ANNUAL REPORT

2012

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.

CEDREN Centre for Environmental Design of Renewable Energy

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Report of the **Board**

The year that is now behind us is CEDREN's fourth year of operation. Our strategic platform, which was originally drawn up in 2010 and which comprised our vision, objectives and success criteria, has been revised in 2012, as is natural for several reasons. In the course of the four years since it was launched, CEDREN has generated new knowledge and gained new experience, while the national and international energy and environmental policy landscape around us has changed. Europe has ambitious goals for renewable energy, and the widespread installation of intermittent renewables such as solar and wind is opening up potential markets for Norway's flexible hydropower. Further development of renewable energy sources that respect the natural environment and the societal considerations are therefore keys to future growth, both for Norway and for the rest of the world.

The framework conditions that have been set, in part by the European Union's Renewable Energy Sources Directive, the Water Framework Directive and Norway's Nature Diversity Act, set out new and more stringent environmental requirements for renewable power generation. Many Norwegian rivers will have their concessions revised and be subjected to new requirements in the near future, and the balance between environmental flows for biological requirements and the need to maintain power production will be challenged. The launch of the Norwegian-Swedish Electricity Certificate Market in 2012 is another example of a mechanism that is advancing the need for more fact-based knowledge regarding environmental design of renewable energy production that weighs different interests and goals against each other.

Several projects that have been with us since our launch have already come to an end, or have entered their final phase in the course of the past year. This also means that results have been delivered and disseminated via a number of scientific and popular publications in journals, news media and meetings. Researchers and students have played their part in providing lectures, presentations, interviews and comments, for which there has been a regular and intensive demand on the part of the media, the academic community, politicians and the authorities. We believe that in this way CEDREN actively contributes to providing a balanced and factual knowledge base in the field of renewable energy and the environment.

A "mid-term" evaluation process was also put into effect in 2012, in which both the Centre itself and all our partners offered their assessments. The evaluation will be concluded by the Research Council of Norway in late summer of 2013. As far as CEDREN is concerned, this contributed to a useful process regarding our own strategy and operation. We believe that the structure of our strategic platform can be retained, but that a natural step will be to move in the direction of more applied research and implementation of methods and knowledge via demonstrations and case-specific studies that our user partners must engage in and contribute to in order to optimise value creation in the period to come. Innovation and the application of knowledge are therefore an area to which the Board and the Centre's management team have paid a great deal of attention during the latest year of operation. It is a pleasure and an inspiration to observe that we were able to identify and document innovative outcomes and that solutions of commercial interest are materialising!

2012 has also been the year in which we had to accept that the financial aspects of new projects are becoming a challenge. In 2013, our financial support will be reduced relative to previous years, thus making it essential to obtain new sources of funding for important projects if we are to maintain our level of activity and ambitions in the future. EnergiX is the Research Council of Norway's new, large-scale research programme, and we have invited industry and the authorities to offer suggestions for new project applications. The response to this initiative was good, and we began to draw up three applications in the thematic areas of energy systems, renewable generation and energy policy. These applications reflect CEDREN's interdisciplinary strengths, and we believe that these applications will be the best point of departure for generating yet more knowledge of relevance for the future environmental design of renewable energy.

The Board believes that the topics that were introduced when the FME scheme and CEDREN were set up in 2008 have become no less relevant today; rather on the contrary. In fact, the Energi21 strategy, the National Energy Roadmap and the National Grid Report all confirm this. The challenges presented by climate change are another driving force that further guarantees the relevance of CEDREN. Within this area, CEDREN has begun to stand out, and has already delivered some very interesting results. Our tasks will continue to be large and important in the future, and in the interactions between technology, nature and society, CEDREN is a unique and well-established arena that is capable of making a difference, through the delivery of relevant fact-based knowledge and by contributing to exciting and meaningful work for everyone who is involved in and around this research centre!

Finally, the Board wishes to express its gratitude to everyone involved for their first-class efforts during the past year; we look forward to continuing our excellent collaboration.

On behalf of the Board of CEDREN

Jan Alne
Chair

CEDREN in **2012**

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 science into better policies and solutions.

Environmental design means that planning, building and operation have to incorporate technical, economic, environmental and social aspects. This is the only way to develop future hydropower plants, wind farms and transmission lines in a sustainable manner. CEDREN's activities are concentrated around this task of providing knowledge for better decision-making and reduced uncertainties.

The CEDREN consortium represents a unique grouping of institutions with internationally recognised competence in hydropower design, hydrology and hydraulics, applied aquatic and terrestrial ecology and social and economic sciences. CEDREN offers scientists, industry and authorities a common site for the development of environmental friendly energy production. The multi-dimensional combination and outcome of different scientific disciplines and close collaboration with end users are enhanced within the research centre framework. The organisation of CEDREN is shaped for this purpose.

The scientific activity in 2012 stayed at a high level and a large volume of results have been produced, as many of CEDREN's projects are approaching their final part. Our activities and results have been documented in 13 journal articles, 30 technical reports and about 100 presentations at international and national conferences and seminars. CEDREN has also communicated results directly to industry partners and the authorities through special meetings. For the general public, CEDREN is investing in communicating results via cedren.no, newsletters and national and international media.

CEDREN financed four post-docs and 14 PhD students in 2012, and one of our PhD candidates successfully defended his thesis. 17 master's theses were completed in CEDREN in 2012, demonstrating the growing interest in our topics among students.

Modern research infrastructure is crucial to enable high-quality research, and CEDREN completed several important infrastructure investments in 2012 through a special funding regime. We now use advanced hydraulic laboratories, a mobile avian radar, upgraded field research stations and modern field equipment in our research.

CEDREN has more than 50 international partners from universities, research institutes and industry, which guarantees access to, and collaboration with, highly qualified personnel. CEDREN has gained funding for research collaboration in China that focuses on sustainable hydropower development to meet future demands, and we are establishing collaboration with HydroNet, a network aimed at promoting sustainable hydropower and healthy aquatic ecosystems in Canada. In order to increase the dialogue over the North Sea about the role of Norwegian hydropower in the future European energy system, CEDREN organised a seminar that

Demonstration of the flume for the minister by Prof. Ånund Killingtveit and scientist Atle Harby.

