





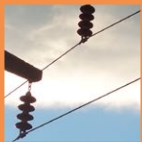
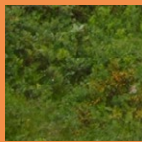

ANNUAL REPORT

2014

CEDREN Centre for Environmental Design of Renewable Energy

FME CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

CEDREN – Centre for Environmental Design of Renewable Energy: Research for technical and environmental development of hydro power, wind power, power line rights-of-way and implementation of environment and energy policy.

SINTEF Energy Research, the Norwegian Institute for Nature Research (NINA) and the Norwegian University of Science and Technology (NTNU) are the main research partners. A number of energy companies, Norwegian and international R&D institutes and universities are partners in the project.

The centre, which is funded by The Research Council of Norway and energy companies, is one of eleven of the scheme Centre for Environment-friendly Energy Research (FME). The FME scheme consists of time-limited research centres which conduct concentrated, focused and long-term research of high international quality in order to solve specific challenges in the field of renewable energy and the environment.

Report of the **Board**

This has been our sixth year of operation, which means that we are entering the final stage of this eight-year regime as an FME in its current form.

The Board has been focusing on the idea that in this final phase we need, even more than before, to emphasise communication and implementation of the valuable results that are gradually taking shape. This is the background for the decision of the Board to slightly modify the organisation of the Centre, focusing to a greater extent on providing resources for communication and implementation.

On several occasions, the Board has discussed the dropping level of project funding as we approach the end of the programme and more and more projects are coming to an end. We are therefore pleased to note that the Centre's management group has succeeded in gaining approval for adding a number of new projects to its portfolio. These will continue past 2014, and will help to maintain the influx of resources at a relatively high level.

The Board and management also dedicated some time to organise a strategic workshop in the autumn of 2014. After a thorough evaluation of the remaining two years, we defined and prioritise tasks and efforts.

Key topics at the workshop were:

- Implementation of knowledge and results (gained)
- Setting the agenda through good communication and dissemination of results
- Points of view regarding a new FME.

The Research Council of Norway has started a process for inviting applications for new FMEs once the current ones have been phased out. In the light of this, the Board has regarded it as a natural step to challenge itself and the Centre's management team over the question of whether there should be a successor to CEDREN, and if so, what it should look like. Given the climate change challenges whose contours we are perceiving at both national and international level, with for example more extreme weather events such as floods, the Board is convinced that environmental design of renewable energy will not become an outdated topic in the near future – rather quite the opposite!

It is in this context that CEDREN has its justification as an important and useful interface for resolving conflicts of interest between technology, nature and society. A new FME with a similar point of departure could well be viable.

Finally, the Board wishes to express its gratitude to everyone involved in the Centre during the past year; a great deal of good work has been done, and we look forward to continuing our excellent collaboration through the final phase of CEDREN!

On behalf of the Board of CEDREN

Jan Alne
Chair

The CEDREN Board having a workshop on important tasks for the final two years of CEDREN. Photo: Anne Olga Syverhuset

The **CEDREN Board** has nine members and one observer from the Research Council (Erland Eggen). The industry partners elect four representatives among themselves for two years. Jan Alne (Statkraft), Sigve Næss (BKK), Øyvind Stakkeland (Agder) and Geir Taugbøl (EnergiNorge) are representing the industry. The Directorate for Water and Energy has appointed Torodd Jensen to the Board. The Environment Agency has appointed Reidar Dahl to the Board. The research and university partners have appointed Petter Støa (SINTEF Energi), Signe Nybø (NINA) and Geir Walsø (NTNU) to the Board.

CEDREN in **2014**

The main objective of CEDREN is to develop and communicate design solutions for renewable energy production that address environmental and societal challenges at local, regional, national and global levels. The research is focused on hydro and wind power production and power transmission systems. CEDREN is an interdisciplinary research centre, building integrated knowledge from the technical, environmental and social sciences into better policies and solutions.

One of the main tasks in many activities and projects in CEDREN is to finance PhDs and Master's students, and engage and include them in our research teams. In 2014, 7 PhDs and 11 master students obtained their degree, and several of them have already been recruited to work in the field of renewable energy bringing the most updated knowledge to their employer.

Climate change, resulting in more severe floods and droughts, in addition to an increased demand for food and the urgent need to give more people access to clean water, lead to increased water stress and will require more storage of water. As unregulated renewable energy is taking over more and more of the electricity production, reservoirs are becoming more important. CEDREN is now focusing more on reservoirs, and we have co-organised two seminars discussing reservoirs. At the World Water Week in Stockholm, the focus was on the water-energy nexus, and in Addis Abeba in Ethiopia, the key role of reservoirs for sustainable development was discussed. A joint CEDREN-CenSes seminar on energy storage also included a focus on reservoirs.

20 years ago the main research partners of CEDREN took the initiative to organise the first international conference on Ecohydraulics. The tenth edition returned home to Trondheim in June, attracting 300 participants from all over the world, presenting their research results from the topics of river system ecology, biology, hydrology and hydraulics. The delegates charcterised the conference as very successful, and many CEDREN scientists and students demonstrated why Norway is in the forefront of ecohydraulics.

