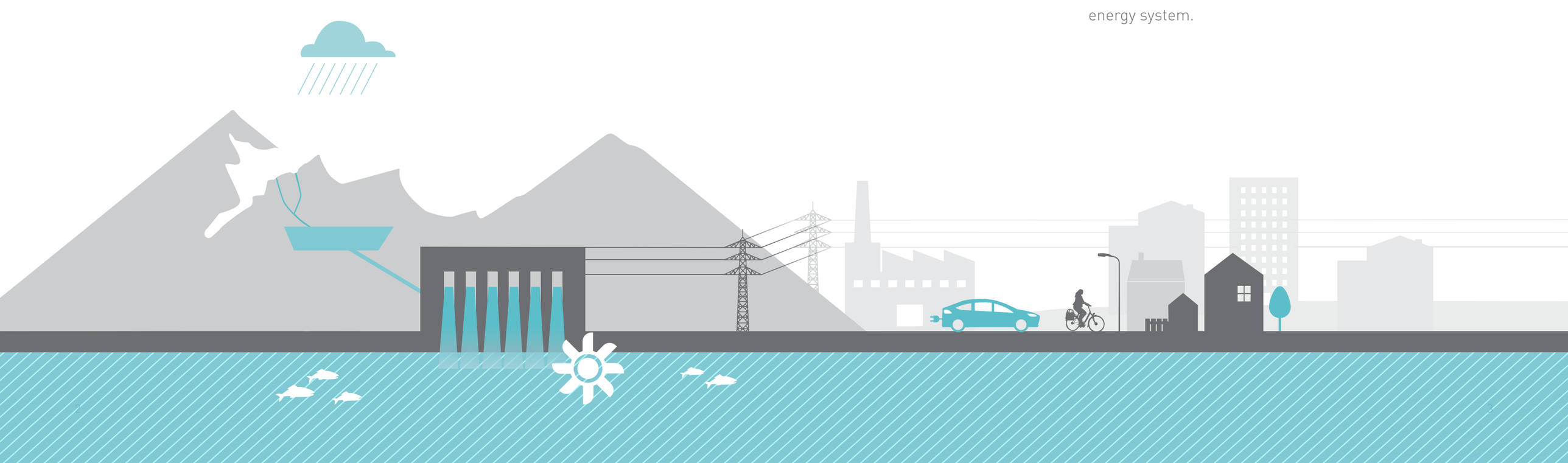
CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

ANNUAL REPORT

2017

Our main objective is to enable the Norwegian hydropower sector to meet complex challenges and exploit new opportunities through innovative technological solutions.

HydroCen will contribute to strengthen Norway's position as a leading hydropower nation and secure the future possibilities for sustainable hydropower development in a renewable energy system.



Ivar Arne Børset
Statkraft

OFF TO A RUNNING START

Once again, we can be proud to say that hydropower built this country, - and continues to do so.

HydroCen has had a flying start and the establishment has been quick and efficient. As much as 13 new projects have been launched in this first year, 14 PhDs have been recruited and they have all started their work. HydroCen researchers have contributed to 28 scientific publications and more than 340 popular science presentations. In addition, three potential innovation results are already registered.

HydroCen builds on the platform of The Norwegian Hydropower Centre and the many years of engagement from the industry that in 2014 established hydropower as a main prioritised area in the national R&D strategy, Energi21. The Norwegian hydropower legacy that built this country is impressive. HydroCen stands on these shoulders as we keep developing the unique renewable resource that hydropower is. As we face the transition to a low-carbon energy system, we also uncover new emerging opportunities for research, development and industrial applications.

Equally important is the fact that HydroCen is a driver for increased enthusiasm for hydropower, both within the industry and in politics. The extent of this enthusiasm has been a contributing factor for the quick take-off in this first year of HydroCen.

Energy and electrification are high on the agenda, both politically and scientifically. No country is better positioned to be a laboratory for testing and verifying technology and solutions for a fully electrified society than Norway. Going forward with this, HydroCen will be a key player.

HydroCen is a large research centre, with a comprehensive spectrum of stakeholders, partners, scientific topics and expertise. The Board, the management and the partners have invested their time and skills in this first year to work on vital, important and necessary discussions to ensure that everyone is on-board for such an important common research effort that HydroCen represents. We are now passed the initial hurdles of start-up.

As we close this first year of operation it is important to address certain issues. Given the efficient founding year, there are expectations that HydroCen will now rapidly advance from start-up mode to delivery mode. To maintain the enthusiasm for the centre, it is important that results are quickly delivered and that they are continuously and expediently communicated. Furthermore, the focus on interdisciplinary work must continue and be enhanced. The utilisation of case-studies is very important, and there are also other tools available in order to achieve necessary integration between activities and projects. The industry and researchers must put their heads together and really make use of the huge advantage of being a research centre where so many fields of expertise are represented.

The HydroCen Board extends its acknowledgements to the consortium partners, the technical committees, the management group, the centre director and all stakeholders for a well accomplished founding year for HydroCen!

On behalf of the Board
Chairman of the Board, Ivar Arne Børset,
SVP Operations and Maintenance management, Statkraft AS

Hege Brende
Executive Director,
HydroCen

HYDROCEN IN 2017

Our first year of operation has been a bit of a rollercoaster-ride, and coming out of it we feel exhilarated and ready for a new ride in 2018!

On January 30th our Minister of Petroleum and energy, Mr. Terje Søviknes, officially opened the FME HydroCen together with over 200 partners and stakeholders at NTNU in Trondheim. With the Nidaros Cathedral and the Archbishop's Palace as a backdrop, NTNU's Rector Gunnar Bovim hosted the dinner to start off our eight year research collaboration. Since then, the whole organisation has put down huge efforts to make HydroCen spring into life from the initial plans, tables and figures.

I am equally impressed every time we are able to gather close to hundred people for our Technical Committee meetings. In our initial year, 2017, we did this twice. I am extremely happy to see that we have been able to recruit and employ more than twelve candidates for PhD and Post doc. positions in 2017. We have also launched several new projects. I could carry on with publications, presentations, innovation results, establishment of headquarter offices, reporting systems, board meetings, international relations etc. But you can read all about these in the coming pages.

The most important thing is that we have all worked around the clock to make the first year successful and combined we have put down a lot more than 20 000 work hours. This has been done with great enthusiasm, spirit and dedication. And also with confusion, discussion and dispute. It has been neither perfect nor elegant at times, but it has been with impressive ambitions and serious efforts from all parties; the Board, the management team, the scientific leaders, the project managers and the user partners.

This first year has created a unique vantage point for further growth and improvement in HydroCen. The Executive Management Team and I are very proud to have such an organisation to work with. Thank you!

Hege Brende
Executive Director, HydroCen

Many participated on our first researchers seminar for interdisciplinary cooperation.

Gunnar Bovim
Rector, NTNU

A HYDROPOWER SUPERTEAM

In the year of the 100th anniversary of the Hydropower Laboratory, HydroCen ensures that it is still an incubator for developing and increasing the value from hydropower

HydroCen has really put together an extraordinary hydropower team. There are a lot of partners and it is satisfying to register that you have a good start together. I note that you have established arenas where you actively increase the quality of your research through interaction and dialogue.

Methods and foundations are now in place to enable HydroCen to extract the potential we all strongly wish to be realized.

An incubator for development

I am pleased to see that the level of activity already is significant, that hydropower is high on the general agenda, and that results are already coming in. You have had a promising start!

It is extremely appropriate that HydroCen's first year was also the year in which we celebrated the 100th anniversary of the Hydropower Laboratory at NTNU. It is said to be the most profitable building in Norway, and now it will be an incubator for a development where we will see an even further increase of the value of hydroelectric power. With our long tradition of knowledge-based innovation in hydropower, it is natural that NTNU takes the lead as the next chapter is to be written.

Brings out the best of NTNU

We know that participation in such an FME raises the quality of education, research and innovation at NTNU. This means that candidates with particularly good professional education can be recruited into the work force and that research and innovation solve actual issues that will bring the industry forward here and now. Such measures simply bring out the best in NTNU, and we are grateful to all partners who help lift us.