Briefing on the avian radar by scientist Roel May and Dr. Kjetil Bevanger.

The Minister for Petroleum and Energy, Ola Borten Moe, inaugurated the tiltable hydraulic flume at NTNU's hydraulic laboratory, and the mobile avian radar. All photos: Thor Nielsen

attracted participants from Germany, France, Spain and the UK. CEDREN is participating in the European Energy Research Alliance (EERA), which develops partnerships and influences EU research priorities and policies for future energy systems in Europe.

Increased possibilities for innovation and value creation are among the main reasons why user partners are joining CEDREN. In 2012, we documented 10 new innovations and solutions to improve value creation, and our strategy for the coming years is now oriented to enabling our user partners to implement methods, models and results. At the same time, CEDREN will continue to perform research for environmental design of renewable energy and to deliver solutions to industry, the authorities and the decision-makers.

Atle Harby
CEDREN Director

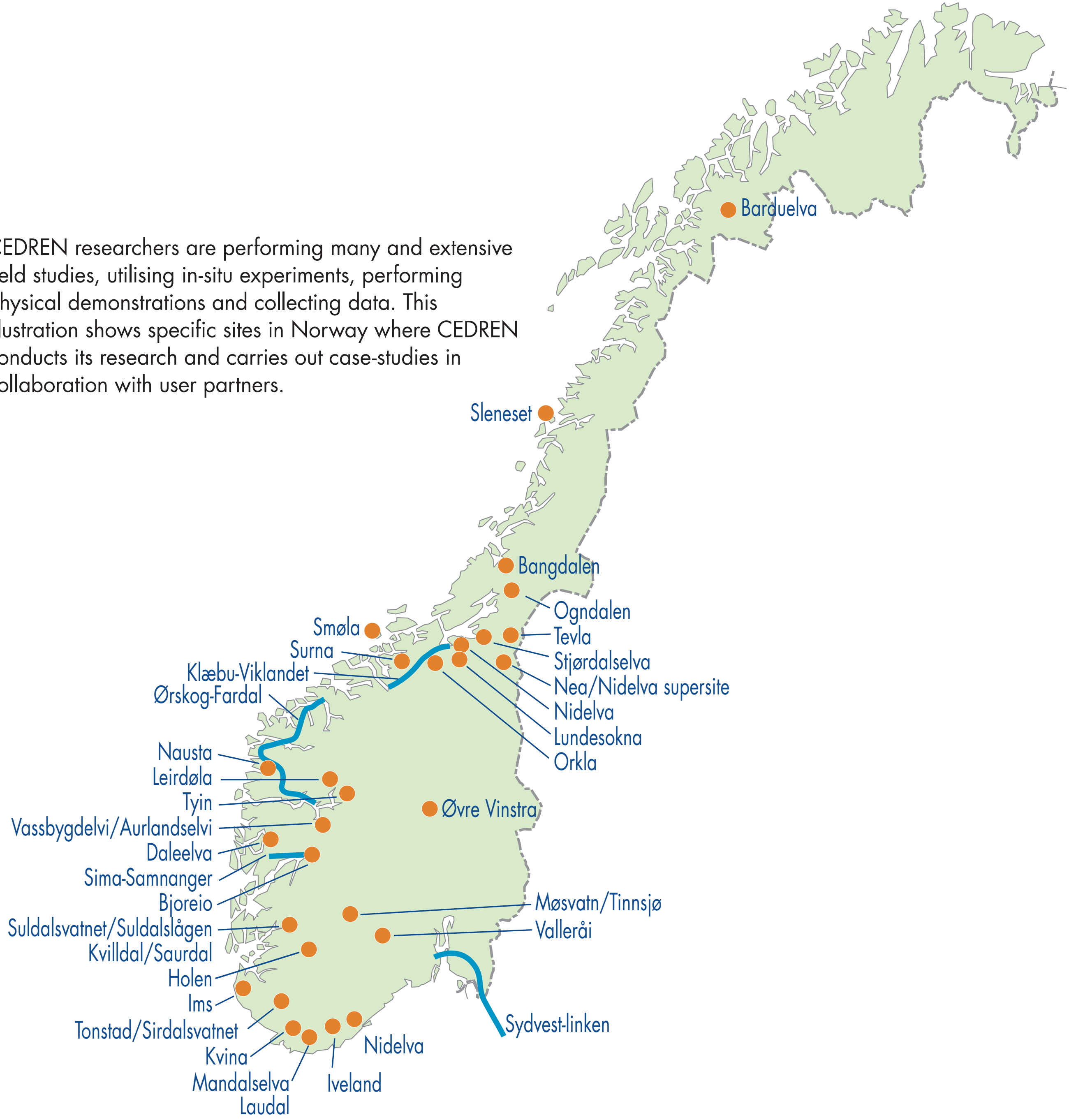
CEDREN **portfolio** 2012

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

Two of the projects started in 2007 and was included in the CEDREN portfolio in 2009 when the centre was established. One project, BirdWind was concluded in 2012 and EcoManage as a new project was included for start-up with funding from the Research Council of Norway and the energy industry.

		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.	2007-2014	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.	2009-2014	37 mill NOK	Tor Haakon Bakken
HydroPEAK	Future hydropower design. Studies on hydropower development for peaking and load balancing.	2009-2014	36,4 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	18,9 mill NOK	Kjetil Bevanger
SusGrid	Sustainable Grid Development. Improving planning tools, and governance procedures facilitating public acceptance and consensual realization of grid projects.	2011-2014	17,5 mill NOK	Helene Egeland
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.	2012-2015	13 mill NOK	Håkon Sundt

CEDREN researchers are performing many and extensive field studies, utilising in-situ experiments, performing physical demonstrations and collecting data. This illustration shows specific sites in Norway where CEDREN conducts its research and carries out case-studies in collaboration with user partners.



Predicting **ice problems** as the climate changes

When ice blocks the inlets to a hydropower plant or obstructs the river downstream, its owners soon begin to lose significant amounts of income. The HydroPEAK project will enable us to simulate ice conditions, even when climate changes take place.

