Centre for environmental design of renewable energy - CEDREN

Atle Harby, Director
8 years (2009 – 2016)
10 large research projects – two more from 2015
7 Norwegian research partners
16 Industry partners and 2 management partners
Budget: ~40 M Euro (5 M Euro in 2016)
21 PhD and 7 Post-doc positions
International collaboration

Renewable energy respecting nature
Hydropower technology

Environmental impacts of hydropower

Environmental impacts of wind power and power transmission

How to reconcile energy and environment policy?
Environmental design of regulated rivers

- Constructing habitats
- Increasing both salmon and power production
- Adapting downstream flow
- Increasing power production
Renewable energy and birds
Electrocution

Death of a white-tailed sea eagle in Norway
In danger!
Energy scenarios

- Transmission and distribution infrastructure
- Energy storage technologies
- Demand side management
- Improved forecasting of resource availability

Maybe as much as 340 TWh of storage volume and 150 GW of balancing capacity needed in Europe by 2050
RES challenges - Germany
High Photovoltaic production
Summer

Significant reduction of peak load due to solar power production at noon

RES challenges
High Wind power production
Winter

Nearly no residual load left to conventional power plants

Wind energy

But back-up capacity necessary

RES challenges
No production from RES Winter

Peak load and nearly whole demand during the week completely covered by conventional power plants

Wind + Solar energy in Germany week 12 2014
Capacity ~30 000 MW Wind + 30 000 MW PV

Sum Wind + Solar PV Generation in Germany week 12, 2014

24/3 2014 at 20.00
550 MW in production
59450 MW unused
Hydro storage – a renewable battery
German Minister of Economy, Philipp Roesler, visiting the Blue battery of Norway – guided by Regional Statkraft Director and CEDREN Chairman of the Board, Jan Alne.

50 000 MW Norwegian hydro capacity to make Germany 100 per cent renewable by 2050
Installed Energy Storage capacity

**Worldwide installed storage capacity for electrical energy**

- **Pumped Hydro**: 127,000 MW
- **Compressed Air Energy Storage**: 440 MW
- **Sodium-Sulfur Battery**: 316 MW
- **Lead-Acid Battery**: ~35 MW
- **Nickel-Cadmium Battery**: 27 MW
- **Flywheels**: <25 MW
- **Lithium-Ion Battery**: ~20 MW
- **Redox-Flow Battery**: <3 MW

Over 99% of total storage capacity

Source: Fraunhofer Institute, EPRI

**Worldwide installed rated power of storage facilities for electrical energy. Such power level can be sustained for up to several hours or shorter**
Goldistal, Germany
Indirect storage

Blåsjø
7.8TWh reservoir
(1000 times Goldistal)
Simulated wind production in the North Sea area in 2030 – 95 000 MW installed capacity
Wind Power North-Sea Region - Jan – March

One week balancing means
Ca 30 000 MW in 168h ⇒ 5 000 GWh energy storage

Same as 1000 typical PSH

Can Hydropower in Norway supply this storage?
Observed Wind energy production
In a system with **76013** MW
installed capacity (Stadium 2012)

Maximum: **44995** MW
Minimum: **1272** MW
Typical: **15400** MW
Capacity Factor: **0.20**
Hydropower in Norway – Resource base

Water, high head

Large natural reservoirs
Norwegian hydropower

Currently:
32 GW
130 TWh/year

- Hundreds of large reservoirs
- 20 reservoirs with more than 100 Mm³
- 20 GW of extra capacity possible
- ~15 TWh always available storage
CEDREN Case study 2030

Tyin
Holen
Tonstad
Hol
Jøsenfjorden
Tinnsjø
Nore
Mauranger/Oksla/Tysso
Kvilldal
Lysebotn
Sima
Aurland

CEDREN Centre for Environmental Design of Renewable Energy
The technical potential

20 000 MW in southern Norway possible
Transmission capacity

- **NO-Sweden**
  - North/Midle-Norway: 1 100 MW
  - South-Norway: 2 050 MW
  - SouthWest-link: 1 200 MW (2019)

- **NO-Denmark**
  - SK1-3: 950 MW
  - SK4: 600 MW (2014)

- **NO-Netherlands**
  - NorNed1 (NL): 700 MW
  - NorNed2 (NL): 700 MW (2016)

- **NO-Germany**
  - NorGer: 1 400 MW (2018)
  - NORD.LINK: 1 400 MW (2018)

- **NO-England**
  - 1 400 MW (2020)

Possible interconnection capacity in 2020:

4 800 + 6 700 = 11 500 MW
Comparing LCOE for Norwegian Pumped Hydro and Gas Power Plants

![Graph showing LCOE vs Load Factor for OCGT-1, OCGT-2, CCGT, and Pumped Hydro plants.](image)

- **OCGT-1**
- **OCGT-2**
- **CCGT**
- **Pumped Hydro**

Increasing $p_{pump}$
...even when grid and cable costs are included
Environmental impacts
Social acceptance
Tesla PowerWall© - 10kWh units for homes

Roof-top solar panel or similar

- Balancing solar energy
- Energy security
- Off-grid solutions
The Great Wall

Cover with Tesla PowerWall©
1,23 TWh = 15 % of Blåsjø
Natural gas grid today

Can we establish a similar electricity grid for exchange?
- Uncertain future – many scenarios – new technologies (?)
- Increased need for energy and water storage
- Rapid changes may come (...Fukoshima)
- Hydro reservoirs = always an excellent energy storage
- We need to value all services from reservoirs properly
www.cedren.no

Contact: atle.harby@sintef.no