Several pilot studies in CEDREN were used as a basis to develop new project proposals for the EnergiX call in the Research Council of Norway in 2014. Two projects were given funding: SafePass, which is dealing with safe two-way migration of fish past power plants and other barriers, and SusWater, which focus on both regulatory and natural science aspects related to the Water Framework Directive.

CEDREN has a strong focus on dissemination of results and findings. In 2014, we have seen a boost in articles produced for cedren.no, and increased activity on Twitter and Facebook. Partners and those who sign up, are now receiving newsletters electronically, and CEDREN scientists and students engage in many fora to spread and exchange knowledge both nationally and internationally.

CEDREN has a strong international focus as it is important to work together and discuss environmental design of hydropower and renewables with scientists and authorities abroad. CEDREN has also increased the number of exchange scientists and students in 2014, giving both young and established scientists the opportunity to work closer together.

The Chinese delegation participating in CEDREN's project FutureHydro (see CEDREN Abroad page 24) were among the participants on the Ecohydraulics excursion to the River Nea. Photo: Ånund Killingtveit

The implementation of results from CEDREN will remain one of the main tasks for the coming two years – a task we hope our user partners from industry and management will engage in – putting into effect improved methods and knowledge to ensure that renewable energy is respecting the nature.

Atle Harby
CEDREN Director

CEDREN **portfolio** 2014

The CEDREN research portfolio consists of eleven main projects. The projects encompass hydro power, wind power, power transmission and governance – with research comprising technology, biology and social sciences.

The BirdWind and EnviDORR projects were started in 2007, and were included in the CEDREN portfolio in 2009 when the centre was established. BirdWind was concluded in 2012, GOVREP was concluded in 2013, and OPTIPOL was concluded in 2014. SusGrid, EcoManage, FutureHydro, HydroBalance, and Tools have been included after the centre was established. Two new projects will start in 2015 (see pages 26-27).

		Duration	Finances	Project manager
BirdWind	Bird friendly localization and design of new onshore wind power plants. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway.	2007-2012	23 mill NOK	Kjetil Bevanger
EnviDORR	Increased power and salmon production. Environmentally designed operation of regulated rivers.	2007-2015	25 mill NOK	Torbjørn Forseth
EnviPEAK	Effects of rapid and frequent flow changes in regulated rivers. Studies on environmental impacts of hydropeaking and guidelines for mitigation measures.	2009-2015	38,3 mill NOK	Tor Haakon Bakken
HydroPEAK	Future hydropower design. Studies on hydropower development for peaking and load balancing.	2009-2015	37 mill NOK	Ånund Killingtveit
GOVREP	How to combine environmental and energy policy concerns. Governance for renewable electricity production	2009-2013	15,6 mill NOK	Audun Ruud
OPTIPOL	Optimal design and routing of power lines. In ecological, technical and economic perspectives.	2009-2014	19,4 mill NOK	Kjetil Bevanger
SusGrid	Sustainable Grid Development. Improving planning tools, and governance procedures facilitating public acceptance and consensual realization of grid projects.	2011-2015	17,5 mill NOK	Audun Ruud
EcoManage	Improved development and management of energy and water resources. Perspectives on energy payback ratio; water consumption in hydro power plants; and ecosystem services in regulated rivers.	2012-2016	13,5 mill NOK	Håkon Sundt
FutureHydro	Sustainable hydropower development in China and Norway to meet future demands	2012-2015	5,6 mill NOK	Atle Harby
HydroBalance	Large-scale balancing and energy storage from Norwegian hydropower	2013-2017	24,9 mill NOK	Michael Belsnes
Tools	Tools to improve efficiency of multi-model analyses and environment-friendly design of flexible hydropower.	2014-2016	5,0 mill NOK	Knut Alfredsen

Photo: Håkon Sundt

Green, yellow or red light for **hydropeaking**?

Grading rivers according to traffic-light rating: CEDREN scientists have developed a method of evaluating the impacts of hydropeaking on fish in downstream rivers.

With the growing use of intermittent renewable energy sources, such as solar and wind power, we can expect that hydropower reservoirs will play an increasingly important role in balancing generation and load. However, hydropeaking and more flexible operation of hydropower plants aimed at meeting short-term changes in demand, can lead to rapid and frequent changes in water level in downstream rivers.

The CEDREN EnviPEAK project has been studying the environmental impacts of hydropeaking on rivers, and has developed a method for determining the ecological effects in downstream rivers and evaluating the peaking regime.

Traffic-light rating system ■ The method is developed to support river management authorities and hydropower operators with a tool that can be used to evaluate effects of hydropeaking in rivers. The method categorises rivers in terms of a traffic-light rating:

- Red light: Major additional impact; hydropeaking is not recommended.
- Yellow light: Moderate additional impact; hydropeaking is acceptable provided that mitigation measures are adopted.
- Green light: Minor additional impact; hydropeaking is acceptable provided that basic operational restrictions are considered.

An evaluation of the impacts of hydropeaking as well as how vulnerable a river system is to frequent changes in flow and water level, is taken into account in determining what colour the traffic-light will show for a given hydropower operation

Assessment of vulnerability based on the handbook for environmental design ■ A series of indicators that focus on salmonids are used to assess the vulnerability of a given river reach including the average number of female fish and the total area and distribution of spawning grounds.

"The evaluation is based on the methodology used in CEDREN's 'Handbook for Environmental Design in Regulated Salmon Rivers'," says Julian Sauterleute, one of the CEDREN scientists who have developed the method.

The evaluation also takes into account the effects of river regulation and other impacts than hydropeaking itself. These include acidification, pollution, diseases and parasites, because these too are important determinants of the vulnerability of the river.

In order to assess the impact of hydropeaking, we must grade the rate of change in water level, the extent of the dewatered area, the magnitude of flow changes and when and how

Photo: Julian Sauterleute

often the changes occur. This permits an overall assessment of the effects on a river or a river reach.

Brings together knowledge from EnviPEAK ■ The research team has defined threshold values that allocate the indicators of sensitivity and impact to particular categories, which are finally added to obtain an overall value. This value determines whether a given stretch of river will be given a red, yellow or green light for hydropeaking.

The selected indicators and the threshold values are based on results obtained by EnviPEAK, the scientific literature and expert evaluations.

"The method brings together much knowledge that we have obtained via EnviPEAK," says Sauterleute.

The project is currently in its final phase, and now requires only minor modifications to the method. In 2015, we will publish a popular summary of the EnviPEAK, which will include a description of the classification method for hydropeaking.

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A travelling **riverbed**

On an exchange visit to Brunswick, Stephan Spiller had a good idea. The result was a much-travelled riverbed that has helped us to better understand the physical effects of hydropeaking in rivers.

Because of fewer natural flooding events in regulated rivers, the surface layer of the riverbed becomes harder and more compact. This in turn leaves less shelter for fish, also making it more difficult for them to find food and for fish to break up the surface layer in order to be able to spawn. The question is how hydropeaking affects this process. How rapidly, and by how much can we raise and lower the water level before the surface layer is affected? Could hydropeaking trigger regular breakups of the surface layer?

Stephan Spiller, who gained his PhD in 2014, contributed to the knowledge on the physical effects of hydropeaking in rivers through his inventive work in CEDREN's HydroPEAK project.

The start of a long journey ■ At the beginning of his doctoral studies, Spiller spent two months in Brunswick as an apprentice at the Leichweiß Institute for Hydraulic Engineering and Water Resources, which is well known for its expertise in performing laboratory experiments on riverbeds. While he was there, Spiller had an idea. "I couldn't take a real riverbed from Germany to Norway, so instead I made a plastic copy of an actual gravel bed in a flume in the Brunswick laboratory, which is similar to a flume that we have here in Trondheim," he says.

Spiller brought the copy back to Trondheim in order to do more experiments. Having a riverbed that can be carried around opened up a number of possibilities for doing other types of experiments than those that could be carried out in Trondheim, and Spiller and his riverbed were soon going on exchanges to the far side of the world. You can follow the route of the riverbed on the following page.

Besides being transportable, an artificial riverbed has the great advantage that the stones that make it up do not move, which means that the state of the bed will be the same in experiment number one as in number 200.

The results of the experiments show that an almost unrealistic level of hydropeaking is needed to break up the surface layer, and that hydropeaking does not seem to either improve or worsen it. At the same time, the experiments provided the first opportunity to visualise specific patterns of flow and forces across the riverbed that had previously only been described in theoretical terms.

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The riverbed on its travels:

Brunswick, Germany
The idea of creating an artificial riverbed arose when Stephan Spiller spent two months as an apprentice at the Leichweiß Institute for Hydraulic Engineering and Water Resources.

NTNU: Department of Marine Technology, Norway
Using a laser-based measurement technology known as Particle Image Velocimetry (PIV), Spiller measured flow speed and turbulence under a range of hydropeaking schemes. One of the major articles that he wrote for his PhD was based on this.

Auckland, New Zealand
Spiller brought his riverbed on an exchange visit to The University of Auckland. In order to study what happens with the forces that affect the riverbed during hydropeaking, he loosened a piece of the riverbed and attached a sensor to it, before running more than 200 hydropeaking experiments.

NTNU: Department of Water and Environmental Engineering, Norway
Back in Trondheim, Spiller's supervisor Nils Rüther and an MSc student measured the surface of the riverbed using a laser. They performed computational flow modelling in order to compare them with the Trondheim laboratory results.

Munich, Germany
Scientists from the Technical University of Munich took a section of riverbed home to Germany after participating in a workshop organised by CEDREN, and are currently developing a 3D model of the bed.

Close up of the artificial riverbed. Photo: Stephan Spiller

Focus on **reservoirs**

The need to store water will increase with population growth, climate change and the growing use of solar and wind power. CEDREN has recently strengthened its focus on reservoirs, studying various topics from better use of reservoirs for large-scale energy storage to how reservoirs affect greenhouse gas emissions, among other topics. Here are more examples of our research on reservoirs.

The water footprint of hydropower

CEDREN is focusing on how reservoirs and electricity generation affect the availability of water in areas with water shortage. This is of great importance for the activities of Norwegian hydropower investors and operators abroad.