Some scientists have a cold job. In the winter they go out on field studies in the Orkla River in order to see how ice forms and changes in the course of the season. They gather physical data that is then used to test and improve a numerical model of ice conditions in the river.

By the end of the project, the utilities will be able to create a range of ice scenarios for their rivers and plan their electricity generation strategy accordingly. One of the difficult questions that needs to be answered is: What happens when a hydropower plant is shut down for a while? Will icing start earlier or later than during normal operation? That is what HydroPEAK is in the process of finding out.

Unique research ■ The Orkla River is the physical world that the HydroPEAK model simulates. During the past two winters, there was open water in the icy river, but this year it has been ice-covered since the hard frost in November 2012. However, the CEDREN scientists no longer need to go out into the field as often as they used to. Last year, they installed measuring instruments at a number of sites on the Orkla River. Two cameras continuously film the run of the river; complemented by aerial photography, these show the ice situation as it evolves. Other sensors measure water and air temperatures, wind speed, humidity and sunlight.

Remarkably little research has been done on ice conditions in steep rivers. CEDREN is performing advanced research on ice formation in steep, turbulent rivers such as the Orkla. Earlier work had studied larger and slow flowing Canadian rivers.

Effects of climate on ice ■ Once they have obtained good agreement between measurement data and simulations, the scientists will be ready to take on the next challenge: What happens to ice formation when the climate changes? Doctoral student Netra Timalsina is extracting a data-set from the Norwegian Meteorological Institute's climate model for Norway for the River Orkla catchment. This provides him with precipitation and temperature input data for river flow to be simulated under various climate scenarios in the future.

The climate data are entered into the numerical ice model, which estimates when ice will form in the river, the extent of the ice-cover, and how long it will persist. If winters become milder, the periods of ice-infestation and thus of restrictions on power generation will be shorter. However, if the ice reforms and melts again several times in the course of the winter, the river's capacity to generate electricity will be affected in other ways.

Hydropower companies with ice problems get help to plan their electricity generation. Photo: Knut Alfredsen, NTNU

The project is attempting to identify the forces that drive the break-up of ice, which is not a simple matter. In one case, heavy rain washed all the ice away, while on another occasion the same amount of rain had no effect and the ice stayed where it was. Cameras installed on a number of rivers around Trondheim record what takes place in the course of the winter.

Useful for the hydropower companies ■ In the short run, the results of HydroPEAK will benefit electricity generators when they simulate future operating strategies. If they know when ice is accumulating in rivers and when it is disappearing, they can adapt their production plans accordingly. In the longer term, they will be able to simulate how climate change will affect ice conditions and thus electricity generation.

The other user group will be people who work in the field of freshwater ecology. These researchers can study how the species composition of a river or a lake will change under various ice scenarios.

This winter, the measurements will be incomplete while everything is covered in ice. However, next autumn will see the approach of a new winter season, when the CEDREN scientists will gather new data that will make their simulations even more reliable.

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Salmon will have trouble with the **climate**

CEDREN scientists have shown that climate change could have serious consequences for salmon in Norwegian rivers. A new modelling tool could help to identify bottlenecks and mitigate the damage.

The IB Salmon model is an individually based salmon population model. With its help, river managers will be able to predict how climate change and river regulation may affect salmon stocks in the future. The first version of IB Salmon is now ready for use, and it will be a powerful tool for modelling how salmon stocks develop in any given river, and for providing answers to a number of other questions.

Data breakdown ■ Based on climate modelling from the Hadley Centre and the Max-Planck Institute, two internationally recognised climate modelling centres, scientists at NVE, met.no and CEDREN downscaled data and modelled various future scenarios for water flow and temperature in the unregulated River Nausta in Sogn og Fjordane and the regulated River Mandal in Agder. The CEDREN scientists have also started to work with future climate scenarios in the River Dale in the County of Hordaland. These scenarios give the input to the new IB Salmon software model to predict how conditions for salmon production may change in future climates. Based on various biological relationships, the model uses flow, water temperature and river data of water-covered area and habitat quality to model the future development of salmon.

The inflow scenarios show that both of these rivers will be significantly affected by climate change. In the River Mandal in particular, climate change with warmer winters and summers could have important consequences for salmon, which are vulnerable to changes in temperature, water covered area and other habitat variables.

The predictions depend to a certain extent on which climate model is employed and which CO_2 emission scenarios that are modelled. For example, there could be much less water in the river during the summer, and more in the winter than there is today, introducing new bottlenecks for the salmon to survive. Less water in the summer will lead to decreased habitat quantity and quality and restrict the salmon population. So far, the model shows that 3 out of 4 scenarios predict lower salmon production, whereas one predicts an increase. The results strongly relate to the summer discharge in different future scenarios. IB Salmon aims not only to predict the effects of climate change, but also to test how regulators can optimise river management and hydro operations to the benefit of both hydropower companies and the salmon under changed climatic conditions. In regulated rivers it will be possible to adapt conditions for this purpose.