Contributes to solve the UN's sustainability goals

Energy has been a research topic at NTNU ever since the first professor was employed at NTH a whole year before the main building was completed in 1910. Together with SINTEF, we have reached a position today where our activity has a major international importance. Our vision «Knowledge for a Better World» commits us to build on all the knowledge we have already cultured and use our unique interaction with industry to be a driving force for the use of renewable energy sources in the future.

Our new strategy, adopted by NTNU's board in December 2017, is crystal clear stating that NTNU shall contribute to solve the UN's sustainability goals. In this respect I have high expectations of both acceleration and quality of our energy research communities.

Gunnar Bovim, Rector NTNU.
NTNU is host institution of HydroCen.

Knut Samdal
Research Director,
SINTEF Energy

Impressive to have come so far - so fast

As one of the main partners for HydroCen, it is important for SINTEF that HydroCen contributes to creating a foundation of knowledge to the benefit of society as a whole, Knut Samdal, Research Director of SINTEF Energi AS says.

Active users who engage in the research projects ensure relevance and focus of the research. The main research partners in HydroCen; NINA, NTNU and SINTEF, have developed their collaboration over many years.

It is a great strength for HydroCen to be able to build on, and continue, the strong collaboration from CEDREN.

One of the consequences of active users and the successful cooperation between the research partners is that HydroCen has rapidly gained momentum.

A research centre like an FME is a large and complex organization. The fact that HydroCen has come so far in a relatively short period of time is impressive.

To the best for society

The way Norway ensures value creation of our energy resources- and technologies are major and important topics.

In SINTEF we see this in many ways, and it also affects our work in HydroCen. Our view is that HydroCen must also contribute to creating a knowledge base for the benefit of society.

To put it briefly, the direction is now set and the centre is up and running.

It is very exciting to be part of such a collaboration together with committed and competent users and research partners.

I have great expectations that HydroCen will make important contributions to secure future value creation in Norwegian hydropower.

Norunn Myklebust
Director, NINA

Development hand in hand with nature and society

Collaboration, expectations and acceleration are some of the key words director Norunn Myklebust at the Norwegian Institute for Nature Research (NINA), uses as she sums up 2017 from her position as one of the main research partners in HydroCen.

The center has rapidly moved forward to a steady cruising speed, and most of the projects have started. The center as an organization has also found its form.

A demanding year

The initiation of such a center with so many shareholders is always demanding, and I am pleasantly surprised that we landed the establishment as well as we did.

Since the center was officially opened in January 2017, there have been many meetings and discussions about the direction of the academic content in HydroCen. Part of that discussion has also occasionally been challenging.

For instance, it has taken a lot of effort to agree on what approach the center should choose regarding the social science component of HydroCen.

High expectations

Energy and electrification has climbed on the agenda, both politically and scientifically. Several cabinet ministers have already visited HydroCen in 2017.

I have registered very high expectations for the research center. I like that. At the same time, I would like to point out that if we are to succeed in realizing these ambitions, development must go hand in hand with both nature and people.

In the year to come I expect that we continue the good cooperation between the shareholders, that we get started with the activities that have not yet begun and that we are given the opportunity to expand the activity with new projects from EnergiX.

HYDROCEN OPENING

The Minister of Petroleum and Energy Terje Søviknes cut the cord and ceremoniously opened the already prestigious research centre HydroCen in January 2017.

Over 200 researchers and partners participated during the opening of Norway's new major initiative on hydropower research. HydroCen is naturally located in the tech-capital Trondheim and has a budget of almost 400 million NOK over the eight-year duration of the centre. Half the funds come from The Research Council of Norway, 25 % from the centre's industry partners and the remaining 25 % from the research partners.

— The combination of strong and interdisciplinary competence, available laboratory infrastructure and experienced industrial partners provide a unique platform for developing and positioning Norwegian hydropower, says Hege Brende, Executive Director of HydroCen.

Great expectations

The industry, government and the research council all have great expectations of HydroCen.

— More has been invested in the Norwegian power sector than in all other mainland industries combined. In that context we need to know what we are doing, commented Per Sanderud, director of NVE, The Norwegian Water Resources and Energy Directorate.

— We are facing a shift in the energy sector where it is important to further develop the hydropower technology to meet the new challenges. Major investments will be made to meet the needs for renewal. I expect that HydroCen will contribute so that the technology will be developed further within hydropower, as it has in solar- and wind power for the last years. And the energy production will be driven in a different way than before, for example with power ramping. The changes we make must be research-based and thoroughly prepared, Sanderud said.

The Research Council of Norway also expects to get value for the money they've entrusted to the HydroCen researchers.

— The Research Council of Norway expects that HydroCen will provide significant and state-of-the-art contribution to science and industry. It is about developing new technologies for more efficient, flexible and safe hydropower, as well as developing knowledge and technology that reduces environmental impact. HydroCen will deliver innovations that can be used in an international market, said Fridtjof Unander.

Photo: Øyvind Buljo and The Research Council of Norway.

GIVING WATER A BOOST

A booster pump helping the turbine might be the solution to avoid large and expensive conversions to flexible pump power stations. The expectations for PhD-candidate Helene Dagsviks research are therefore pretty high.

Helene Dagsvik is investigating whether a booster pump in the draft tube downstream of the turbine can make it possible to convert an existing power plant into a pump power plant – without having to blast out larger waterways.

A reversible pump power plant can produce electrical energy whenever it is in demand, and pump water back to the upper reservoir when there is an excess of energy in the grid.

Only a few pump power plants are in operation in Norway today. However, with an increase in the need for flexibility in the grid, the question is whether ordinary power plants may be converted into pump power plants, without excessive costs and downtime in production.

Challenging and costly to fit a new turbine

Installing a reversible pump turbine into an existing power plant entails several challenges and extensive costs. Since the turbine is required to pump water back to the upper reservoir, it must be able to pump the water with a force that exceeds the friction losses in the waterway.

This means that the reversible runner must be much larger and further submerged than the original one to prevent cavitation and cracks in low pressure areas of the turbine.

May increase pressure

To avoid these costly operations, Dagsvik is investigating an alternative solution: Fitting a booster pump in the draft tube (the waterway downstream of the turbine). The booster pump will provide enough pressure for the pump turbine to exceed the required pump head while at the same time avoiding cavitation on the turbine.

A living laboratory

Sira-Kvina has put Roskrepp power plant at the disposal of the booster pump project and this will form a foundation for further research.

In addition, laboratory tests will be conducted at the Waterpower Laboratory at NTNU, as well as simulations of the dynamics and interaction between booster pump and reversible pump turbine.