In the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, a number of renewable technologies were compared in terms of how much water that is required to generate 1 MWh. The values for hydropower ranged from 0.3 m^3/MWh to more than 200 m^3/MWh. The highest values are much higher than for the other renewable energy technologies, and were due to evaporation from the reservoirs. This came as a surprise to many people, and was the background for Tor Haakon Bakken's ongoing PhD project. He carried out a wider-ranging comparison of more sources of data, and has published an article that criticises the methodology of the original study.

"The numbers were very few and the methodology weak. One of the problems was that they had not used the estimated net consumption of water from the reservoir," says Tor Haakon Bakken.

In Norway, many reservoirs are based on existing lakes, but the method used for the IPCC report did not take into account whether a lake already existed at a given location, so that there had already been evaporation prior to the regulation.

Multiple-use reservoirs ■ Many reservoirs are used for multiple purposes. Their functions as reliable sources of drinking water, water for irrigation and flood control may be just as important as electricity generation. Multi-purpose reservoirs are particularly common in areas of water scarcity.

"The need for reservoirs are highest in areas with scarce water resources and clear periodicity in the availability of water. In these regions the evaporation rates might be very high," says Bakken.

Bakken argues that in cases where reservoirs are used for several purposes, water losses must be divided among all the functions they serve, rather than being attributed to power production alone.

A number of international initiatives that focus on the water footprint are under way, and Bakken has been involved in modifying the methodology. Even though the problem is less important in Norway, it is extremely relevant abroad, and affects the image of hydropower.

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Photo: Antti Eloranta

Ecological effects of reservoir regulation

How much can we regulate reservoirs without causing major environmental effects?

Future scenarios involve more dynamic operation of Norwegian hydropower schemes than today, with more frequent changes in water level in both rivers and reservoirs. Therefore, we need more knowledge of the effects of regulation in reservoirs

However, it is difficult to generalise environmental conditions in reservoirs. In Norway, there are wide variations between reservoirs in the lowlands and the mountains, and in the north and south of the country. Climate, drawdown zone, geology and the operation of the reservoir are some of the factors that affects the ecosystems in the reservoirs. The challenge is to separate the effects of regulation from all the other natural and anthropogenic conditions that make a reservoir ecosystem what it is. To this end, the HydroBalance project uses 'space-for-time' models to bring together data on the physical shape, pattern of regulation and environmental status of a large number of natural and regulated lakes.

The goal is to understand which parameters that are important for evaluating the effects of regulation and water level changes on reservoirs and lakes. This information is essential when we are going to recommend how reservoirs can be operated in the future energy system.

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A new generation of **environmental designers**

The future of environmental design of renewable energy looks bright, given that so many keen and talented students have chosen to base their master's degrees on CEDREN projects.

By the end of 2014, 66 master's students had completed their time with us, and made important contributions to CEDREN projects. Here we introduce a few ongoing and recently finished master's projects:

Water balance studies

Christian Almestad

is working on water balance studies in the Albanian watershed Devoll, where Statkraft is building two major hydropower plants.

Irrigation is an important aspect of the regional water balance in Devoll. Almestad will be looking at the competition for water resources given different scenarios for climate change and the development of irrigation systems in the catchment. He will use hydrological modelling to simulate climate change impacts and to find out how reservoir design and operation will affect water consumption and the amount of water available for irrigation, drinking water and hydropower generation.

Pumped storage hydropower and markets

Ingunn Norang

will perform an investment analysis of the planned Illvatn pumped storage plant in the river Fortun in Western Norway.

Hydropower reservoirs, supplemented with new pumped storage plants, can balance energy demand and supply, supporting the increasing use of variable renewable energy sources. It can also supply many other services (ancillary services) to the power grid in order to secure safe operation and optimal use of the various generation sources. Norang will investigate current and future markets for ancillary services, and whether the extra investments and operating costs can be met by the additional income derived from such services.

The handbook for environmental design in practice

Johan Kristofers

has studied, in collaboration with Statkraft, how to improve the conditions for salmon in the Swedish river Ljungan, using CEDREN's 'Handbook for Environmental Design in Regulated Salmon Rivers".

Kristofers found that one of the most obvious bottlenecks affecting salmon production in Ljungan is that the river has relatively limited spawning areas. In addition, the river provides little shelter. Both may be the result of a reduction in the size and frequency of flood events, which in turn leads to more sedimentation. To improve the conditions for salmon, Kristofers suggests a number of solutions, such as cleaning the substrate and placing artificial spawning beds at strategic locations.

An academic **CEDREN journey**

Unafraid to adopt methods that cut across subject boundaries, Ana Adeva Bustos has made important contributions to CEDREN's research as an intern, a master's student and now a PhD candidate.

Adeva's time in CEDREN started in 2013, with an internship in EcoManage's subproject 'Ecosystem services and biodiversity offsets', working in the River Mandal. She also gathered data from two Spanish rivers for another subproject on water consumption.

After finishing her internship, she got the chance to write a master's thesis in CEDREN. She had already taken several master's level courses at home in Spain, where she focused on the restoration of fresh-water resources The topic that she got to study at CEDREN was therefore 'just the thing' for her.

"I liked the CEDREN concept, which combines several topics in a single project. Restoration cannot be based on only one topic," says Adeva.