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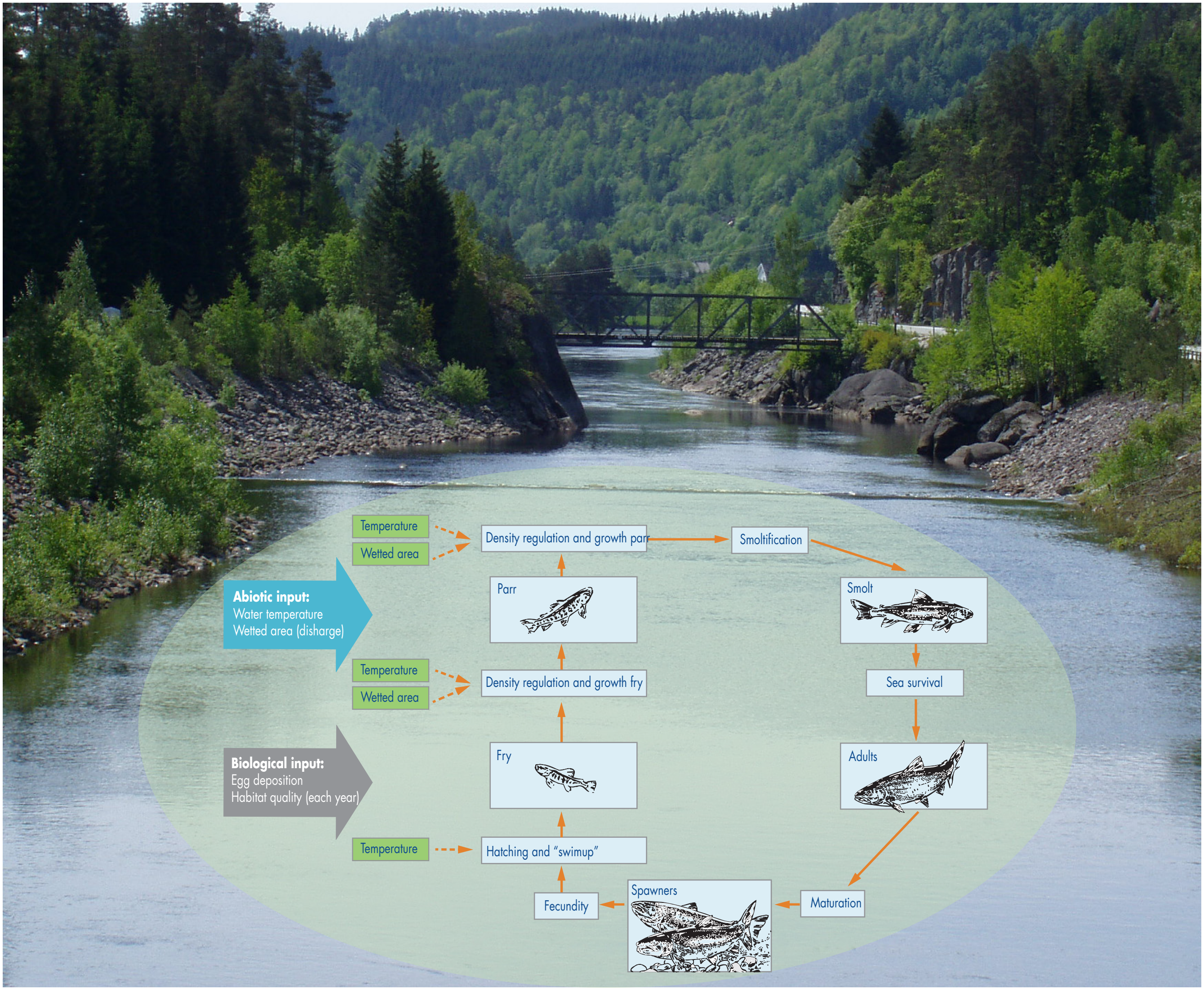

This is a schematic overview of the new modelling tool, IB Salmon. It shows important biological processes of Atlantic salmon and the influence of water temperature and wetted area (abiotic input) in the model. Together with climate data this produce specific future scenarios for fish production under varying conditions in the river system. Illustration: NINA. Photo: Eva B. Thorstad, NINA

Looking for **answers** on the riverbed

Researchers are beginning to really understand how major variations in water flow affect life in rivers. Their new knowledge is being transformed into useful tools for river regulators and industry.

In collaboration with the University of Stuttgart, CEDREN is continuing the development of a modelling tool that will predict how living conditions for young salmon are affected by hydropeaking (frequent and rapid changes in electricity generation). The University of Stuttgart and the German consultancy Schneider and Jorde Ecological Engineering have developed the CASIMIR software modelling tool, which German and Norwegian scientists are now adapting to conditions in Norwegian rivers. Their work was done as part of the EnviPEAK project, where researchers and students from both countries utilised the River Surna in Surnadal and Rindal Municipality for field studies, with supplementary field-work in the River Dale in Vaksdal.

Sediment movement ■ The CEDREN scientists have already done a great deal of work on how river-bed conditions affect habitat, and how sediment movements change these conditions on the river bed over time. Small fish occupy the interstitial space between the stones in the river bed, and the scientists believe that the size and number of these gaps change over time due to river regulation, operation and hydropeaking.

A number of different observational techniques have been used to register these changes. The simplest method, which has also been fairly effective, has been to sink a bucket into the river-bed, take it up after a while, and examine how the make-up of the sand, gravel and stones has changed.

Another technique has been to press a pipe down into the bed and then fill it up with liquid nitrogen. This freezes the sediments, enabling an undisturbed sediment core to be extracted for later study in the laboratory. The project has also used a micro-drone to photograph the river-bed from the air. The results of these observations are used to calibrate the models and thus enable them to produce more reliable predictions of how changes in flow will affect sediment movement and thus habitats.

Pioneering work ■ There has been a great deal of speculation regarding how river-bed conditions change when rivers are regulated and managed to generate electricity, and how this in turn affects the living conditions of fish, but our understanding of this field has been very limited. This pioneering work is enabling CEDREN and the University of Stuttgart to develop top-level expertise in sediment transport in rivers, and its effects on fish; expertise that few other groups in the world possess. Several international workshops have been held the last years, and undergraduate and doctoral students are taking their degrees and specialising in this field via model development and fieldwork in Norwegian rivers. The well-known Austrian university BoKu (University of Natural

Ass. Prof. Nils Rüther works on sediment sampling by freezecoring in the River Surna. Photo: Nils Rüther, NTNU

Resources and Life Sciences) in Vienna has also been involved in certain aspects of the programme.

Stranding, the phenomenon of fish ending up on dry land when water levels fall, has also been in focus in 2012, and more effort will be put into this aspect in 2013, when EnviPEAK will continue development of the salmon population modelling software **IB Salmon** with a stranding module.

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Norwegian **balancing power** in demand

Norwegian hydropower could meet a significant proportion of the balancing power and energy storage that Europe will need in the next twenty or thirty years. There is currently a great deal of international interest in CEDREN's efforts to deal with the challenges involved.