Supervisor: Associate Professor Pål-Tore Selbo Storli, NTNU

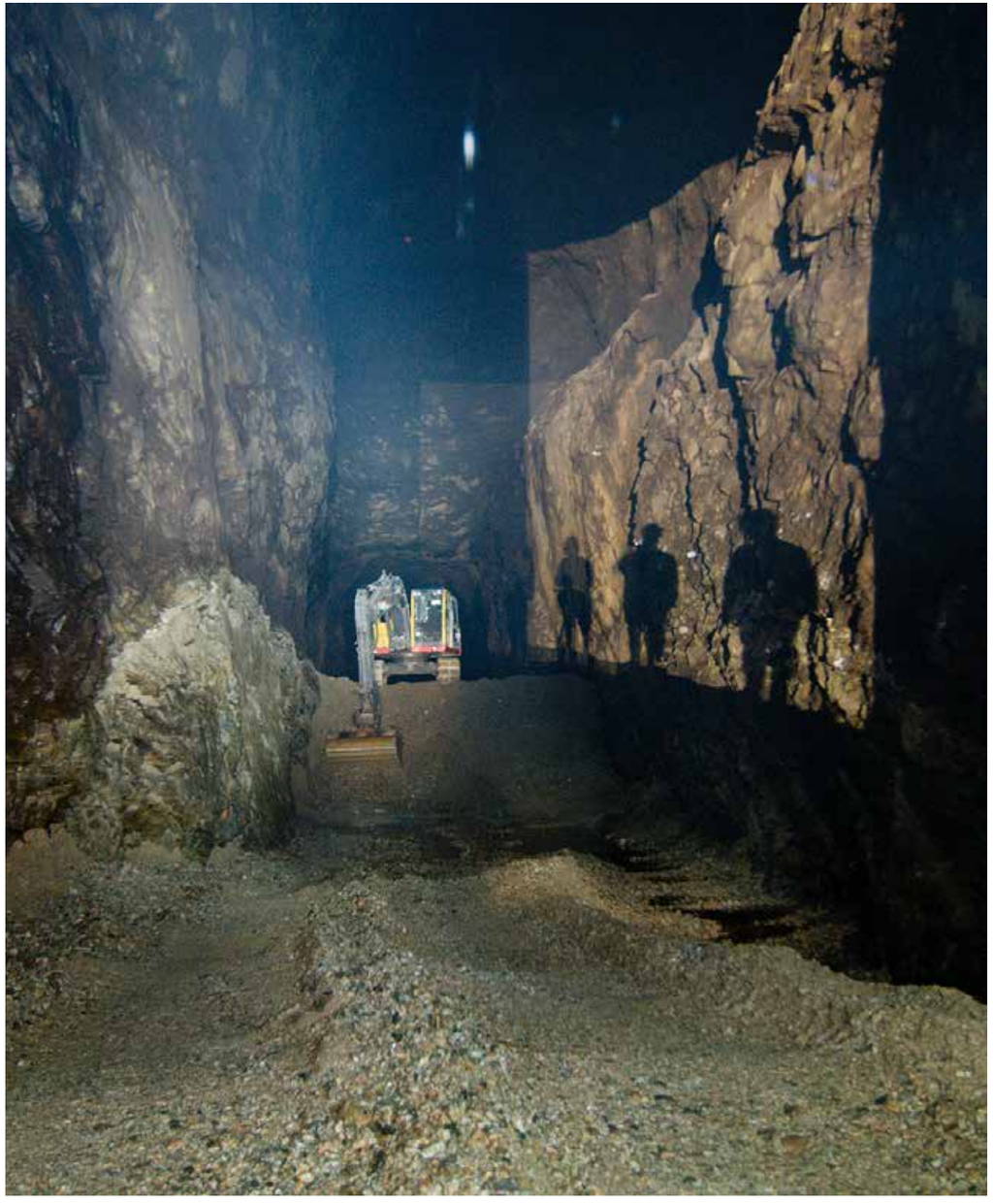


Photo: Kai Nessler

THE ROCK TRAPPERS

Are the rock traps in today's power plants good enough to prevent sediments from reaching the turbine? Will they still work with reversed flow caused by pump turbines or increased production? These are some of the questions Ola Haugen Havrevoll is researching in his PhD.

Pure water is incredibly important in hydropower. Sediments like rock, gravel, sand and clay wear down the steel in turbines and other components and lead to heavy maintenance costs.

In Norway, we have hard rock and clean water, but in many other countries it is important to consider sediment-leading rivers both when it comes to power plants and the environment. Those who research sediment management thus address a global problem for economics, environment and sustainability.

In 2017 a cooperation with, among others, researchers in Nepal and India has been established to investigate these issues. It is likely that there will also be increased activity in this area in HydroCen in the coming year.

An increasing problem in Norway

In Norway, sediment transport from the tunnel has gained more attention lately, as it turns out that many power plants have sediment problems, especially due to upgrades of turbines and higher discharges than beforeThese challenges can increase in Norway with a greater extent of peaking power and pumped storage plants in the future. Havrevoll will look at how rock traps should ideally be designed to stop sediments as effectively as possible.

There is very little research, literature and documentation of how rock traps in Norwegian power plants really work, so there is a knowledge gap that needs to be sealed.

Building a model rock traps

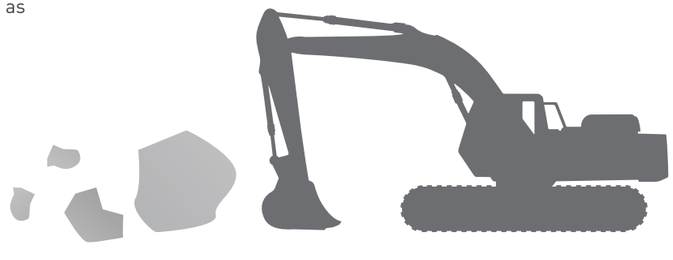
That is why the construction of a large model of one of the rock traps at Tonstad Power Plant (Sira Kvina Power Company) has been started. It is built in the scale 1:20. Here the researchers will try different methods to improve existing rock traps.

Field work in existing power plants

Havrevoll and several researchers were also exploring the conditions in the emptied headrace tunnels at Sima power plant (Statkraft) in Eidsfjord and Ulset power plant in the Orkla watercourse. They returned with important data.

Havrevoll is seeking input from other power station owners if they have problems or challenges with their rock traps or with wear on the turbines.

Supervisor: Professor Leif Lia, NTNU



WILL DESIGN A TURBINE-RUNNER THAT CAN «CHANGE GEARS»

To drive at a constant speed down the highway a car really only needs one gear. Same goes for turbines. So, when the highway changes into a more diverse road-system, you need more flexibility. PhD-candidate Igor Iliev will design a high-head Francis turbine for variable speed operation

Ever since the 19th century, hydropower played a key role in the generation of electricity worldwide, which resulted in an unprecedented industrialization and globalization shortly after.

Features like: High efficiency, low environmental impact, safety, robustness etc. have only proved that this technology is here to stay.

More than 100 years later, is it fair to say that hydropower has reached its maturity and there is nothing else to be done?

New need for flexibility

The answer is no. Hydropower is facing many challenges that have risen from the modern trends of electricity markets and generation. One of them is the need for enhanced flexibility and increased efficiency for the entire operating range of the turbines.

Rotating speed of the turbine is one parameter that, in any traditional hydropower plant, is kept constant along the operating range. An analogy to this might be a car with only one gear available and while this might be good for driving on a highway, it will be dangerous and inefficient in urban areas and vice versa.

Therefore, just as cars can be driven at any speed, the present effort is to enable the rotating speed of the hydraulic turbines to be adjusted as well.

This is one measure towards meeting the future requirements for flexibility and efficiency of the hydropower plants and prevention of unplanned major overhauls.

As the traditional design methodology and optimization is based on the fixed-speed operation, Iliev is going to explore the possibility for a variable-speed design methodology to maximize the effect from being able to adjust the speed freely.

This method will be applied for the design of a replacement turbine runner and, to verify the method, a scaled down model of the turbine will be built and experimentally tested in the Waterpower laboratory at NTNU.

Supervisor: Professor Ole Gunnar Dahlhaug, NTNU.

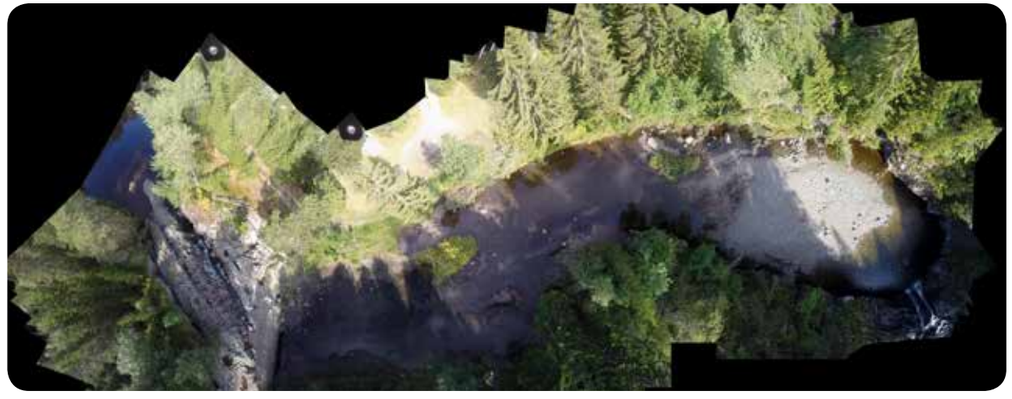


Photo: Anders Foldvik/NINA

DIGITALISATION TAKES KNOWLEDGE TO A NEW LEVEL

New access to technologies like satellites, drones and laser measurement tools takes knowledge of the Norwegian rivers to a whole new level.

PhD-candidate Håkon Sundt will research how we can enhance and expand the Environmental design-methodology using new available technology. The goal is still the same: to minimize the effect power production has on nature, and make sure decision makers have sufficient means to govern our rivers in a sustainable way.