In her master's project, she modelled the trade-off between salmon and electricity generation in Laudal hydropower plant on the River Mandal. Adeva combined hydrological, hydraulic, ecosystem-response and mitigation cost models, and demonstrated that it is possible to create good conditions for the salmon with less water than the required minimum flow, and hence higher income for the hydropower company.

Her project led her to winning the 'Excellence Award' from the Academic Commission of the Spanish Master's Programme in Ecosystem Restoration, in addition to obtaining the highest grade for her thesis.

"Adeva is very clever, adaptable and unafraid to adopt methods that cut across subject boundaries," says senior scientist David Barton, who supervised her master's project.

In parallel with her master's work, Adeva assisted with the Ecohydraulics Conference and worked for SINTEF on EcoManage projects in the River Mandal.

"For CEDREN, continuity and commitment are important for obtaining good data and performing first-class analyses," says EcoManage project manager Håkon Sundt, who adds that Adeva's contribution to several subprojects has been a good way of integrating different parts of the project. The development of practical tools for users is a central aspect of EcoManage, and Adeva has contributed to both data analysis and the development of methods that are of wider relevance than just those subprojects in which she has participated.

Still in CEDREN, Adeva is now studying for a PhD on the topic of 'Environmental flow in regulated rivers' at the Department of Hydraulic and Environmental Engineering at NTNU, where she will continue to work on identifying 'best practice' methods for setting environmentally based flow rates.

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10th International Symposium on **Ecohydraulics**

CEDREN's main research partners initiated the very first International Symposium on Ecohydraulics in Trondheim twenty years ago. In 2014, the conference returned home.

Since the beginning in 1994, the ecohydraulics conferences have been held at locations all over the world. On the occasion of the 20th anniversary, CEDREN had the pleasure of organising the 10th International Symposium on Ecohydraulics, thus bringing the conference back to where it started.

The event attracted around 300 participants, and leading scientists from all over the world presented their research results from the topics of river system ecology, biology, hydrology and hydraulics.

"The conference offers an arena for the exchange of new and improved methods and models for identifying environmental impacts and good environmental standards in regulated rivers," says Atle Harby, who was chair of last year's conference and also assisted to organise the first Ecohydraulics meeting.

The last two days of the conference focussed on the application of research results, and on how to find a balance between the need to generate electricity, economics and ecosystem services. A number of people who are working on the implementation of the EU Water Framework attended the Symposium and held their own workshop on Ecological Flows with invited participants including CEDREN scientists.

"The big question is how to find the environmental flow. The requirements of the ecosystem must be weighed against hydropower and society's needs. That makes knowledge about the relationship between flow regimes and ecology a priority. Conferences of this sort contribute a great deal to that," says Harby.

Network group for young researchers founded

During the conference, a group of young researchers established the network 'Early Careers on Hydraulics Network' (ECoENet). Roser Casas-Mulet, who completed a CEDREN PhD in 2014, was among the initiators of the network. The aim is that it should act as a platform for young scientists where they can discuss their ideas and results as part of their networking activities.

At the the end of 2014, ECoENet has 44 members, several with a background as CEDREN graduate students. The network plans to meet every second year in connection with the Ecohydraulics Symposium, which will be held next time in Melbourne, Australia, in February 2016.

In 2014, CEDREN organised the 10th International Symposium on Ecohydraulics, an international conference with over 300 participants from all over the world. On the first day, the participants got to experience the Nidaros Cathedral through a magnificent organ concert. Photo: Anne Olga Syverhuset

Special issues of scientific journals ■ Special issues of no fewer than three journals will be published in the wake of the conference. 'River Research and Applications', 'Limnologica' and 'The Journal of Applied Water Engineering' will bring out special issues with selected contributions from the conference. Members form the Scientific Committee of the conference are working as guest editors to ensure high quality articles.

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Climate research in CEDREN

Developing management-oriented models of the effects of climate change on hydropower and water resources has become one of CEDREN's specialities.

Renewable energy is an important part of the solution to the global climate challenges facing us, but at the same time, it also poses some local environmental challenges. Hence, it is important to base the gradual replacement of fossil fuels on environmental design in order to tackle this double challenge. In this respect, all of CEDREN's efforts can be related to climate, but we also work directly on the effects of, and adaptations to, climate change.

From major global climate scenarios to local effects on rivers and reservoirs ■ CEDREN is working on the development of models that are relevant to the electricity generation sector and the management authorities. The major global climate models provide future scenarios for changes in temperature, precipitation and occurrence of extreme weather events. What do these scenarios mean in concrete terms for the salmon or for ice formation in a given regulated river? Moreover, how will this influence how hydropower stations are operated in the future?

In the EnviDORR project, we have used downscaled climate scenarios to examine how the changes will affect salmon in the River Mandal. Linking future precipitation scenarios with hydrological models that can simulate run-off, gives us a water supply time series that we can use as input to a power regulation model that takes all the power plants, reservoirs and operational strategies in the river system into account. This in turn enables us to determine how much water is available at a given river reach at a given point in time, and further use this information in a biological model to reveal the effects on salmon. The purpose is not merely to predict the effects of climate change, but also to test how the utility companies can optimise their operations with respect to both electricity generation and salmon in a changing climate.

The same procedure is being used in other CEDREN projects, for example in order to estimate how much water that will be available for electricity generation under various scenarios, or to predict icing in regulated rivers and reservoirs under future climatic conditions, as we have done in our HydroPEAK project. This will provide hydropower companies with useful information as they must adapt to a new climatic regime.

Using downscaled climate scenarios in order to create management-relevant models, has become a speciality of CEDREN, and our TOOLS project is currently developing modelling tools that will simplify the task of analysing the effects of climate on hydropower and water resources.

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Photo: Knut Alfredsen

Some more glimpses of climate-related research from CEDREN researchers:

- Extreme conditions and what more precipitation and heavier flooding could mean for infrastructure, river-beds, sediments and erosion
- Climatic effects on the use of hydropower reservoirs in the future
- Climate change and dam safety
- The capacity of Oslo's water resources to supply a growing population under various scenarios
- Comparison of the energy efficiencies of various methods of electricity generation in Norway
- Cause-effect relationships that relate water temperature to biological effects

CEDREN researchers have also contributed to several international climate-relevant reports and working groups, including:

- The 'IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation'
- The summary report on 'Snow Water, Ice, and Permafrost in the Arctic (SWIPA)', via the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP)
- The Working Group on Climatic Effects on Ice in Lakes and Rivers in The Nordic Centre of Excellence – Cryosphere Atmosphere Interactions in a Changing Arctic Climate.

Recommendations for less contentious national **grid development**

The debate over the 'monster pylons' crossing the Hardanger fjord was a clear example of how power transmission grid development can be a source of conflict. CEDREN's SusGrid project has been studying how this problem can be better dealt with, including comparative studies in the UK and Sweden.

The SusGrid project looked at various aspects of grid policy and development, with the aim of improving our understanding of what leads to conflicts. This has resulted in concrete recommendations for grid companies and the authorities for a less controversial grid development process. SusGrid emphasises good communication, and has summarised the advice and results in a popular scientific brochure, in addition to holding dialogue seminars in Oslo and London.

Several sub-projects have illustrated grid policy from different angles.

Expert-driven grid development regime ■ Studies of historical guidelines and management procedures that dominates planning and concession processes show that the grid development regime in Norway is expert-driven and dominated by electric power engineers. In the UK on the other hand, national policy has a bigger say in these matters, while in Sweden, regional and local authorities are much more closely involved.

Little knowledge of the national grid among the general public ■ In order to learn more about public attitudes to knowledge of power lines and the electricity grid, we carried out a survey of the general public in Norway, Sweden and the UK. This revealed that many people know little about the distribution network, and that planning processes are regarded as 'top-heavy'.

Financial compensation ■ Our studies of the challenges related to the use of financial compensation as a policy instrument show that investments that benefit the local community or the local environment are preferable to direct financial compensation.

Need for better integrated planning ■ Our studies of the political and planning challenges related to Norwegian grid policy reveal that grid planning is still not a completely holistic process. Better coordination of different societal interests would offer benefits, such as fewer conflicts and a reduction in the overall use of time and resources.

The professionals involved are more positive ■ Case studies of a number of development projects of the national grids of Norway and the UK show that while professionals in this field in general are positive to the planning process, local people tend to be far more negative, and regard participation in planning processes as being challenging and not very realistic.

Balbergskaret in Lillehammer. Photo: Øystein Aas

Successful workshop in London ■ In November 2014, the findings from SusGrid were presented at a workshop in London that organised in cooporation between University of Exeter and CEDREN. Here researchers, grid owners, the authorities, non-governmental oranizations and other interested parties from all over Europe came together to discuss the challenges regarding participation and acceptance by local people in grid development processes. We also held a similar workshop with Norwegian user partners in Oslo.

Synthesised advice from SusGrid

- Perform a more integrated planning process
- Strengthen strategic communication
- Seek stronger local involvement

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CEDREN **Abroad**

Through international cooperation, CEDREN is contributing to the integration of the concept of 'Environmental Design of Renewable Energy' into major new hydropower projects.

CEDREN's work on sustainable hydropower have attracted international notice. In 2014, we have spread our knowledge of environmental design via a number of international conferences and through participation in international working groups. A few examples of our involvement follow here:

Ethiopia ■ In autumn 2014, CEDREN co-organised a workshop on 'Sustainable Hydropower Reservoirs – Challenges and Opportunities' in Addis Ababa, Ethiopia. There is a great deal of ongoing hydropower development, and the aim of the conference was to strengthen the expertise in sustainable hydropower and help to ensure that the CEDREN-way of thinking about environmental design is incorporated into the new projects.

The event involved the cooperation between NTNU, CEDREN, ICH (International Centre for Hydropower) and AAIT (Addis Ababa Institute of Technology), as well as 9 other Ethiopian university and R&D institutions, and the workshop resulted in plans for future cooperation in education and research.

Asia ■ The efforts to bring Chinese and Norwegian researchers together to discuss the future development of hydropower in the two countries through the FutureHydro project continued in 2014. A Chinese delegation visited Trondheim during the Ecohydraulics Conference, and one conference session was devoted to the topic of sustainable hydropower in China. The delegation was specially invited to participate on a technical tour to Selbu and Tydal, where the main topics discussed were hydropower and environmental measures in the River Nidelva. FutureHydro has also studied the need for pumped hydroelectric storage in China, which is currently in rapid expansion, since the country is now the world's biggest producer of solar and wind energy.

In 2014, we started planning a cooperation with Indonesia and Myanmar, where CEDREN scientists are expected to be involved in various competence building and research efforts. Environmental design of hydropower will be an important topic.

International working groups ■ CEDREN scientists contribute to a number of international working groups, including:

The International Energy Agency (IEA)'s working group on hydropower, IEA Hydro. CEDREN is currently represented in several IEA working groups. Hans Petter Fjeldstad leads the group 'Hydropower and Fish', which started its work last year. Ånund Killingtveit and Tor Haakon Bakken are members of the group 'Hydropower Services', which examines the many user interests and societal demands covered by hydropower and its reservoirs. Both the IEA and IHA (International Hydropower Association) have working groups on greenhouse gas emissions from hydropower reservoirs, and Atle Harby and Håkon Sundt participate in these.

CEDREN-researchers at the Koka dam, Ethiopia. Photo Ånund Killingtveit

The 'United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009)' will now be extended to include renewable energy. A working group has been working on a revision of the classification, so that it can also be used for renewable resources such as hydro, solar and wind energy. CEDREN's Ånund Killingtveit was invited to join this task on the suggestion of the IHA.

You can read about more CEDREN's contributions to international working groups in the article about climate research at CEDREN on page 20.

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Fish-migration and water management in **new projects**

At the end of 2014, EnergiX funded two new projects from CEDREN: SusWater and SafePass.

"These two new projects are based on previous CEDREN activities, and will help to fill obvious knowledge gaps," says CEDREN centre director Atle Harby.

SusWater – Water management in regulated rivers

Norway is committed to develop comprehensive water management plans across local and regional government boundaries in accordance with the EU Water Framework Directive. At the same time we encourage the development of renewable energy sources in line with the EU Renewable Energy Directive. Furthermore, many hydropower licences may be revised in the coming years. The challenge lies in finding ways to satisfy these quite different sets of requirements taking into account various concerns and commitments.

SusWater will shed light on various aspects of water management in regulated rivers, and examine different paths towards a more unified water management policy that will be accepted at both local and national levels, while meeting our international obligations.

"We are looking at both the economic, social and environmental aspects," explains project manager Audun Ruud.

The research team will try to answer a number of specific questions:

1. What are the regulatory challenges associated with strengthening of water governance in regulated rivers?
2. How much water is sufficient to meet given environmental objectives?
3. How can different socio-economic benefits and costs be measured and operationalised better?
4. Can we formulate a framework for better integrated decision-making processes by means of multi-criteria analysis?
5. How can we achieve an improved and more dynamic water management in regulated rivers?

Our ambition is to develop a decision-support tool to improve water management;" says Ruud, "a tool that we hope will raise the level of acceptance of mutually agreed solutions."

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Electro-fishing boat downstream of Rånåsfoss Power Plant in Glomma. Photo: Børre K. Dervo

SafePass gives guidance to the best solutions for both fish and hydropower

Enabling fish to migrate past dams and other hydro installations is one of the major remaining challenges to ensuring that we have good fish stocks in regulated rivers. It is also an important aspect of revising conditions for hydropower licences, issuing new permits and implementing the Water Framework Directive.

"We aim to find the best solutions from the perspectives of both the fish and the hydropower industry," says SafePass project manager Torbjørn Forseth.

Even though we have built more than 500 fish ladders in Norway in the past 100 years, we are still at the starting point for implementing a research-based approach to the problems of fish migration in regulated rivers. International collaboration, funding for a PhD student and a post-doc, in addition to CEDREN's well-established interdisciplinary culture, combine to give a unique boost to the research on this topic in Norway.

"I am particularly pleased to put the spotlight on the problems related to downstream migration of eels past hydropower plants, but we also still have a great deal to learn about good solutions for downstream migration of salmon. In addition, we are rolling up our sleeves in order to take a look at inland rivers, where both upstream and downstream migrations of trout and grayling are a challenge," says Forseth.

In April 2015, a large-scale experimental study using 3D telemetry and hydraulic modelling will start in the River Mandal.

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Key **figures**

Personnel ■ More than 100 researchers were involved in CEDREN in 2014. CEDREN was funding 12 PhDs and 5 Post-docs in 2014. Six of these are Norwegian, and eight are female. CEDREN also had 11 MSc-students in 2014. Seven of these are Norwegian, and five are female.

Publications

CEDREN publications and dissemination measures in 2014. A complete list of publications can be found at www.cedren.no

Type of publication	2014	Total
Articles published in scientific/scholary journals or series	26	88
Articles published in anthologies		3
Monographs published	5	8
Reports, memoranda	6	94
Masters thesis	11	66
Briefs		3
Articles, presentations at international conferences	42	173
Posters at international conferences	5	30
Articles, presentations at national and international seminars and meetings	23	196
Dissemination measures for the general public		29
Popular science articles and media articles referring to CEDREN	73	903

Funding and cost ■ The total funding in 2014, excluding in-kind, was NOK 38 180 049. In addition, the consortium partners had an in-kind contribution of NOK 8 124 216.

CEDREN funding in 2014.

Partner	Funding (NOK)
RCN Grant FME	11 000 000
RCN Grant SusGrid	2 565 480
RCN Grant EcoManage	3 174 175
RCN Grant FutureHydro	1 000 000
RCN Grant HydroBalance	3 792 678
RCN Grant Infrastructure	2 296 946
Agder Energi AS	900 000
BKK AS	513 000
E-CO Vannkraft	700 000
Eidsiva Vannkraft	300 000
Energi Norge	3 000 000
Norsk Hydro Produksjon AS	400 000
Sira-Kvina kraftselskap	950 000
Statkraft AS	5 100 000
Statnett	1 200 000
TrønderEnergi Kraft	100 000
Norges vassdrags- og energidirektorat	415 000
Hafslund Nett AS	250 000
NTE Nett AS	100 000
Troms Kraft Nett AS	100 000
Lyse Produksjon AS	300 000
Others	855 038
Transfer from other years	-832 268
TOTAL	38 180 049

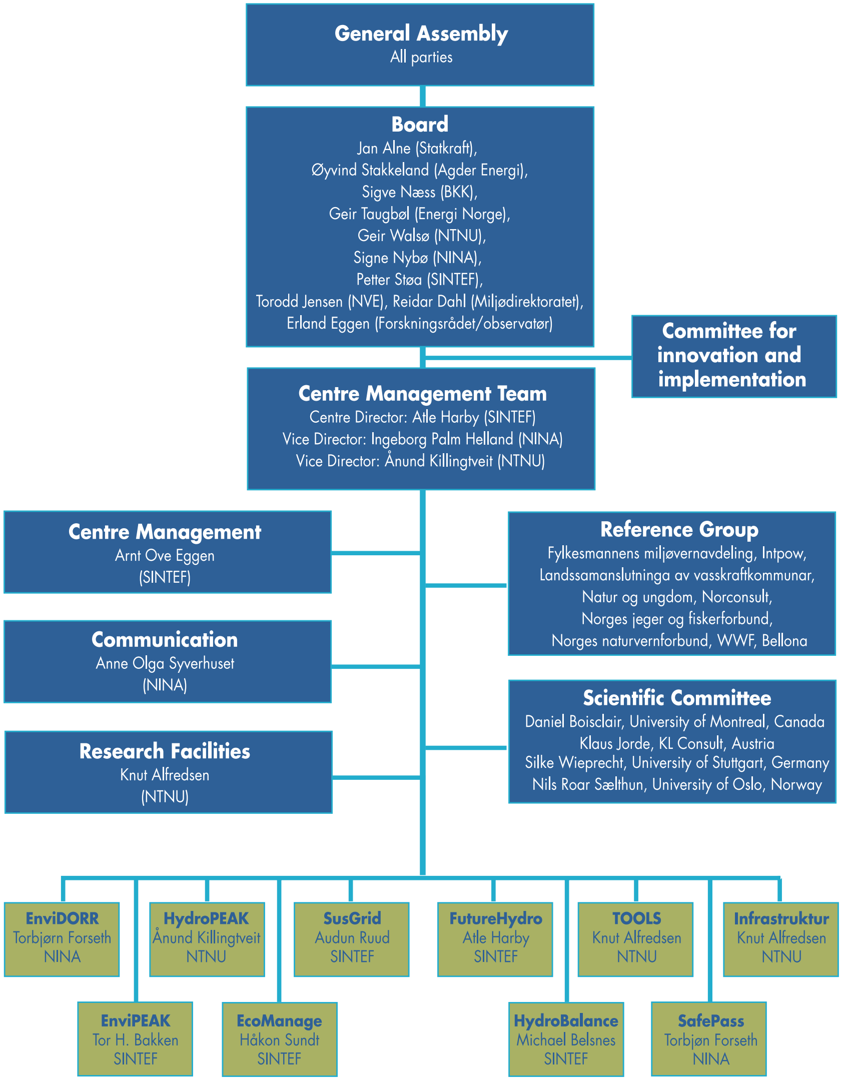
Cost per project and per partner in 2014.

Project	Cost (NOK)
Centre Management	3 422 435
Common Centre Activities	4 101 692
Pilot studies	2 737 661
EnviDORR	762 775
EnviPEAK	1 846 083
HydroPEAK	5 948 648
OPTIPOL	1 044 563
SusGrid	3 995 567
EcoManage	3 898 811
FutureHydro	725 337
HydroBalance	5 949 777
Tools	1 449 758
Infrastructure	2 296 946
TOTAL	38 180 049

Partner	Cost (NOK)
SINTEF Energy Research *	16 971 221
NINA	10 267 247
NTNU	9 259 576
LFI at UiO	306 953
NIVA	94 256
Uni Research	825 258
Others	455 538
TOTAL	38 180 049

** Including international partners*

CEDREN organisational chart 2014



Renewable energy
respecting
nature!

CEDREN March 2015
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