When the wind doesn't blow and electricity generation from wind-farms drops off, Norwegian hydropower could act as a huge "blue battery" that would ensure continuity of supply. CEDREN and its partners foresee no significant technological challenges that need to be dealt with before Norwegian electricity generators can supply balancing power to an unstable European market. Nevertheless, CEDREN has identified a need for research and studies of environmental impacts, the development of commercial measures, social aspects and the regulatory framework.

Such research will have to take place in parallel with developing business models and establishing political legitimacy. Research and studies will need to demonstrate and document the environmental consequences and break down current myths.

The authorities and decision-makers at both ends of the cable must also do their part of the job by coming to basic agreement and drawing up long-term contracts that will clear the ground for commercial contracts. Laws, regulations and practise in each country will also have to be harmonised.

International interest ■ The high level of international interest in the work of CEDREN was demonstrated during the seminar "Large-scale balancing from Norwegian hydropower" in Sand in Suldal last September, where Norwegian researchers met participants from Germany, France, Spain and the UK.

Both British and German participants identified new cable connections as the "first stop" on a road-map for a Northern Europe in power balance, and suggested that as far as possible, these should be installed and operated as commercial, private-sector projects.

In technical terms, Norway could deliver about 20 GW balancing power to Europe by using existing hydropower reservoirs. However, this would meet only a fraction of the requirements that are already beginning to become evident in the European market, and that are about to increase dramatically during the next twenty or thirty years, as more and more solar and wind energy are introduced. The most important challenge will be to establish sufficient cable connections between the countries.

Environmental and regulatory challenges ■ CEDREN has analysed some of the environmental challenges involved in exchange of large amounts of balancing power. Researchers have modelled how changes in water level in three potential expanded production systems (Rjukan, Holen and Tonstad) will be affected if they are used to balance

Scientists and partners from Norway and other European countries discussed how Norway can help to solve Europe's climate problems at the seminar "Large-scale balancing from Norwegian hydropower" in Sand in Suldal on September 11 – 13 last year. Photo: Atle Abelsen, Teknomedia

electricity generated by wind turbines in the North Sea area. These are preliminary studies. There is a need for more in-depth descriptions of the demand for balancing power, and for further development of the potential of technical systems.

Political agreement and social acceptance are other important topics that need further research efforts before we can establish a balancing power market in Northern Europe. A pilot study performed by CEDREN has found that there is widespread support among interested and affected parties for the concept of Norway as Europe's "green battery". However, there is some scepticism regarding the political and economic realism of these projects. New business models and markets will have to be developed.

Other EU obligations, such as the Water Framework and the Renewable Energy Directives, as well as national commitments to biodiversity also play a role in this respect. It is important to involve all relevant parties as soon as possible, in order to establish their ownership of the processes concerned. Local communities must experience that they are benefitting from the value that a balancing power service creates in the Norwegian system.

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Grid **development** and new tools

In the future, expansion of the national grid could become less controversial and resources-intensive. SusGrid has shown how interested and affected parties can become more involved in the concession processes. Meanwhile, OPTIPOL has developed a powerful new software package that will ensure that all important aspects are weighed against each other.

SusGrid has performed a study as that compares the development of the grid in Norway in relation to the grid development regimes in Sweden and the UK. In Norway, political guidelines are virtually non-existent when Statnett draws up plans to extend the National Grid. In contrast to Sweden and the UK, the Norwegian system is much more expert-oriented and dominated by considerations that take the electricity distribution system itself into account.

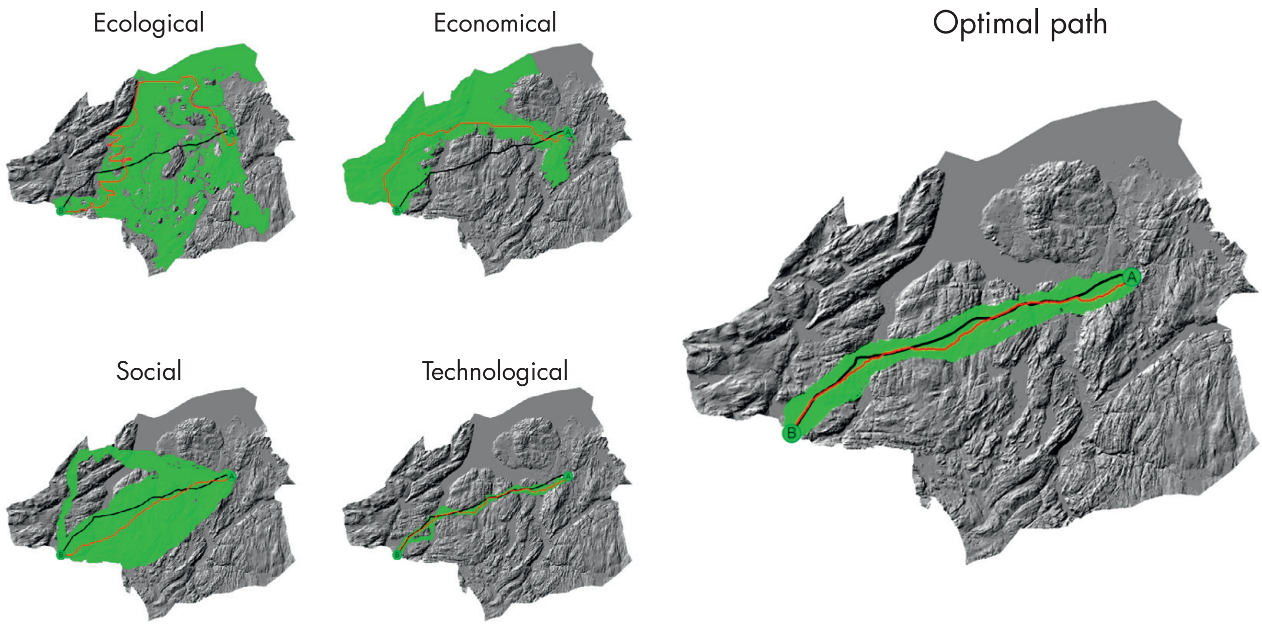
This emphasis on the requirements of the electricity supply system, such as security of supply, often create problems related to public acceptance and political legitimacy, because it can be difficult to persuade the general public of the importance of such needs.