Environmental design is important to ensure that those who use - and live in - the rivers can keep doing just that while there is also power production in the water course. In FME CEDREN researchers did a lot of work on salmon and environmental design, and now Sundt will see if these methods can be developed to benefit other species as well.

HydroCen will work with various tools for mapping and analyses, such as drones with high-resolution cameras, laser measurements to make detailed models of the terrain and satellite photos for long-term surveillance of changes in rivers. These can be used to model how water levels in the river connects to important factors like water-covered area and river bottom conditions, both in space and time.

Important field work

When we get to know more about these physical relationships, researchers can use these results to say something about how for example fish relate to these changes in the rivers. Using new technology, we can get better results and thus a better basis for decision making.

Sundt will also participate in field work studies to map where the fish are and what factors control them, to better understand the connection of physical factors and biology.

Supervisors: Professor Knut Alfredsen, NTNU and Senior Researcher Torbjørn Forseth, NINA.

Photo: Bibek Neupane

The delegation at Roskrepp dam: Bibek Neopane, Helene Dagsvik, Ola Haugen Havrevoll, Anna Helene Urdal, Livia Pitorac, Krishna Panthi, Anne Leroquais and Henki Ødegaard.

TUNING INTO ROSKREPP

HydroCen researchers were given full access when they visited Roskrepp power plant to make important measurements in the field.

Real life case studies and cooperation with the industry is essential in HydroCen. The researchers will be using Roskrepp power plant as a living laboratory to examine conversion of existing hydropower plants to pump power plants.
— We were given free reins at Roskrepp power plant, which is a unique opportunity. We were able to run the power plant in a way that was optimal for our measurements, says Kaspar Vereide who is a project developer at Sira-Kvina kraftselskap and part-time associate professor at NTNU.

If the plant is to be converted to pump power it needs to be able to withstand a completely different load on the system than today.

The researchers wanted to make thorough measurements of pressure increase and the power plant's behaviour during an emergency stop from full load.
— To illustrate the increase in pressure at an emergency stop at Roskrepp power plant, one can compare it to a 175,000 tonne train crashing. The forces are rather large, says supervisor Vereide.

Five PhD-students took part in the inspection: Two from the department of civil and environmental engineering, two from geoscience and petroleum and one from mechanical and industrial engineering. In addition there were two master's students, associate professor Krishna Panthi as well as two representatives of Sira-Kvina power company.

The plan is to use the measurements to build a numerical simulation model of the power plant. The numerical simulation model will be used to test conversion to a pump power plant.

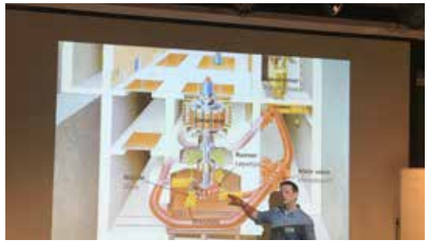
Mapping the geology

As the measurements in the power plant were made, the geology engineering students mapped the geology in the area.

— It is important to know whether the tunnels can withstand the increased load when power plants are upgraded. With this in mind we will be mapping the geology in the area so that we can assess the risk of a tunnel collaps, says Vereide.

HYDROCEN RESEARCH

REACHING ACROSS DICIPLINES



Professor Ole Gunnar Dahlhaug explains how the turbine works.

Researcher Torbjørn Forseth explains why fish migrate.

Many had an «aha-moment» when Linn-Emelie Schäffer showed how we can make tools for future production planning.

Even though they are experts on some things, the researchers in HydroCen don't know everything. Yet.

— Fish migrate.

— Oh.

— Just like we travel to work, to our holiday cabins, to family visits and so on, the fish also need to travel to do what they need to do in their everyday life.

— Huh?!

— Just like you go to Trondheim to get the nation's best education within hydro power, the salmon goes out to sea to fatten up and grow big. It is not so good to get killed by a turbine on the way there.

— Aha!!

The goal of HydroCen is to create innovation in the hydropower sector, and we strongly believe that interdisciplinary research is the way to go.

Therefore cooperation and knowledge-sharing is extremely important. One arena to do this in HydroCen is at the researcher seminars twice a year.

Here they can learn from each other and find areas for interdisciplinary development.

The basics of the power station

To explain something complicated in an easy way is a true art. During the first seminar in HydroCen professor Leif Lia used his skills to ensure that everyone has the building blocks to understand the basic works of the power station.

He effectively used pictures and drawings to guide the participants through the power station all the way from the attributes of the reservoir, over the over spillway, through the dam, under the intake, past the rough walls of the tunnels to the important sand trap. Then further through the pitch-dark surge chamber, down steep steel pipes to the massive turbine where you can figuratively tip your head back and look up into the heart of the power station – the generator.

From an outside point of view a power plant looks like it is one thing, but Lia demonstrated that a power plant is a combination of every detail one needs to produce electricity.

Communication for social acceptance

Why is it that the Mardøla- and Alta demonstrations still frequently come up in discussions about Norwegian hydropower, even decades after the conflicts?

Could it be because the hydro power industry has a communications problem? That question was put forward by senior researcher Audun Ruud. Ruud pointed out how important it is for researchers to talk to local interests and the hydropower industry early in the process, to avoid misunderstandings and poor cooperation.

Looking into the crystal ball

Hydro power supplies Norway with affordable and renewable electricity. But how will the energy market look like in the future?

The EU has vowed to drastically decrease use of nuclear, coal and gas and is demanding more green energy. In only a few years the Nordic and European power market will most likely look completely different.

Thomas Welte and Linn-Emilie Schäffer presented some of the methods many consider to be the most abstract topics of HydroCen.

Unlike the physical fieldwork in rivers and tunnels and the heavy steel models of in the Hydropower laboratory, the research done on markets takes place right at the office desk.

The goal is still clear: Develop highly advanced data models that will anticipate real-life situations of the future. This will enable power station managers to better prepare for changes in the power market, and researchers to consider different scenarios in their work to develop innovative equipment and ensure that the environmental impacts of hydro power are sustainable.

OPINIONS

FROM THE TECHNICAL COMMITTEES

Anne Marit Ruud

Vice President
Civil constructions,
Power Generation,
Statkraft

What are your thoughts on HydroCen's first year?

It is excellent that the research programme shares activities and events in many different channels. It is good to be able to keep track of what's going on throughout the programme and in each of the work packages.

What do you gain from participating in the technical committee?

We have good discussions about academic challenges and what priorities should be done in the work package «Hydropower constructions».

Going forward, what are your expectations for HydroCen?

To continue the good and close dialogue we have about priorities in the work package. Also, to be updated on the status of the different activities and receive good information about findings and results as they are delivered.

Lars Lone

Principal Engineer and Component Manager at Hydro Energy, responsible for the technical condition of all Hydro generators.

What are your thoughts on HydroCen's first year?

It has been interesting. It has been very good to follow what the different groups are doing in their research topics. Also, seeing how the centre evolves and realising what challenges and opportunities we have in the future.

What do you gain from participating in the technical committee?

We get a deeper insight into the things that actually concern us, things we are faced with every day in the power stations. I think that a lot of the topics being researched now will be part of our everyday life in the future.

Going forward, what are your expectations for HydroCen?

That we actually get something out of this, that we can profit from this and that it helps raise the value of Norwegian hydropower as a whole. Collaborating with researchers means that you get a much wider overview and get a larger perspective on what you are doing.

Kari Bråtveit

Dr.ing,
Supervision and Contingency Planning Department,
Division for Dam Safety,
The Norwegian Water Resources and Energy Directorate

What are your thoughts on HydroCen's first year?

I really like that there is a lot of focus on interdisciplinary work, and I agree that there is much to gain from it. There are many interesting topics to follow.

What do you gain from participating in the technical committee?

Specifically, we are working with work package 1, Hydropower Constructions, where we provide input on the research topics and tasks. It is useful that we can be involved in discussing what directions this research should take.

Going forward, what are your expectations for HydroCen?

We think this is very interesting and there are several branches of NVE that should have participated in the discussions in the the technical committee. It is a bit like looking into the crystal ball to predict what might happen. It is useful to get some ideas of what might lie ahead of us and what issues we will be concerned about in 10 to 15 years, for example.