Close relationships ■ The links between the different levels in grid planning are insufficient. The protests in Hardanger have demonstrated that the development of the grid at various levels must be seen in an overall context. There is little integration between local energy plans, regional power system plans and Statnett's national transmission grid development plan.

The central driving force is provided by the grid-owners themselves, particularly Statnett, which assesses the need for new distribution networks and initiates projects via its annual grid development plans. Local or regional political authorities do not play prominent roles in the Norwegian grid planning system, and the central political level only becomes involved when planning appeals are being considered.

Virtually all applications for expansion of the National Grid are appealed, and the appeals procedure often takes the form of a new review of the project. The concession procedure thus creates ideal conditions for what the researchers have identified as a "participation paradox"; the longer a party waits to enter the licensing process, the more effective is its participation. When individual participants eventually join the appeals process, the concession process is drawn out and becomes more expensive.

Part of the solution – a new toolbox ■ In the OPTIPOL project, CEDREN is developing a method that could help to increase the involvement and insight of the general public through geographical and topical goal-oriented impact studies concerning the choice of new power-line routes. The new OPTIPOL-LCP (Least Cost Path) is a GIS-based planning software model that calculates optimal corridors for transmission lines. The software is being developed in collaboration with the Norwegian Water Resources and Energy Directorate (NVE) and Statnett, and it has also aroused a great deal of interest at international conferences.



The illustration shows how the optimal power-line corridor is generated from compiled conflict maps from point A to B in a given area. The LCP toolbox is validated with a 420 kV power line built from Klæbu to Viklandet in central Norway in 2005. Input from Environmental Impact Assessments (EIA) made prior to the construction phase was implemented in the toolbox and the result correlates very well with the constructed power line path.

OPTIPOL-LCP should be brought into the planning process as early as possible, preferably well before a public notification for the impact assessment plan is made. It can be used to guide the aims of the process by delimiting the area and topics that need to be investigated in detail, thus saving the executive agency involved both time and money.

OPTIPOL-LCP encourages user involvement and enables interested and affected parties to engage in defining criteria for evalutions. The idea is that involvement can help to reduce conflicts and establish ownership of decisions among the affected parties.

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Dilemma for Norway

Small-scale hydropower is not necessarily better for the environment than the construction of large hydropower projects. A CEDREN study has compared the environmental impacts of small and large hydropower projects.

Hydropower is affected by political forces that collide to a certain extent. Policy for renewables encourages increased development of hydropower generation, while environmental considerations may reduce the production potential. These opposing forces are represented by the European Union's Renewable Energy Sources Directive (RES) and the Water Framework Directive (WFD), both of which are being implemented by Norway.

The RES Directive stimulates the introduction of new instruments, and the joint Norwegian-Swedish Renewable Electricity Certificate market of 2012 is a direct result. The WFD requires Norway to improve the environmental quality of regulated rivers. Just how this is to be implemented, and what can be defined as good ecological status and potential, remain unclear.

Energy and environmental policy often appears to be a zero-sum game, in which we are obliged to choose between energy production and conservation of the environment. However, CEDREN research shows that there are nuances to such a conclusion. It is possible to maintain energy production while improving environmental quality.

Small is not always more environmentally friendly ■ Research done by CEDREN indicates that small hydropower plants are less environmentally friendly than large projects, if we regard them in terms of kilowatt-hours generated. This is among the conclusions of the report "Many small or large and few?", which was published in 2012 as part of the GOVREP project. The report is based on a straightforward systematic approach that compared 27 small and 3 large hydropower projects in the County of Sogn og Fjordane. The upper limit of "small hydropower" is defined by 10 MW installed capacity. The environmental impacts differ in type and size. This means that an individual assessment and political or public administration priorities tend to have a decisive influence on the preferred strategy for hydropower development.

Small hydropower projects have been preferred and can often be justified. Their environmental impact of all hydropower will depend on how the individual hydropower plant has been designed and what type of natural setting it is installed in, rather than on its size. All interventions have an impact on the environment, and any assessment will depend on political and administrative values and priorities: is it more important to protect species on the IUCN Red List, vulnerable and valuable strains of fish, landscape qualities, or to keep as large an area as possible of the landscape undisturbed?

First time ■ The report is a first attempt to develop a method capable of comparing hydropower projects, no matter what their size. Not only can projects be evaluated individually; they can also be examined in relation to one another in order to assess their accumulative effects, something that is still difficult to do at technical and political levels.

The GOVREP report "Many small or large and few?" is a first attempt to develop a method for comparing hydropower projects. Projects can be evaluated individually, independent of size, and in relation to one another in order to assess accumulative effects, something that is still difficult to do at technical and political levels. Photo: Thomas Welte, SINTEF/SINTEF

Research done by GOVREP is helping to spotlight certain powerful forces that drive power production from renewable sources: the Renewable Electricity Certificate market and the European Union's RES Directive, which requires Norway to generate 67.5% of its electricity from renewable sources by 2020. At the same time, the WFD and Norway's own Nature Diversity Act are creating uncertainty regarding what all this will mean in practice.

The GOVREP report was adopted as part of the basis for the action programme that the Norwegian government presented for ESA last June, regarding how Norway intends to meet its renewable energy targets. With regards to the Water Framework Directive, which requires Norway to draw up action plans for all its rivers by 2015, the report helps to ensure that their hydropower potential will be assessed irrespective of their size. This will make it easier to evaluate their environmental impacts, and determine which factors should be given priority – particularly since the need for a reliable electricity supply must also be taken into account.

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Innovation and **value** creation in CEDREN

An important aspect of CEDREN's objectives is that research results should contribute to value creation for the user partners, both private companies and the public authorities.

In 2012, CEDREN increasingly focused on innovation, where a gradual shift towards the application and implementation of results has taken place. This is backed up by CEDREN's Strategy Platform, formulating "Innovations and new opportunities for renewable energy solutions".