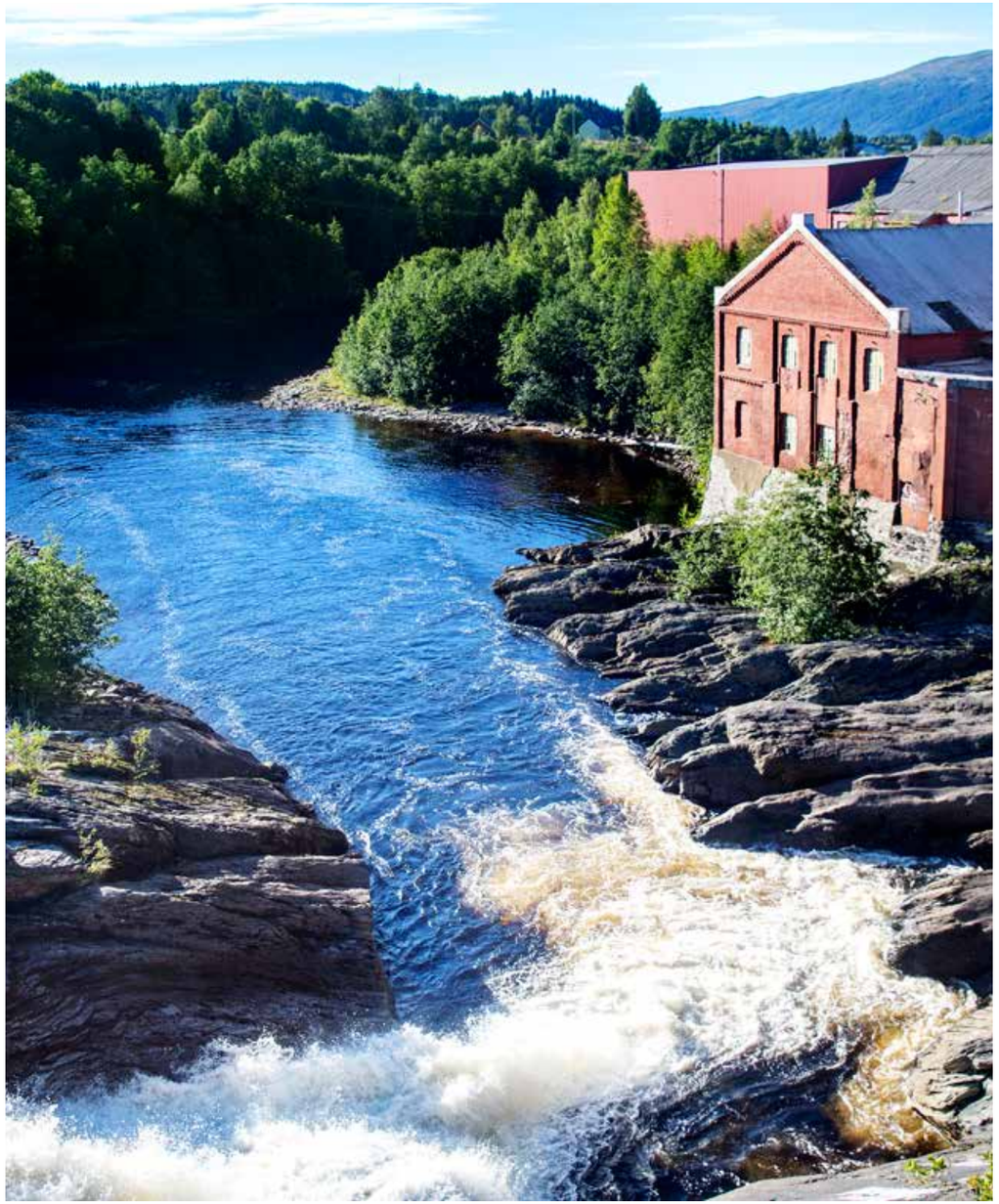


Photo: P.K. foto

WITH A HEART FOR HYDROPOWER

The last 7 years she's been Norway's most eager agent for hydropower, the past year she has embraced HydroCen and cultivated the love for hydropower research at every opportunity. Does Sigrid Hjørnegård really know what she is doing, leaving the business in favour of agriculture?

Photo: Energy Norway

— It's very strange and quite sad that my commitment for hydropower is over. I consider this to be the best of what the society and future needs, she says.

It was during her time as political adviser in the Ministry of Petroleum in 2008 that she first realized the value of Norwegian hydropower.

— My eyes opened to how unique and valuable our reservoirs are. When you combine that with such a competitive product and the truly unique flexibility of hydropower it is impossible not to love it, she says.

May 1st she will step down from her position as Director of Renewable Energy in Energy Norway and take up the tailor-made position of assistant Secretary General at the Norwegian Agrarian Association, where she will be in charge of climate-policy.

— Just like hydropower, I feel like agriculture is about managing nature for the utility and value creation for society. It must be green, it should create value and it should be useful, she says.

Even so, she is not light hearted about leaving hydropower at this point.
— Working with HydroCen has been one of the most important and interesting tasks in Energy Norway. I really believe that this will succeed, and I will continue to follow the development from an outside point of view, she says.

She is impressed with how the industry and researchers have come together in hydropower to create new value, technology and knowledge for the future.

— In many other arenas people complain that they aren't seen, or that people don't realize how important they are. But the hydropower industry took the matter into their own hands and invested in research and new knowledge. That is admirable, she says.

Her favourite picture, both literal and figurative, is the one with the digger in the river with the CEDREN researchers.

— Sometimes there are conflicts of interests between nature and power production, and I have respect for that. We should always weigh those against each other, but when we can find new methods too get around those conflicts it is wonderful. We, in the industry, already believe that producing green energy is good for both nature and climate, so when we can unite both it is really amazing – both for fish and power.

INTERNATIONAL INTEREST IN HYDROCEN

Increased energy needs and ambitions of developing fully renewable energy systems has caused several countries to look towards hydropower again. We see that the value of developing innovation and knowledge in this sector is internationally recognized.

In 2017 HydroCen has engaged in valuable cooperation with several international research communities.

Full lectures when professor Bjørn Nilsen was invited by Power China to speak at Zhoghnan Engineering Company and Central South University (CSU) in Changsha, China in November.

We continue the close cooperation with Kathmanu University that NTNU has built over the last decade

We have had fruitful meetings with IIT Rorkee in India and plan to cooperate on new research.