Collaboration to optimise value creation ■ As a research centre, CEDREN is optimised for the generation of knowledge-based results, where scientific methodology and a fact-based approach provide the common platform where the scientific community, industry and the authorities meet to deal with challenges and produce new insights. The centre has actively facilitated close collaboration with user partners and among researchers via a range of meeting-places. The annual open CEDREN seminar, meetings of the Scientific Committee, the Reference Group and the Board, kick-off seminars and regular project user-group meetings are examples of central arenas that exchange knowledge, encourage networking and develop potential new research projects.

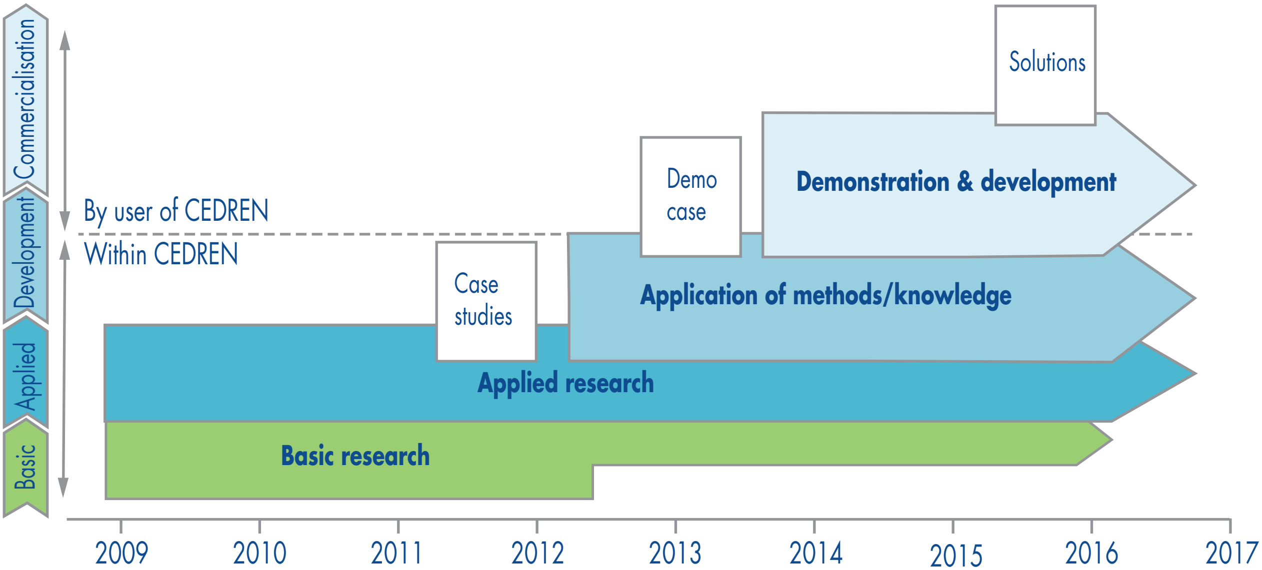
Identification of potential and solutions ■ In order to ensure that ambitions for innovation are achieved, CEDREN has appointed a Committee for Innovation and Commercialisation (CIC) as a permanent body within the central organisation, reporting directly to the Board. In 2012, the new innovation model was put into effect, focusing on documenting and validating our research results and identifying their commercial potential, value creation for our user partners and their importance for further scientific progress. In 2012 several user-initiated projects delivered their final results. These included SusGrid, the HydroBalance pilot, Environmental Management Concept and Water Flow Targets. So far, ten specific innovation results have been identified, including one that is ready for commercialisation.

Saving smolt

In regulated rivers, migrating smolts may swim into hydropower turbines and be killed. The EnviDORR project has developed a method that scares the fish away from the turbine intake tunnel by means of an unorthodox method: strobe lights. SmoltStrobeLight has been tested in the Laurdal Power Station in the River Mandal, with good results.

Recreating nature in the laboratory

Last year, CEDREN installed advanced research equipment that is expected to produce results that will lead to innovations in the energy sector. A new tiltable hydraulic flume in NTNU's River Laboratory will enable scientists to study the effects of more variable water-flow regimes in rivers and waterways, researching flows, erosion and sediment transport under well-defined and controlled conditions. The flume will be used in a number of doctoral degree projects at CEDREN and later also in contract research projects for energy utilities and the authorities.



CEDREN's increased focus on innovation is illustrated in this model. The research shall aim for even more use of case studies and demonstration projects in collaboration with user partners in order to secure application and implementation of results from the centre.

Some examples of CEDREN innovations

1 Elevated perches for eagle owls on power-line crossbars to avoid electrocution.
2 Avian radar as a tool to improve the quality of environmental assessments for wind farms.
3 MS-UT-Smolt: Model-based management of migrating smolt passed turbine intakes
4 SmoltStrobeLight: Installation to repel smolt from turbine intakes in regulated rivers.
5 Least Cost Path (LCP) toolbox for transmission line corridors.
6 Computational tool to characterise rapid fluctuations of flow and stage in rivers caused by hydropeaking.
7 Environmentally friendly electricity generation: More salmon and more production, the Kvina case-study.
8 Mapping river topography using micro-drone.
9 Environmental impacts of small- and large-scale hydropower.
10 Energy-efficiency tool (Energy Payback Ratio) adapted to Norwegian conditions.

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Key **figures**

Personnel ■ In 2012 a total of 106 researchers where involved in CEDREN.

In addition, CEDREN had 14 PhD and 4 Post-docs positions in 2012. Five of these are Norwegian, and ten are female. One PhD and one Post doc finalized their work in 2012. CEDREN also had 17 MSc-students in 2012. Seven of these are Norwegian, and three are female.

Publications

CEDREN publications and dissemination measures in 2012. A complete list of publications can be found at www.cedren.no.

Type of publication	2012	Total
Articles published in scientific/scholary journals or series	11	25
Articles published in anthologies	1	3
Monographs published (PhD Dissertation)	1	3
Reports, memoranda	30	66
Masters thesis	17	36
Briefs	1	3
Articles, presentations at international conferences	50	103
Articles, posters presentations at international conferences	5	23
Articles, presentations national and international seminars and meetings	41	116
Dissemination measures for the general public	13	25
Popular science articles and media articles referring to CEDREN	146	768

Funding and cost ■ The total funding in 2012, excluding in-kind, was NOK 43 409 198. In addition, the consortium partners had an in-kind contribution of NOK 11 483 656.