CANADA

EU

CHINA

NEPAL

INDIA

AUSTRALIA

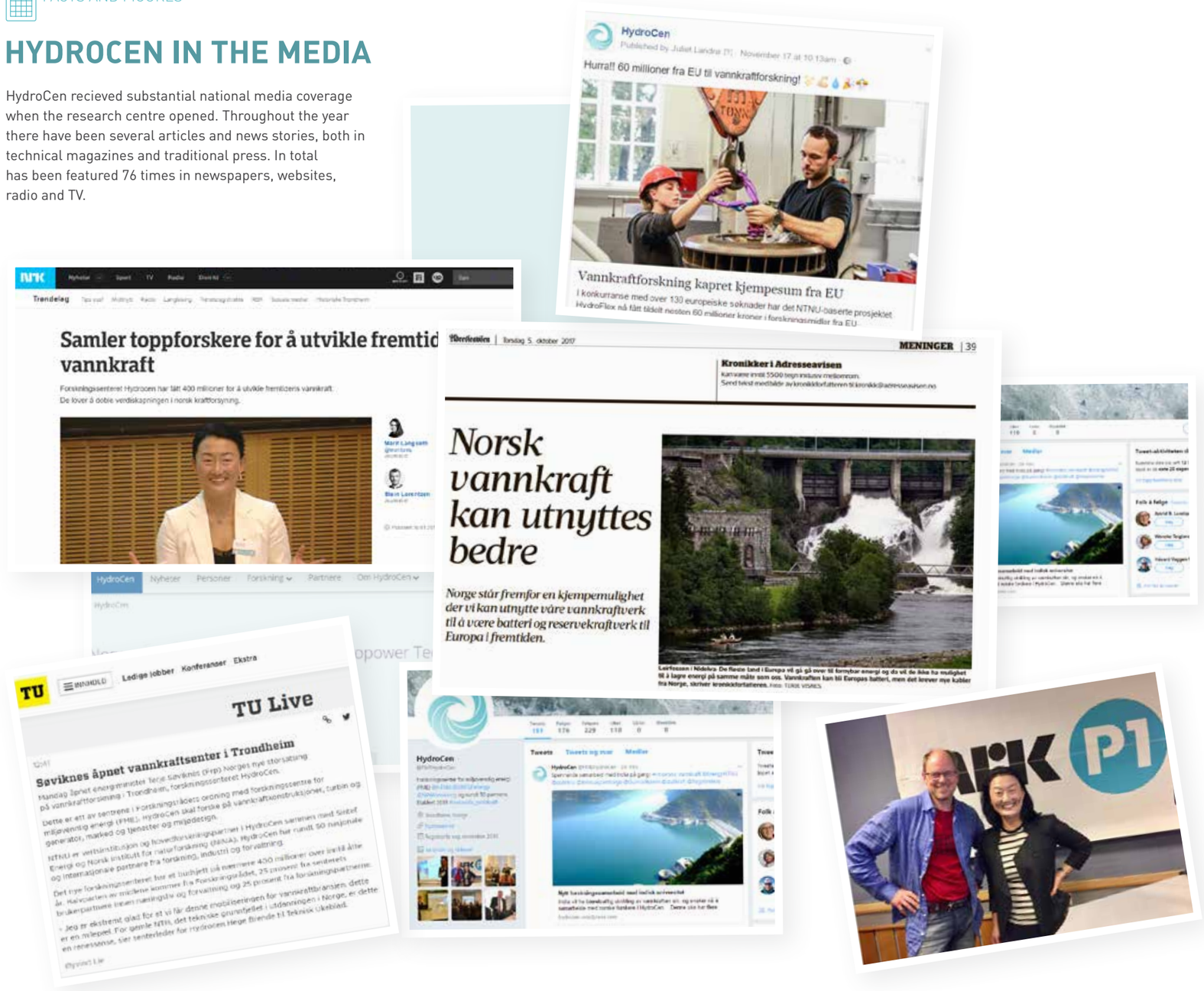
We have teamed up with some of the world most recognized fish biologists in the prestigious project HYCANOR —Partnership on Sustainable Hydropower in Canada and Norway, funded through INTPART.

EU plans to reduce greenhouse gas emissions by 80-95% by 2050, and that may mean new potential for hydropower. HydroCen lead a discussion titled «Recharging hydropower in Europe?» during the NTNU alumni conference in Bruxelles.

The Australian delegation that visited from IEA Hydro and Hydro Tasmania wished to learn more about the research on flexible operation as wish to become Australia's "green battery".

HYDROCEN IN THE MEDIA

HydroCen recieved substantial national media coverage when the research centre opened. Throughout the year there have been several articles and news stories, both in technical magazines and traditional press. In total has been featured 76 times in newspapers, websites, radio and TV.



OUR OUTLETS

Newsletter:
Public newsletter, 5 publications, 208 subscribers and an opening ratio of 40-60%

Blog:
44 blog posts with information and news from HydroCen in 2017, more than 3000 users and about 200 readers per post on www.hydrocen.blog

Vannposten:
Weekly newsletter for researchers and partners . 11 publications, and 90 recipients

Website:
Static information and contact details for all projects and researchers in HydroCen. Publications and innovations will also be accessible from www.hydrocen.no

SOCIAL MEDIA

8000

Twitter:
151 tweets, 8000 views per month, increasing number of followers

1400

Facebook:
Launched in November 2017, 200 followers by end of the year.
Average post reach is 1400

78 +

LinkedIn:
78 followers and increased activity

ORGANISATION

Administration and management of HydroCen

Name	Institution	Function
Hege Brende	NTNU	Executive Director
Astrid Bjerkås / Juliet Landrø	NINA	Head of Communications
Kari Haugan	NTNU	Centre coordinator
Merete Fiveltun	NTNU	Economy

Board

Name	Institution	Function
Ivar Arne Børset	Statkraft	Chairman of Board
Norunn Myklebust	NINA	Board member
Knut Samdal	Sintef Energi	Board member
Sigrid Hjørnegård	Energi Norge	Board member
Rune Flatby	NVE	Board member
Dagfinn Vatne	SKL	Board member
Alf-Inge Berget	E-CO	Board member
Erling Ildstad	NTNU	Board member
Hege Brende	NTNU	Executive Director / Board secretary
Kari Haugan	NTNU	Referee
Harald Rikheim	Forskningsrådet	Observer
Astrid Bjerkås / 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

Name	Institution	Function
Hege Brende	NTNU	Executive Director
Ole Gunnar Dahlhaug	NTNU	Member
Ingeborg Helland	NINA	Member
Michael Belsnes	SINTEF Energi	Member
Hans Erik Horn	Energi Norge	Member
Kari Haugan	NTNU	Referee
Astrid Bjerkås/ Juliet Landrø	NTNU	Head of Communications
Merete Fiveltun	NTNU	Economy

Researchers

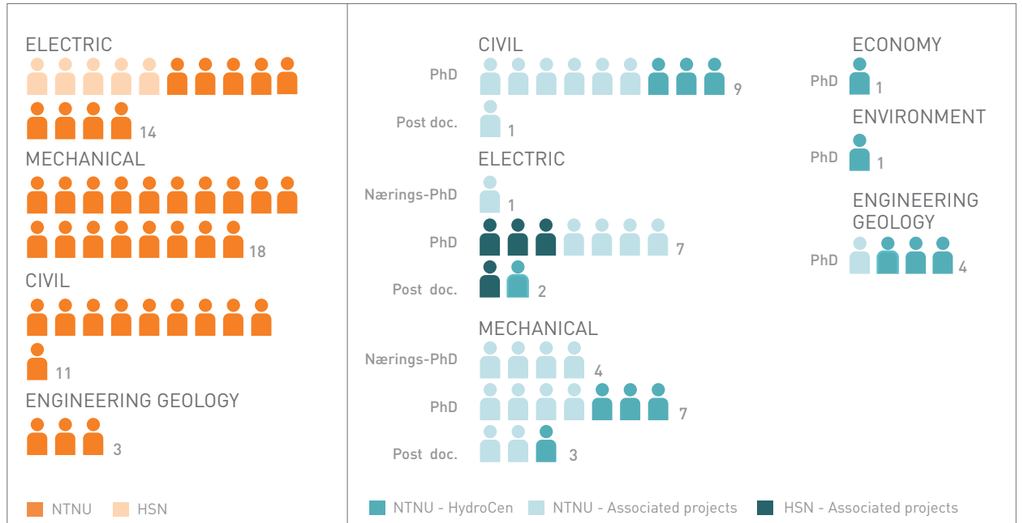
Name	Institution	Main research area
Aberle, Jochen	NTNU	Hydropower structures
Alfredsen, Knut	NTNU	Environmental design
Engevik, Erlend L	NTNU	Turbine and generators
Fleten, Stein-Erik	NTNU	Market and services
Korpås, Magnus	NTNU	Market and services
Nielsen, Torbjørn	NTNU	Turbine and generators
Nilsen, Bjørn	NTNU	Hydropower structures
Nilsen, Roy	NTNU	Turbine and generators
Olsen, Nils Reidar Bøe	NTNU	Hydropower structures
Olsson, Roger	NGI / NTNU	Hydropower structures
Panthi, Krishna	NTNU	Hydropower structures
Rüther, Nils	NTNU	Hydropower structures
Sigtryggsdottir, Fjola G.	NTNU	Hydropower structures
Storli, Pål-Tore	NTNU	Turbine and generators
Uhlen, Kjetil	NTNU	Turbine and generators
Valavi, Mostafa	NTNU	Turbine and generators
Bakken, Tor Haakon	SINTEF Energi	Market and services
Charmasson, Julie	SINTEF Energi	Environmental design
Eggen, Arnt Ove	SINTEF Energi	Market and services
Fjeldstad, Hans Petter	SINTEF Energi	Environmental design
Harby, Atle	SINTEF Energi	Environmental design
Helseth, Arild	SINTEF Energi	Market and services
Hvidsten, Sverre	SINTEF Energi	Market and services
Mo, Olve	SINTEF Energi	Market and services
Naversen, Christian	SINTEF Energi	Market and services
Schäffer, Linn Emelie	SINTEF Energi	Market and services
Solvang, Eivind	SINTEF Energi / NTNU	Turbine and generators
Welte, Thomas Michael	SINTEF Energi	Turbine and generators
Foldvik, Anders	NINA	Environmental design
Köhler, Berit	NINA	Environmental design
Ruud, Audun	NINA	Environmental design
Skår, Margrete	NINA	Environmental design
Sundt-Hansen, Line	NINA	Environmental design
Teixeira da Silva, Ana	NINA	Environmental design
Uglem, Ingebrigt	NINA	Environmental design
Lie, Bernt	HSN	Turbine and generators
Hegglid, Gunne	Skagerak Energi/HSN	Turbine and generators

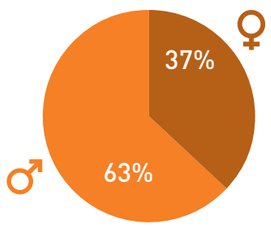
MASTER STUDENTS

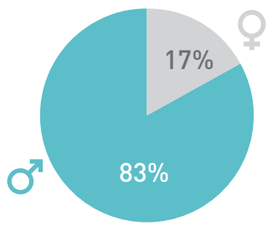
In 2017 we had a total of 46 master students at NTNU and University College of Southeast Norway (HSN) within the field of hydropower. The distribution between the disciplines civil, mechanical, electrical and engineering geology is shown in the figure below.

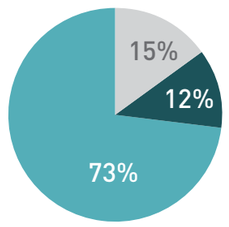
PHD AND POST DOCS.

In 2017 a total of 40 PhDs and Post Docs. where working within the civil, mechanical, electric, economy, environment and engineering geology









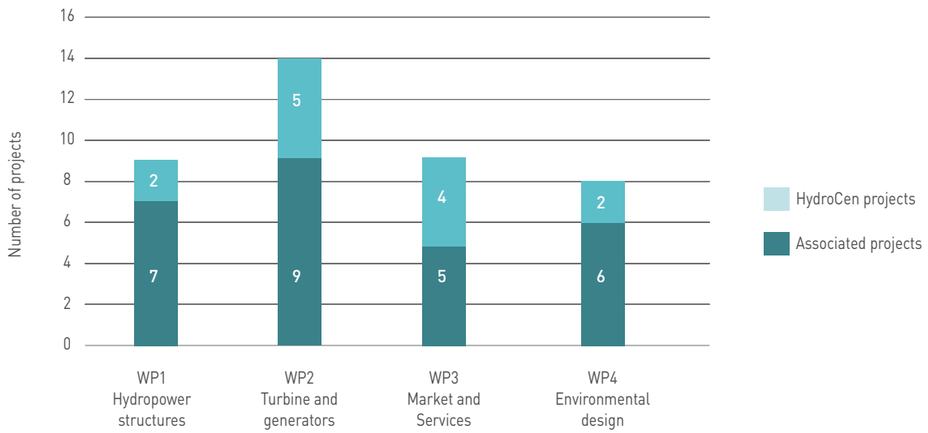
PhD and Post doc. in HydroCen, employed in 2017

Name	PhD Post doc.	Nationality	Period	Gender	Topic
Andreas Kleiven	PhD	Norwegian	2017-2021	M	Investment Decisions in Upgrading and Refurbishment of Hydropower Plants
Bibek Neopane	PhD	Nepalese	2017-2021	M	Long-term impact on unlined tunnels of hydropower projects due to frequent start stop sequences
Celine Faudot	Post doc.	French	2017-2019	F	Fatigue Loads on Turbines attached to a Conduit System
Ganesh Hiriyanna Rao Ravindra	PhD	Indian	2017-2020	M	Embankment dam safety under extreme loading conditions
Helene Njølstad Dagsvik	PhD	Norwegian	2017-2020	F	Reversible Pump-Turbines in Existing Power Plants
Henki Ødegaard	PhD	Norwegian	2017-2021	M	Rock stress and pressure tunnel design
Håkon Sundt	PhD	Norwegian	2017-2020	M	Environmental design for multiple interests under future flexible hydropower operation
Igor Iliev	PhD	Mecedonian	2016-2019	M	Design of a high-head Francis turbine for variable speed configurations
Kristian Forfot Sagmo	PhD	Norwegian	2017-2020	M	Flow manipulation for improved operation of hydraulic turbines
Lena Selen	PhD	Norwegian	2017-2021	F	Effects of swelling rock and swelling clay in water tunnels
Livia Pitorac	PhD	Romanian	2017-2020	F	Upgrade of hydropower plant capacity influences the behavior of hydraulic transients in waterways and surge tanks
Ola Haugen Havrevoll	PhD	Norwegian	2017-2021	M	Rock traps in pumped storage and peaking power plants

PhD og Post doc. seminar in HydroCen.

PROJECTS OVERVIEW 2017

A total of 40 projects related to hydropower were ongoing in 2017. 13 of these are new projects within HydroCen, and 27 are associated projects within hydropower where HydroCen' s research partners are involved.



HydroCen Projects			
Project name	Project leader	Field of study	Project owner
1.1 Tunnels, penstocks and surge chambers	Bjørn Nilsen	Hydropower structures	NTNU
1.2 Dam construction and dam saftey	Fjola G. Sigtryggsdottir	Hydropower structures	NTNU
2.1 Variable speed operation	Arne Nysveen	Turbine and generators	NTNU
2.2 Fatigue loads on turbines	Torbjørn Nielsen	Turbine and generators	NTNU
2.3 Pumpe turbines in existing power plants	Pål-Tore Storli	Turbine and generators	NTNU
2.4 Turbine and generator lifetime	Thomas Welte	Turbine and generators	SINTEF Energi
2.6 Design of guide vanes	Pål-Tore Storli	Turbine and generators	NTNU
3.1 Future market structures and prices	Birger Mo	Market and services	SINTEF Energi
3.2 Remaining useful life, failure probability	Arnt Ove Eggen	Market and services	SINTEF Energi
3.3 Optimal hydro design in the future power system	Birger Mo	Market and services	SINTEF Energi
3.5 Water resources assessment	Tor Haakon Bakken	Market and services	SINTEF Energi
4.1 Governance and social acceptance	Audun Ruud	Environmental design	NINA
4.3 Multiple interests under future flexible hydropower operation	Atle Harby	Environmental design	NINA

This overview shows the ongoing projects that has relevance for the research in HydroCen, 27 associated projects in 2017.

Associated Projects					
Project name	Connection HydroCen	Project leader	Field of study	Type	Project owner
Fleksible Sandfang (FlekS)	1.1, 1.3	Kaspar Vereide	Hydropower Structures	Industry	Sira Kvina Kraftselskap
TunnelRoughness	1.1	Jochen Aberle	Hydropower structures	KPN	NTNU (NVKS)
FlomQ	1.2	Nils Rüther	Hydropower structures	IPN	Energi Norge
PlaF (I-II)	1.2	Leif Lia	Hydropower structures	Industry	Energi Norge
Skred i magasin	1.2	Leif Lia	Hydropower structures	Industry	NVE/NTNU
Stable Dams	1.2	Bård Arntsen	Hydropower structures	KPN	Norut
SediPASS	1.3	Nils Rüther	Hydropower structures	KPN	NTNU (NVKS)
HiFrancis KPN	1.3, 2.1, 2.2, 2.4, 2.5	Ole Gunnar Dahlhaug	Turbine and generators	KPN	NTNU (NVKS)
HiFrancis FSI Toolkit	2.1, 2.2, 2.5	Martin Holst	Turbine and generators	IPN	EDR Medeso
Francis-99	2	Chirac Trivedi	Turbine and generators	Internal	NTNU
HydroFLEX	2, 3, 4	Ole Gunnar Dahlhaug	Turbine and generators	EU H2020	NTNU
Levetidsberegning for Francis	2.1, 2.4, 2.5	Petter Østby	Turbine and generators	IPN	Rainpower
Reversible pumpeturbiner	2.3	Torbjørn K. Nielsen	Turbine and generators	PhD	NTNU (NVKS)
HydroStator	2.1, 2.4, 2.5	Arne Nysveen	Turbine and generators	KPN	NTNU (NVKS)
MonitorX	2.1, 2.4, 2.5, 3.2	Thomas Welte	Turbine and generators	IPN	Energi Norge
EnergizeNepal	1.3, 2	Nawaraj Sanjel	Turbine and generators	MFA	Kathmandu University
PRIBAS	3	Arild Helseth	Market and services	KPN	SINTEF Energi
IBM	3.1, 3.3, 3.4	Arild Helseth	Market and services	KPN	SINTEF Energi
MultiSHARM	3.4	Marte Fodstad	Market and services	KPN	SINTEF Energi
e-Highway2050	3.1	SINTEF Energi	Market and services	FP7	Consortium
HydroBalance	3	Michael Belsnes	Market and services	KPN	SINTEF Energi
Miljødesign Mandalselva	4	Torbjørn Forseth	Environmental design	Skattefunn/Industry	NINA
FIThydro	1.3, 4.1.1, 4.3	Peter Rutschmann	Environmental design	EU H2020	Coordinator Technical University of Munich, Germany
SusWater	3.5, 4.1.1, 4.3	Atle Harby	Environmental design	KPN	SINTEF Energi
HYCANOR	4.2, 4.3	Ingeborg Palm Helland	Environmental design	INTPART	NINA
SafePASS	1.3, 4.2, 4.3	Torbjørn Forseth	Interdisciplinary	KPN	NINA
Elvemuslingens miljøkrav	4.3	Bjørn M. Larsen	Environmental design	Government	NINA

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Demand response with shiftable volume in an equilibrium model of the power system. I: 12th IEEE Power and Energy Society PowerTech Conferende PowerTech Manchester 2017. IEEE Press 2017 ISBN 978-1-5090-4238-8.ENERGISINT
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Topographic Effect in the Selection of Unlined Pressure Tunnels / Shafts - A Review of a case from Nepal Himalaya. World Tunnel Congress 2017; 2017-06-09 - 2017-06-15
NTNU

Basnet, Chhatra Bahadur; Panthi, Krishna Kanta.
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NTNU

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NTNU

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Numerical investigation of the flow phenomena around a low specific speed Francis turbine's guide vane cascade. IOP Conference Series: Earth and Environment 2016 ;Volum 49. s. -
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Influence of winding layout and airgap length on radial forces in large synchronous hydrogenerators. I: 2017 20th International Conference on Electrical Machines and Systems (ICEMS). IEEE conference proceedings 2017 ISBN 978-1-5386-3246-8.
NTNU

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Transient pressure measurements at part load operating condition of a high head model Francis turbine. Sadhana (Bangalore) 2016 ;Volum 41.(11) s. -
NTNU

Nysveen, Arne; Dahlhaug, Ole Gunnar.
Bruk av variabelt turtall i norske kraftverk. Elektrisk utrustning og nettintegrasjon Turbinteknologi. Produksjonsteknisk konferanse (PTK 2017); 2017-03-06 - 2017-03-08
NTNU

Panthi, Krishna Kanta.
Review on the prevailing methods for the prediction of potential rock burst / rock spalling in tunnels. I: Fjellsprengningsdagen, Bergmekanikkdagen, Geoteknikkdagen. Oslo: Norsk Forening for Fjellsprengningsteknikk, Norsk Bergmekanikkgruppe og Norsk Geoteknisk Forening 2017 ISBN 978-82-8208-059-0. s. 29.1-29.8
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NTNU

Rathore, Ajender; Panthi, Krishna Kanta.
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NTNU

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NTNU

Biraj Singh Thapa, Ole Gunnar Dahlhaug, Bhola Thapa.
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NTNU

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Efficiency and loss calculations in design of converter-fed synchronous hydrogenerators. ICEM, Lusanne, Sveits. September 2016.
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NTNU

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NTNU

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NTNU

Wolfgang Richter, Kaspar Vereide, Gerald Zenz.
Upgrading of a Norwegian pressurized sand trap combined with an open air surge tank. Geomechanics and Tunneling. October 2017.

FINANCIAL STATEMENT HYDROCEN 2017

The total turnover in 2017 amounted to 29 306 000 NOK, including in-kind from industry and R&D-partners. Of this, the cash flow amounted to 18 904 000 NOK.

In total, HydroCen achieved 76% of its originally planned budget.

The budget achievements between the three major research partners were distributed like this:

NTNU 96%
SINTEF Energy 59%
NINA 70%

Funding	Funding	In-kind	Total
The Research Council of Norway	9 804		9 804
Industry partners	9 100	4 016	13 116
Research partners; NTNU, SINTEF Energi and NINA		6 386	6 386
Totalt	18 904	10 402	29 306
Costs	Funding by the project	In-kind	Total
Sintef Energi	6 136	2 209	8 345
NINA	2 862	1 174	4 036
NTNU	9 906	3 003	12 909
Industry partners in-kind		4 016	4 016
Total costs 2017	18 904	10 402	29 306

TECHNICAL COMMITTEES 2017

WP 1 Hydropower stuctures	WP2 Turbine and generator	WP3 Market and services	WP4 Environmental design
Leif Lia, NTNU (leader)	Arne Nysveen, NTNU (leader)	Birger Mo, SINTEF Energi (leader)	Torbjørn Forseth, NINA (leader)
Anne Marit Håstein Ruud, Statkraft	Aleksander Lundseng, Voith Hydro	Andreas Sylte, Statkraft	Bjørn Høgaas, NTE
Eve C. Walseth, Energi Norge	Arne Småbrekke, BKK	Atle Frøland, Tafjord	Bjørn Otto Dønnum, E-CO Energi
Grethe Holm Midttømme, NVE	Birgit Longva, NVE	Bjørn Austrud, Agder Energi	Eilif Brodtkorb, NVE
Hanne Nøvik, Multiconsult	Bjarne Børresen, Multiconsult	Christian Oshaug, NTE	Eirik Bjørkhaug, NVE
Helge Martinsen, Glitre Energi Produksjon	Eivind Kjerpeset, SKL	Eirik Veirød Øyslebø, NVE	Erling Otterlei, SKL
Kaspar Vereide, Sira-Kvina kraftselskap	Erik Pedersen Ulvenes, SKL	Frode Vassenden, TrønderEnergi Kraft	Geir Taugbøl, Energi Norge
Magne Skog, Agder Energi Vannkraft	Geir Peder Brænd, SWECO	Hans Ole Riddervold, Hydro Energi	Ingvill Stenseth, BKK
Magne Wraa, Skagerak Energi	Gunne John Hegglid, Skagerak Energi	Jakop Bjelland, SKL	Jo Halvard Halleraker, Miljødirektoratet
Morten Skoglund, NVE	Harald-Knut Kvandal, Skagerak Energi	Kjell Johnny Kvamme, Sunnfjord Energi	Mari Roald Bern, Statkraft
Oddmund Brevik, E-CO Energi	Henning Lysaker, Rainpower	Magnus Landstad, Lyse Produksjon	Morten Kraabøl, Multiconsult
Per Vidar Halsnes, BKK	Inge Lines, Agder Energi Vannkraft	Sven Per Lønne, Glitre Energi Produksjon	Nils Henrik Johnson, TrønderEnergi Kraft
Ragnhild Hoel, Tafjord	Ingunn Granstrøm, Skagerak Energi	Tarald Espeland, BKK	Per Ivar Bergan, SWECO
Siri Stokseth, Statkraft	Iren Aanonsen, Energi Norge	Vidar Hansen, E-CO Energi	Per Øyvind Grimsby, Sira-Kvina
Tore Okkenhaug, SKS	Jan Petter Haugli, Statkraft		Roy M. Langåker, Miljødirektorartet
Øystein Huuse-Røneid, SWECO	Kjell-Tore Fjærvold, Statkraft		Runar Myhrer Rueslåtten, Eidsiva Energi
	Lars Lone, Hydro Energi		Stein Øvstebø, Hydro Energi
	Linda Haugvaldstad, Lyse		Svein Haugland, Agder Energi Vannkraft
	Line Drange Ruud, Glitre Energi Produksjon		Tone Knudsen, Statkraft
	Magnus Glomnes, SWECO		Trond Erik Børresen, Lyse Produksjon
	Martin Aasved Holst, EDR Medeso		Trygve Øderud, Glitre Energi Produksjon
	Morten Bjerke, Votih Hydro		
	Peder Golberg, E-CO Energi		
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PARTNER OVERVIEW

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