CEDREN funding in 2012.

Partner	Funding (NOK)
Agder Energi AS	809 976
BKK AS	250 000
E-CO Vannkraft	700 000
Eidsiva Vannkraft	300 000
Energi Norge	750 000
Norsk Hydro Produksjon AS	400 000
Sira-Kvina kraftselskap	500 000
Statkraft AS	5 175 000
Statnett	900 000
TrønderEnergi Kraft	100 000
Direktoratet for naturforvaltning	715 000
Norges vassdrags- og energidirektorat	447 600
Hafslund Nett AS	150 000
NTE Nett AS	100 000
Troms Kraft Nett AS	100 000
Others	260 215
Transfer from other years	2 332 815
RCN Grant FME	10 000 000
RCN Grant RENERGI	12 105 338
RCN Grant SusGrid	3 781 400
RCN Grant EcoManage	1 140 000
RCN Grant Infrastructure	2 361 854
Total	43 409 198

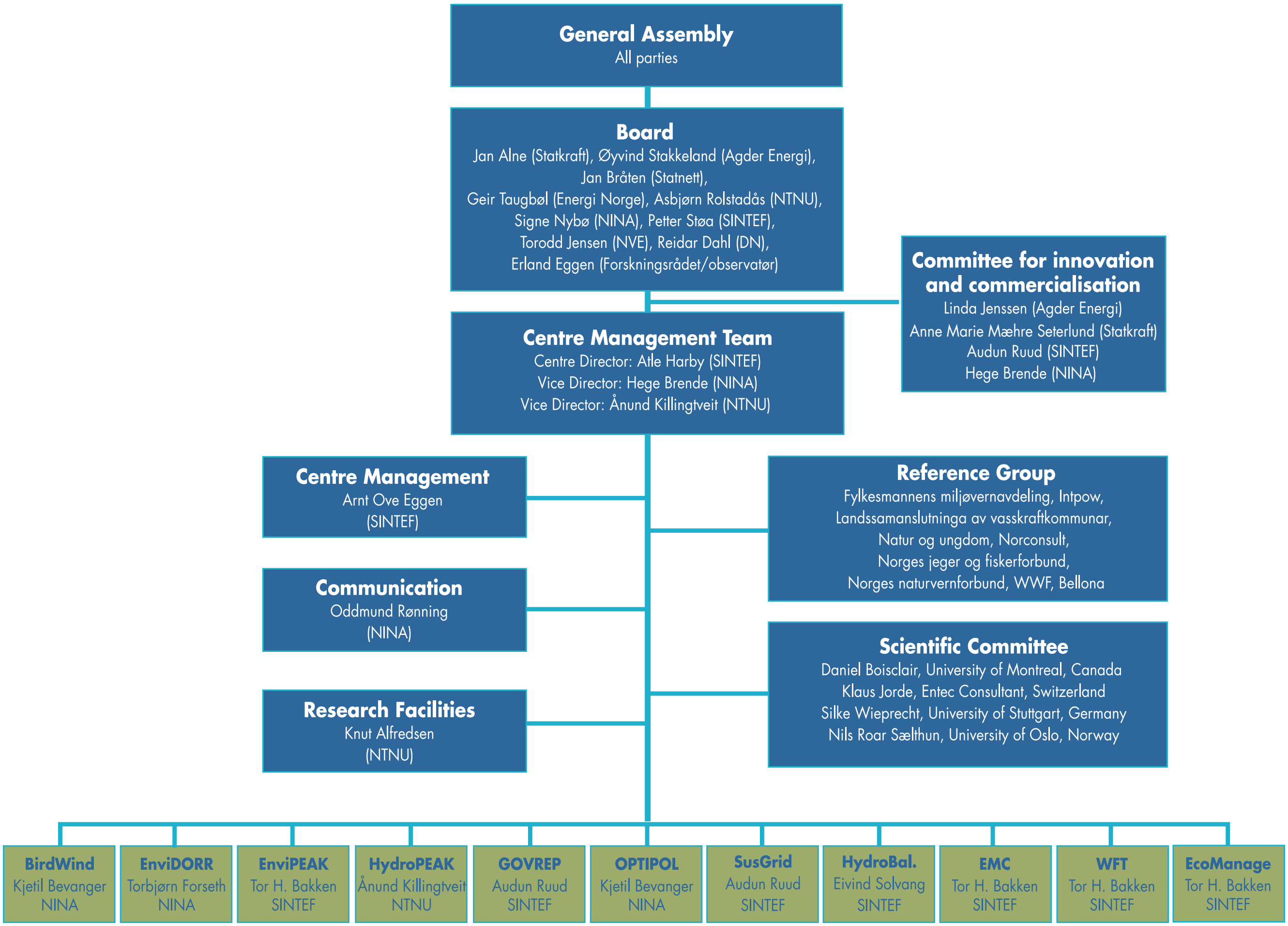
Cost per project and per partner in 2012.

Project	Cost (NOK)
Centre Management	3 851 553
Common Centre Activities	3 501 053
BirdWind	371 857
EnviDORR	2 656 063
EnviPEAK	6 120 589
HydroPEAK	6 972 236
GOVREP	2 432 810
OPTIPOL	4 911 675
HydroBalance	2 195 384
EMC	777 264
Water Flow Targets	633 638
SusGrid	5 256 134
EcoManage	1 387 892
Infrastructure	2 341 052
Total	43 409 198

Partner	Cost (NOK)
SINTEF Energy Research*	20 119 471
NINA	11 986 611
NTNU	9 287 348
LFI at University of Oslo	60 000
NIVA	88 433
Uni Research	1 867 335
Total	43 409 198

** Including international partners*

CEDREN organisational chart 2012



Renewable energy respecting nature!

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CEDREN Centre for Environmental Design of Renewable Energy

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH