



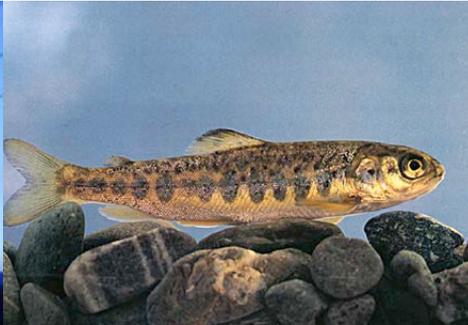
# Centre for environmental design of renewable energy - CEDREN



NATURHISTORISK MUSEUM  
UNIVERSITETET I OSLO



Atle Harby, SINTEF Energi



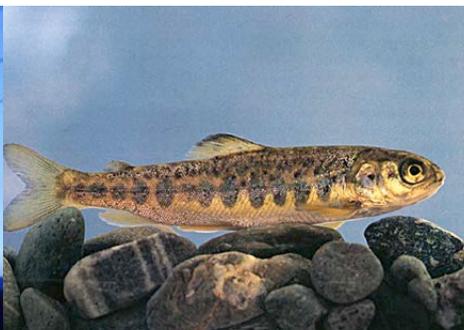


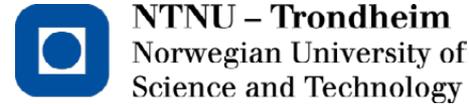
## CEDREN - Centre for environmental design of renewable energy

- ▶ 10 store forskningsprosjekter
- ▶ 6 norske forskningspartnere
- ▶ 16 brukerpartnere fra industri og 2 fra forvaltningen
- ▶ Budsjett: ca 350 MNOK (40 MNOK in 2015)
- ▶ 21 PhD og 7 Post-doc studenter
- ▶ Kobler teknologi, økonomi, miljø og samfunnsfag



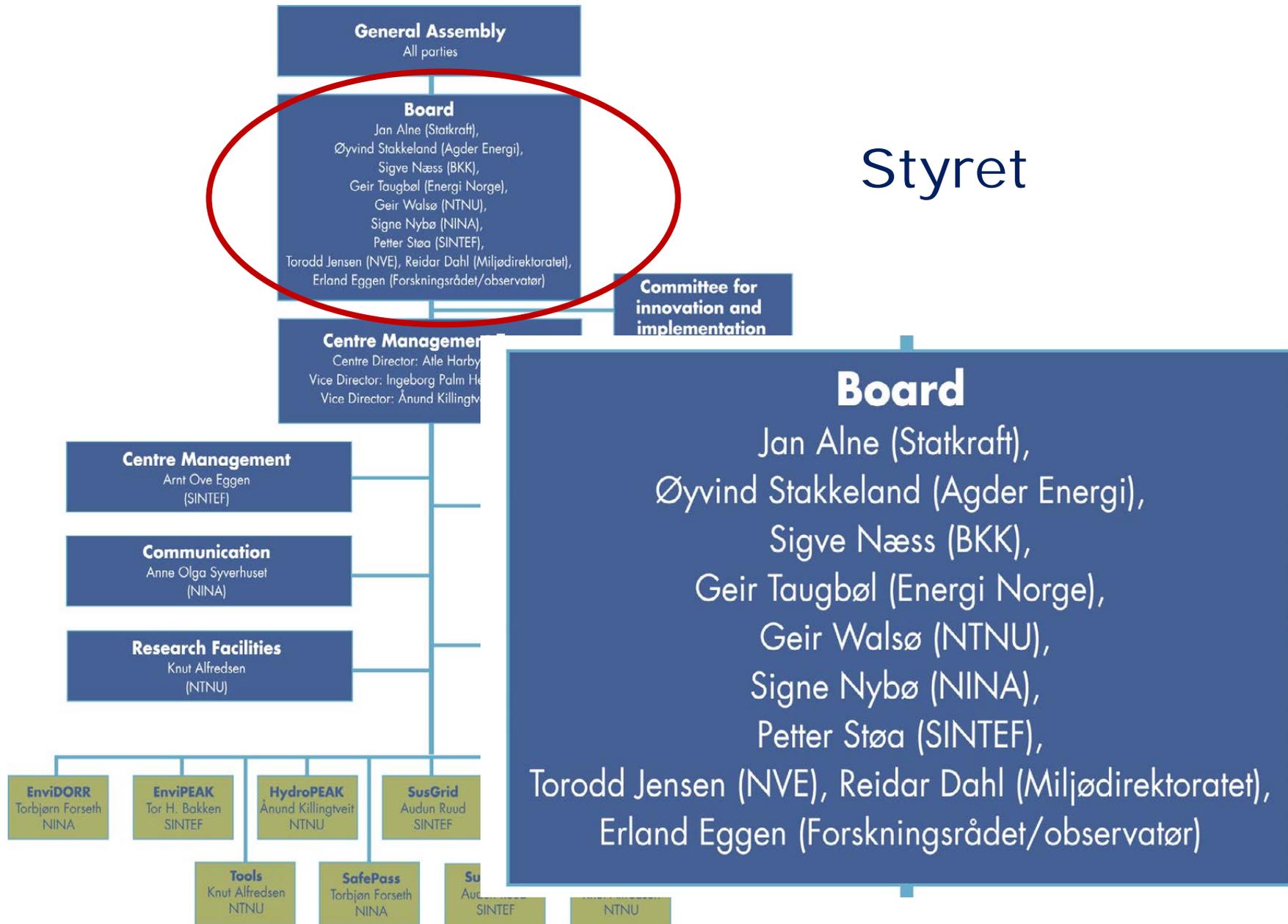
## Fornybar energi på lag med naturen



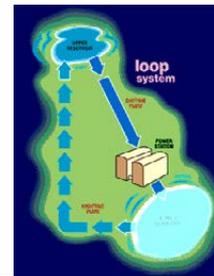


International partners:





## Vannkraftteknologi for framtida



## Miljødesign av vannkraft



## Miljøvirkninger av vindkraft og overføringslinjer



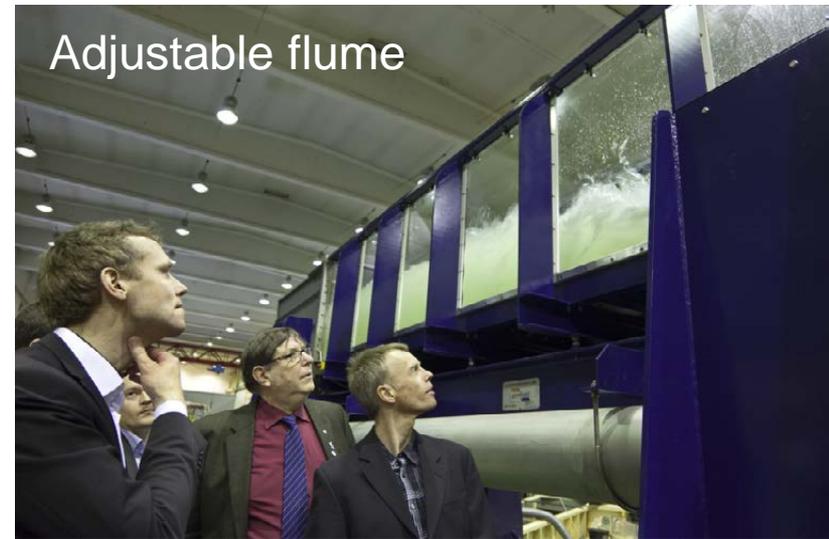
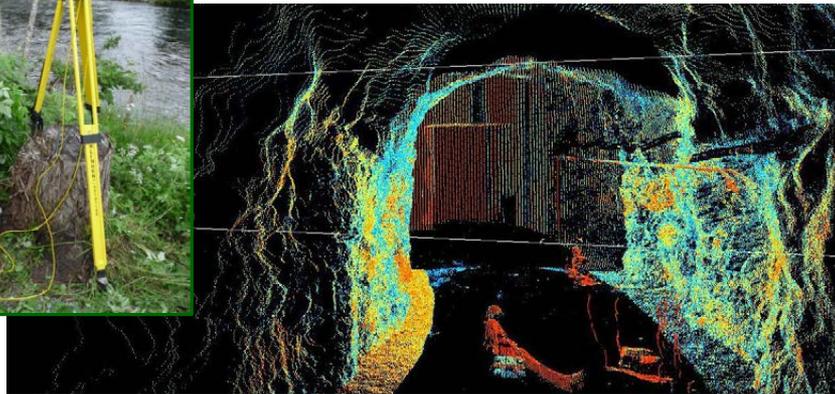
## Hvordan forene miljø- og energipolitiske hensyn?



# Research facilities



Field equipment:  
GPS and laser scanner







**CEDREN**

Centre for Environmental Design of Renewable Energy





**CEDREN**

Centre for Environmental Design of Renewable Energy



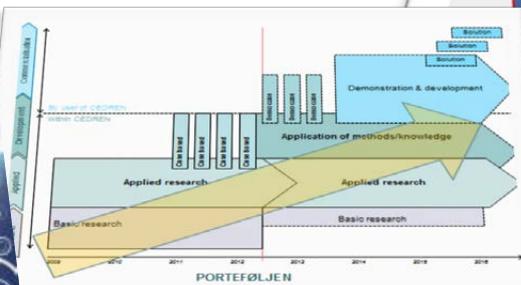
**FEM**  
CENTRE FOR  
ENVIRONMENTAL  
FRIENDLY ENERGY  
RESEARCH

# Media

**CEDREN**  
Centre for Environmental Design of Renewable Energy

## Strategy platform

www.cedren.no



**CEDREN**

Centre for Environmental Design of Renewable Energy

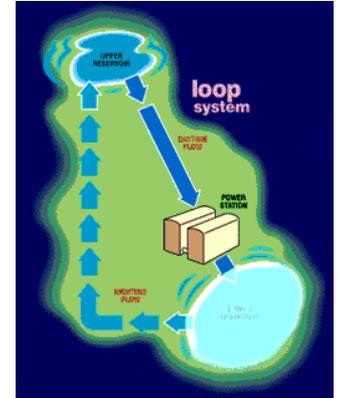
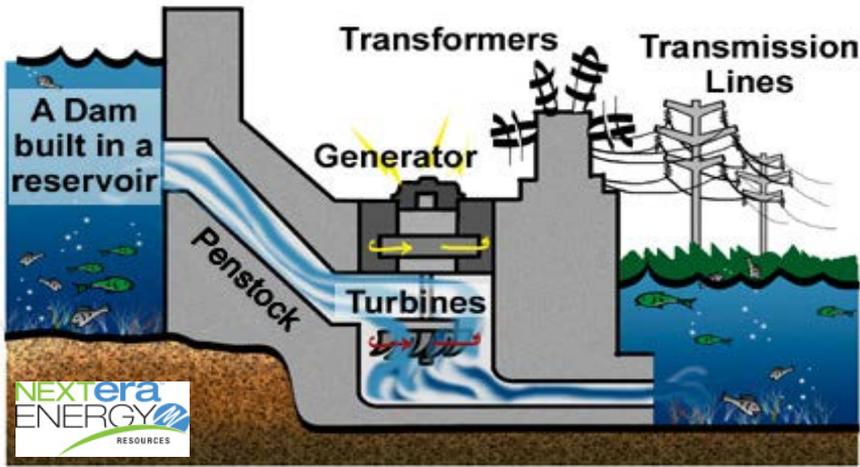
**FM**  
CENTRE FOR  
ENVIRONMENTAL  
RENEWABLE ENERGY  
RESEARCH



## Meetings, workshops, dialogue and collaboration



# Framtidas vannkraft





### Motivation:

- *Increased importance of hydropower peaking due to flexible energy markets*
- *How is bed stability affected by rapid flow fluctuations?*
- *How can effects on flow fluctuations be mitigated?*

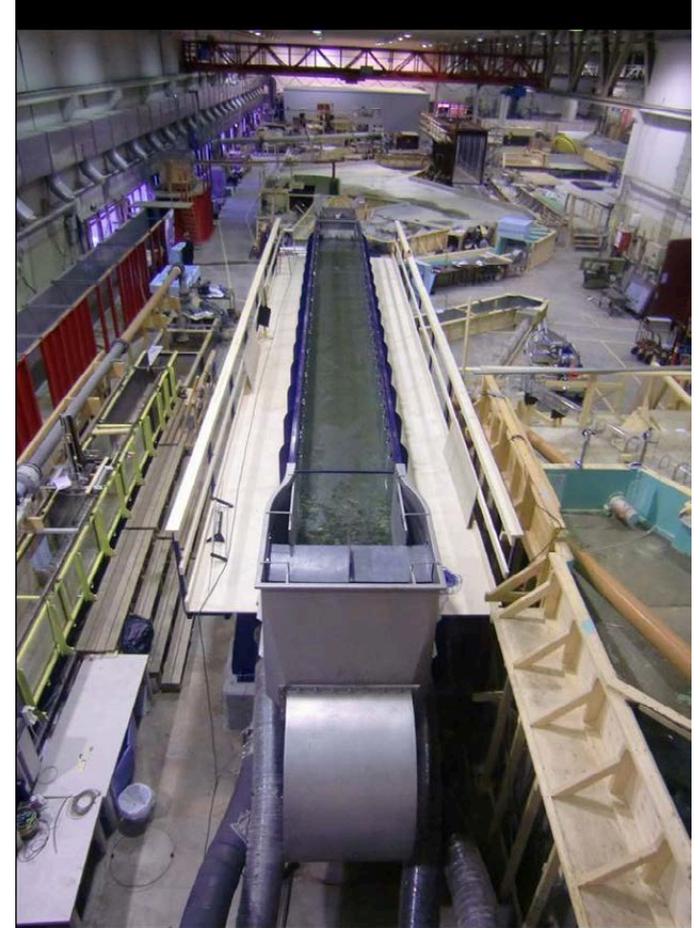


Photo: © Ånund Killingveit, NTNU



Photo: © Stephan Spiller, NTNU

# Åpning av "Ola-renna" 16 Mars 2012

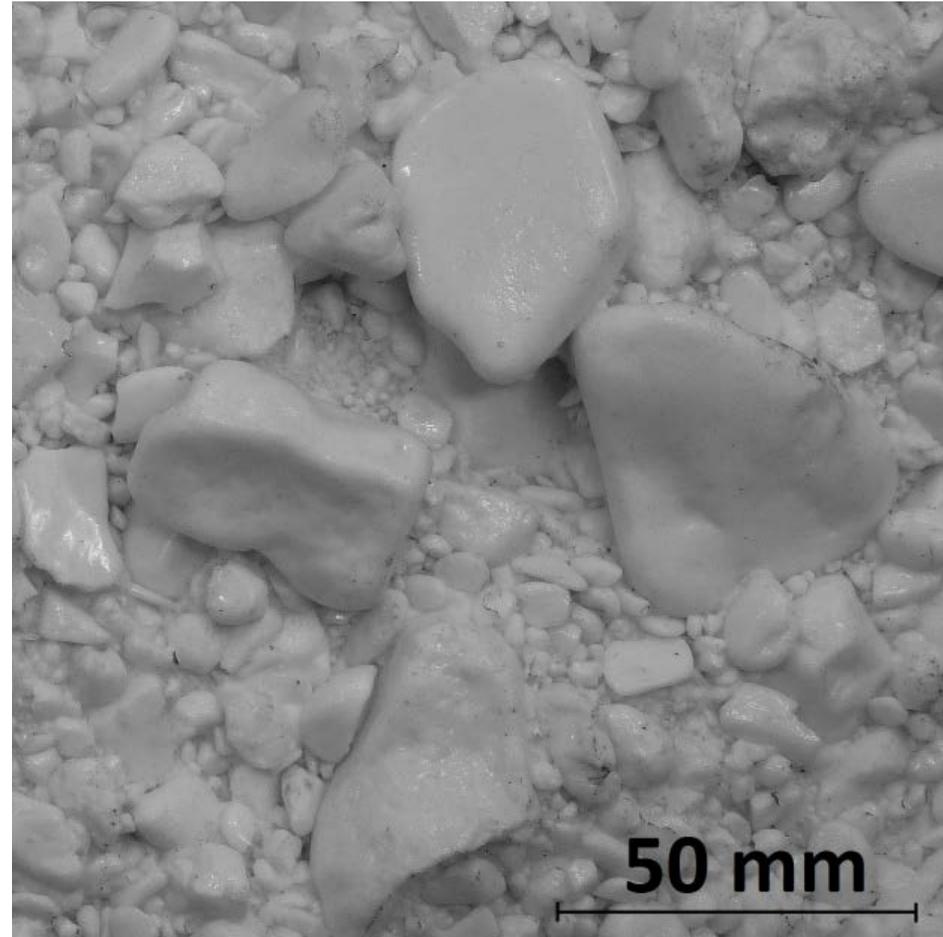


Ny forsøksrenne på vassdragslaboratoriet

Artificial streambed – An exact copy of a gravel bed river  
Making it possible to run repeated experiments with same river bed



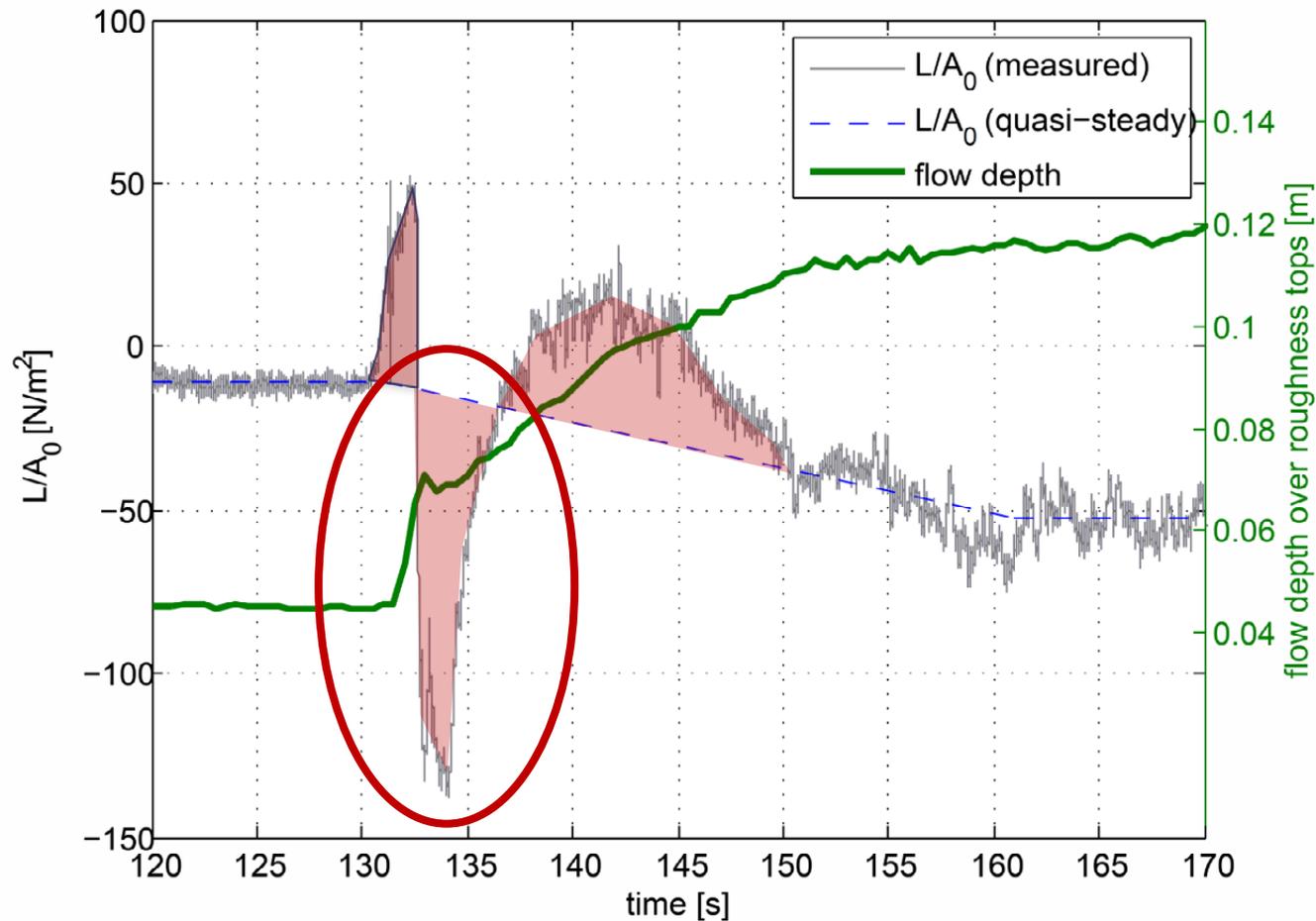
*Static armor layer*



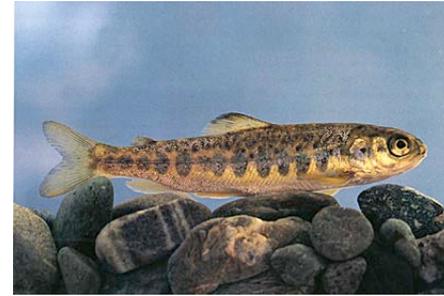
*Artificial copy*

## Results – Lift Force

Unsteady flow can have significant dynamic effects on the lift acting on a streambed compared to the bed-shear stress.



# Hvor mye vann er nok?



for vannkraft og  
økosystemet





**CEDREN**

Centre for Environmental Design of Renewable Energy



**FEM**  
CENTRE FOR  
ENVIRONMENT-  
FRIENDLY ENERGY  
RESEARCH



The image is a collage of three nature-related photographs. The top-left photo shows a clear, green stream flowing over mossy rocks. The top-right photo shows a fast-moving, white-water river with many rocks. The bottom photo shows a large concrete dam in a mountainous landscape with snow patches and a blue lake.

## Øko Hydrologi

- Med god kunnskap og tverrfaglig samarbeid er det mulig å finne gode løsninger
- Vi har nå et veletablert samarbeid mellom biologer, hydrologer og eksperter på kraftverksdrift

Vannkraft

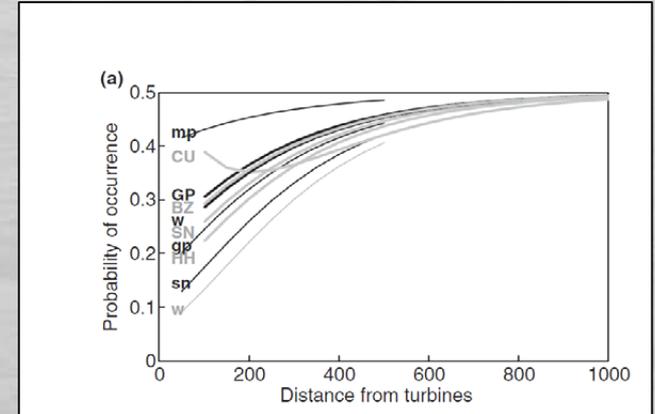
# Birds and wind turbines - always a conflict?



# Vindkraft og fugl – en stedsspesifikt konflikt



# ..... og en artsspesifikt konflikt

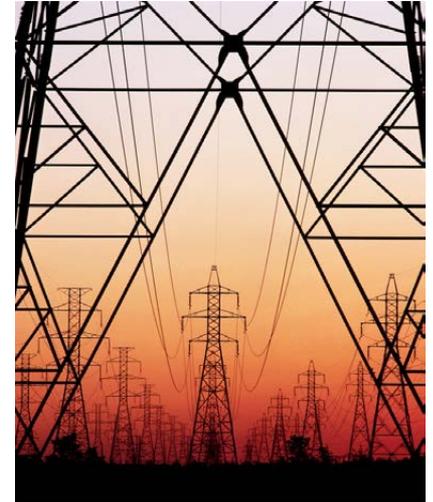


Art	"minskning" i %
Musvåk	41
Myrhauk	53
Heilo	39
Enkeltbekkasin	48
Storspove	42
Heiplierke	15
Steinskvett	44

*Pearce-Higgins et al. 2009*

# Power transmission

- Environmental impacts
- Reducing conflicts
- Sustainable grid development
- Public acceptance



# Overførings- linjer

→ Alltid:  
Miljøvirkning

- Arealbeslag
- Fugledød
- Oppstykking av landskap
- Barrierer
- Visuell effekt
- Elektromagnetiske felt og helse

# Visuell effekt



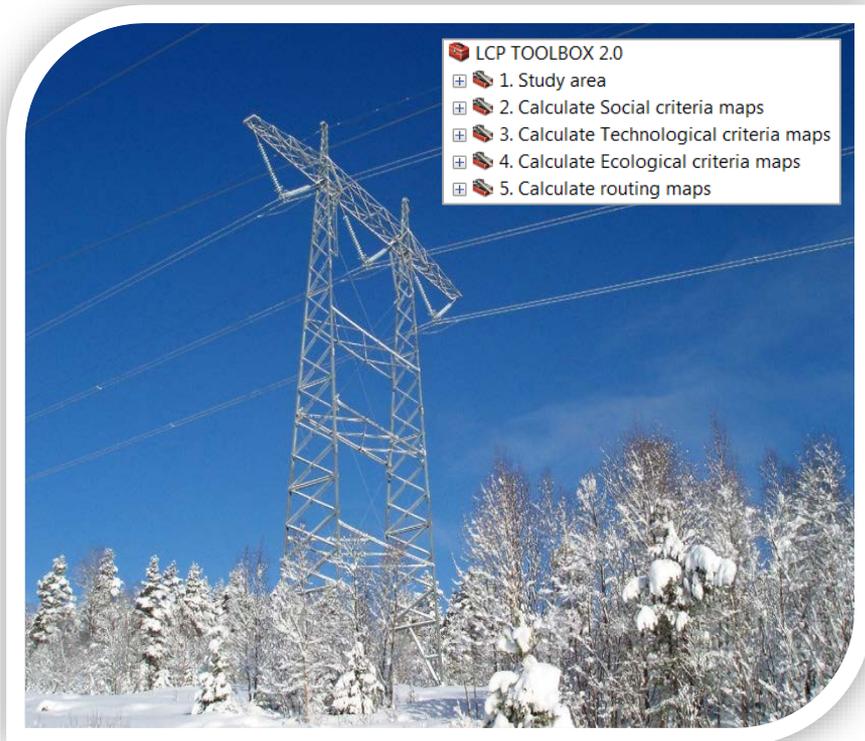


Totalt areal til kraftlinjer i Norge: 1 766 km<sup>2</sup>  
Dovrefjell-Sunndalsfjella nasjonalpark: 1 693 km<sup>2</sup>



# Least Cost Path (LCP)

## - Lokalisering av kraftledninger



**OPTIPOL LCP 2.0**

- Tekniske kriterier
  - Miljøstress, eksisterende inngrep, topografi, bunnforhold og rasfare
- Samfunnsmessige kriterier
  - Friluftsliv, kulturminner, kulturlandskap, bebyggelse, EMS, reindrift, landskaps-estetikk og synlighet
- Økologiske kriterier
  - Naturvernområder, INON, rødlistearter, skogsfugl, rovfugl og villrein
- (Økonomiske kriterier)

# International collaboration

- Access to high-level research
- International user partners
- Seminars, workshops for R&D, authorities and industry
- Together with Norwegian industry
- Case-studies to test our methods

HydroNet (Canada) – CEDREN seminar



CEDREN i Kina



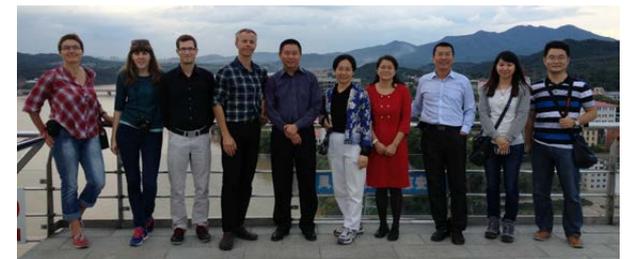
The IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation

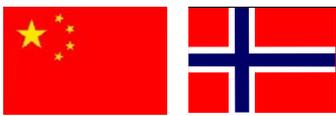


End-user meeting in India

# Environmental design of hydropower

- Environmental flows in regulated rivers
  - New methods
  - Awareness for authorities, NGOs, stakeholders and developers
  - Training in application
  - Applied to Devolli project in Albania and Adjari project in Georgia
- Meetings, seminars and conferences organized in many countries
- Greenhouse gas control in reservoirs
  - Seminars, workshops
  - Training in methods
  - On-site investigations
- University collaboration
  - Teaching, student exchange





# CEDREN in China

## FutureHydro



Visit to Beijing and Fengman Hydropower



Presentations, Discussions



New dam to be constructed at Fengman



Group work

# Re-regulation dam



Purpose:  
dampening of  
hydro-peaking

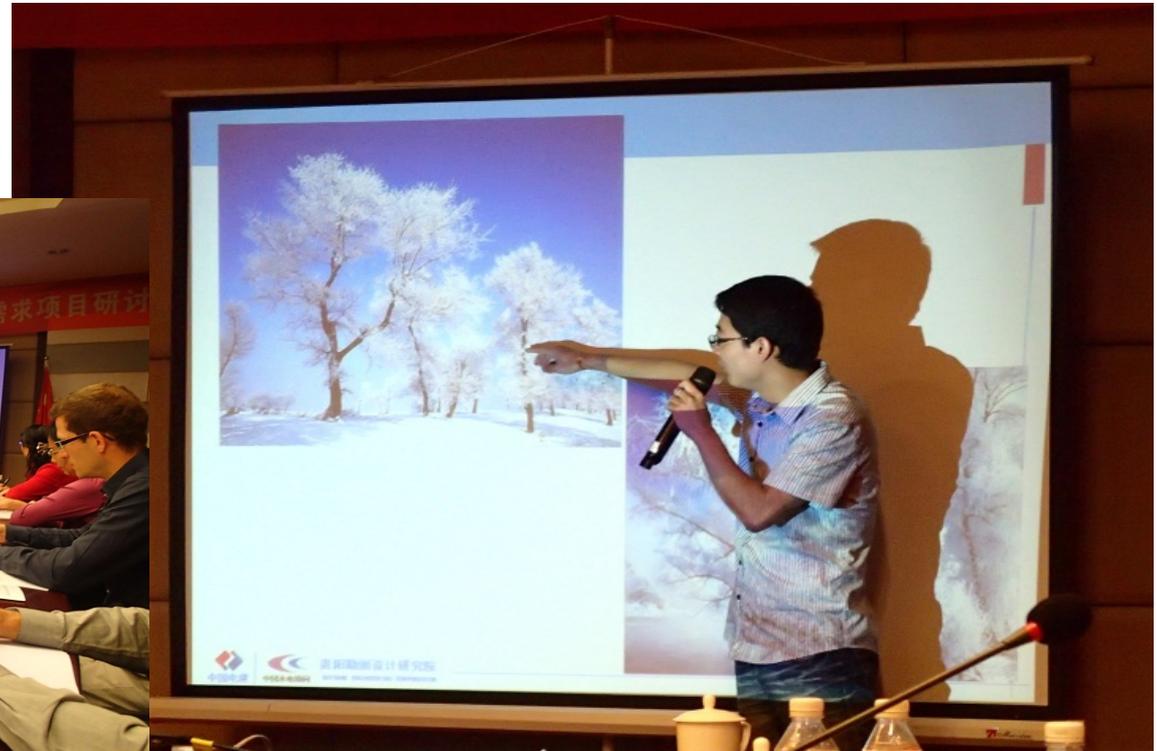


Discussing the  
planned position of  
the fishway at the  
re-regulation weir



# Fengman power company

Day 4,  
Meeting with Fengman  
power company



Among the special requirements which the power company has to fulfill:  
Release of water for the "Ice Tree Festival" during night time over three months.

# Fokus på magasin



## Run-of-river hydro

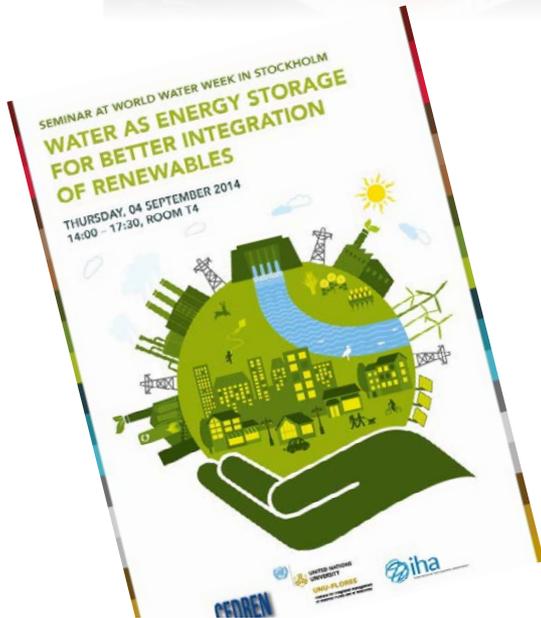


# Hydropower typology, covering all scales of development

## Storage hydro



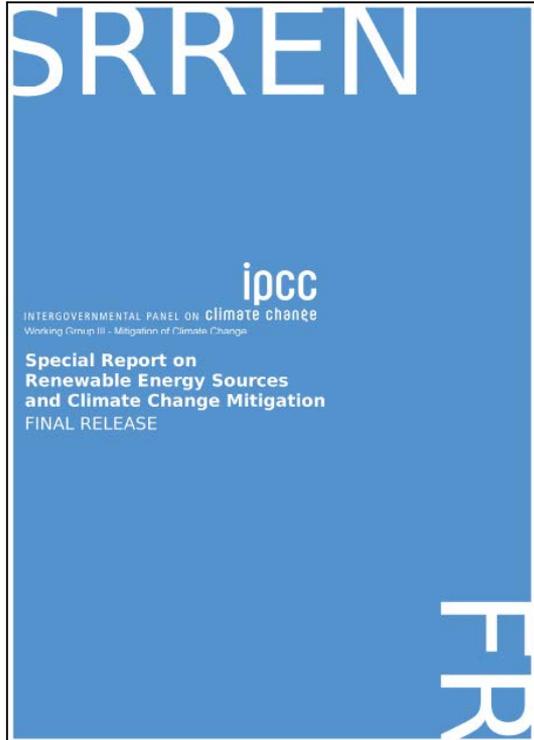
## Pump-storage hydro



*Seminar at World Water Week, Stockholm, Sep 2014*

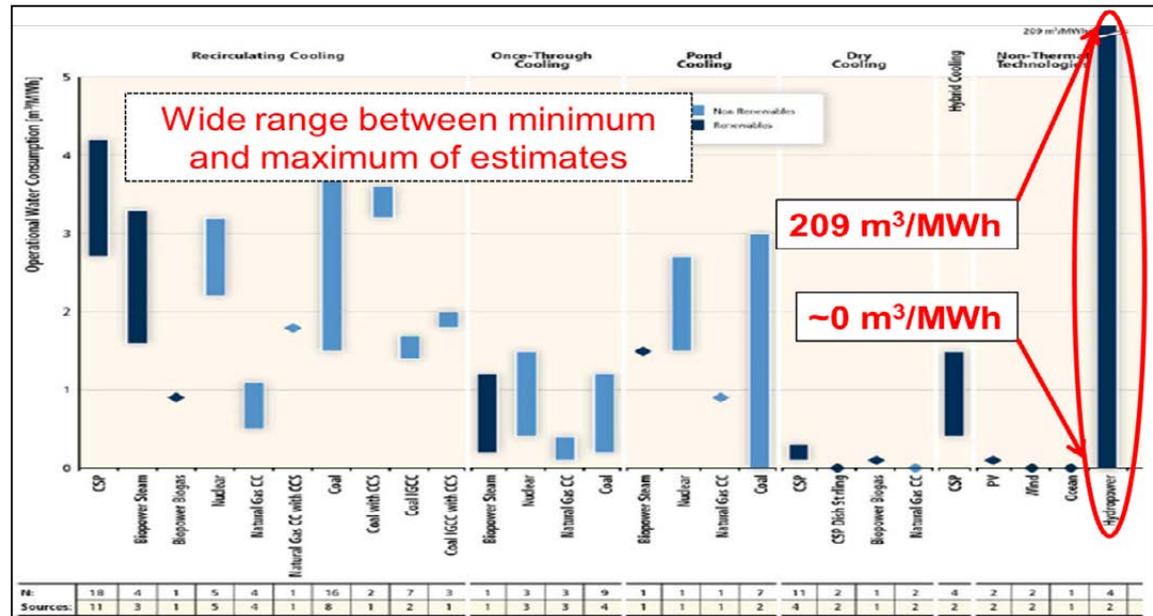
*From Taylor, IHA*

# Water consumption - what raised the attention?



IPCC Special Report on Renewable Energy (2011):

- The different technologies benchmarked with respect to various criteria, including 'water needed to produced 1 MWh electricity (*water consumption*)'

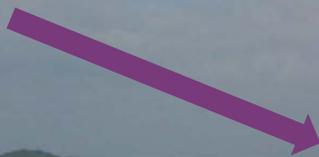
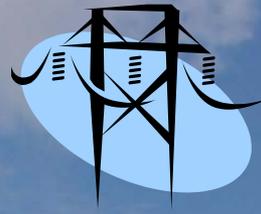


Source: IPCC (2011)

How to allocate the losses to the different uses of the reservoir?



Water losses -  $m^3/year$



Functions of the reservoir



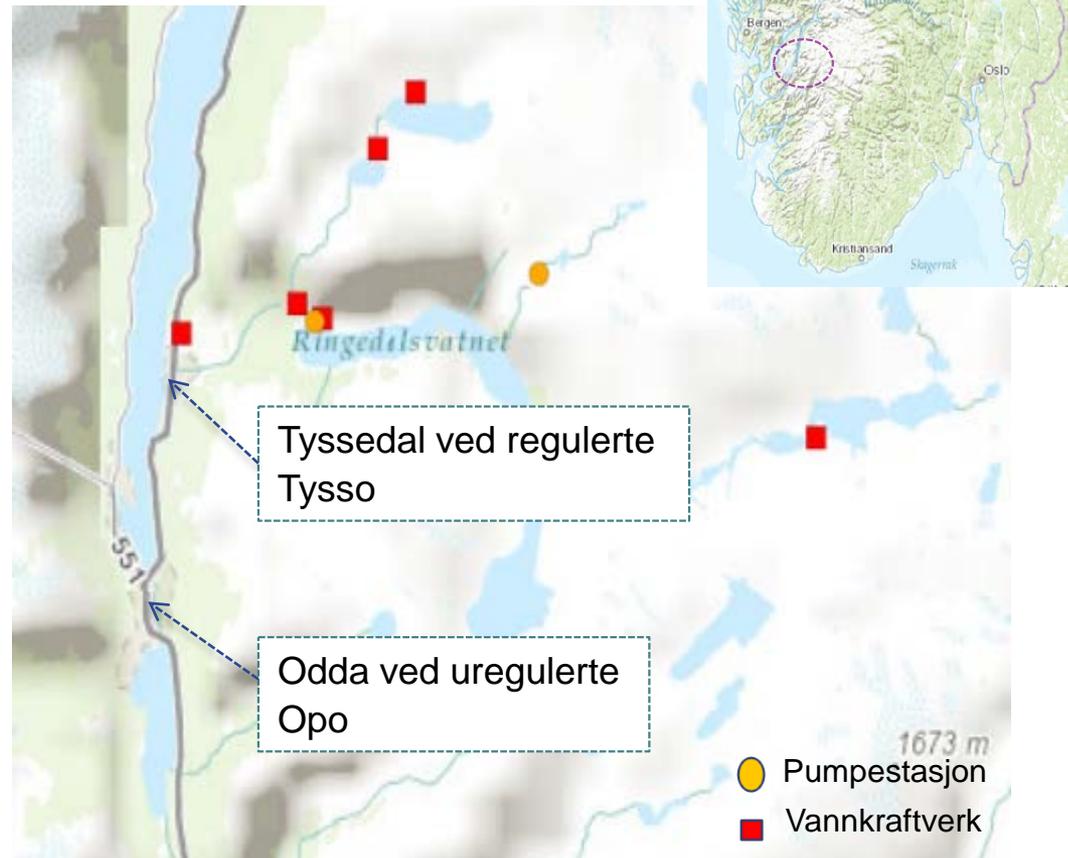
# Odda ved vernede Opo – oktober 2014



fra Jan Alne  Statkraft

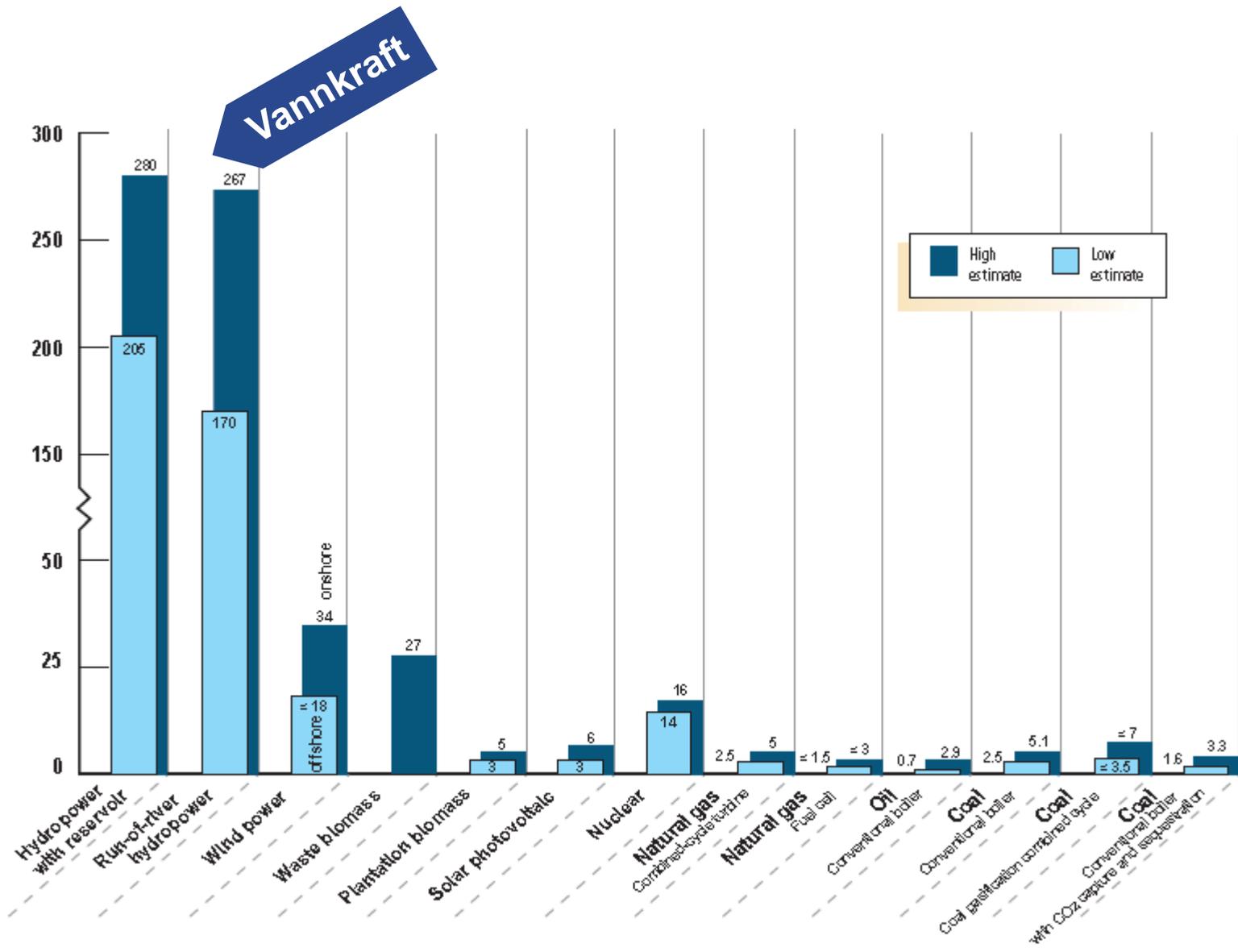
# Tyssedal og Odda oktober 2014: Regulert vassdrag hindret flom

- Tyssø – regulert vassdrag
  - Ca. 500 m<sup>3</sup>/s tilsig redusert til ca 10 m<sup>3</sup>/s gjennom Tyssdal sentrum
  - Kraftig flomdemping og ingen skade ved aktivt bruk av magasiner
- Opo – vernet vassdrag
  - 780 m<sup>3</sup>/s tilsig i Opo
  - Ingen mulighet til flomdemping og store skader i Odda sentrum



fra Jan Alne  Statkraft

# «Energy Payback Ratio» (EPR) viser hvor effektiv en teknologi er



# Energy storage technologies

## 1) Electrochemical Storage

Batteries, Super Capacitors

## 2) Chemical Storage

Hydrogen, Methanol, Ammonia

## 3) Thermal and Geothermal Storage

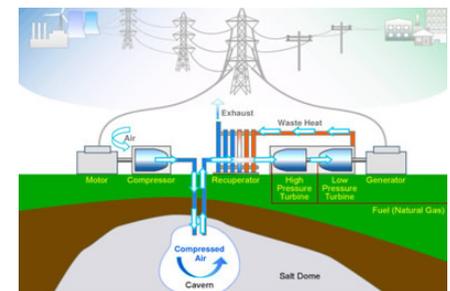
Heat, Advanced Fluids, PCM, Cold

## 4) Mechanical Storage

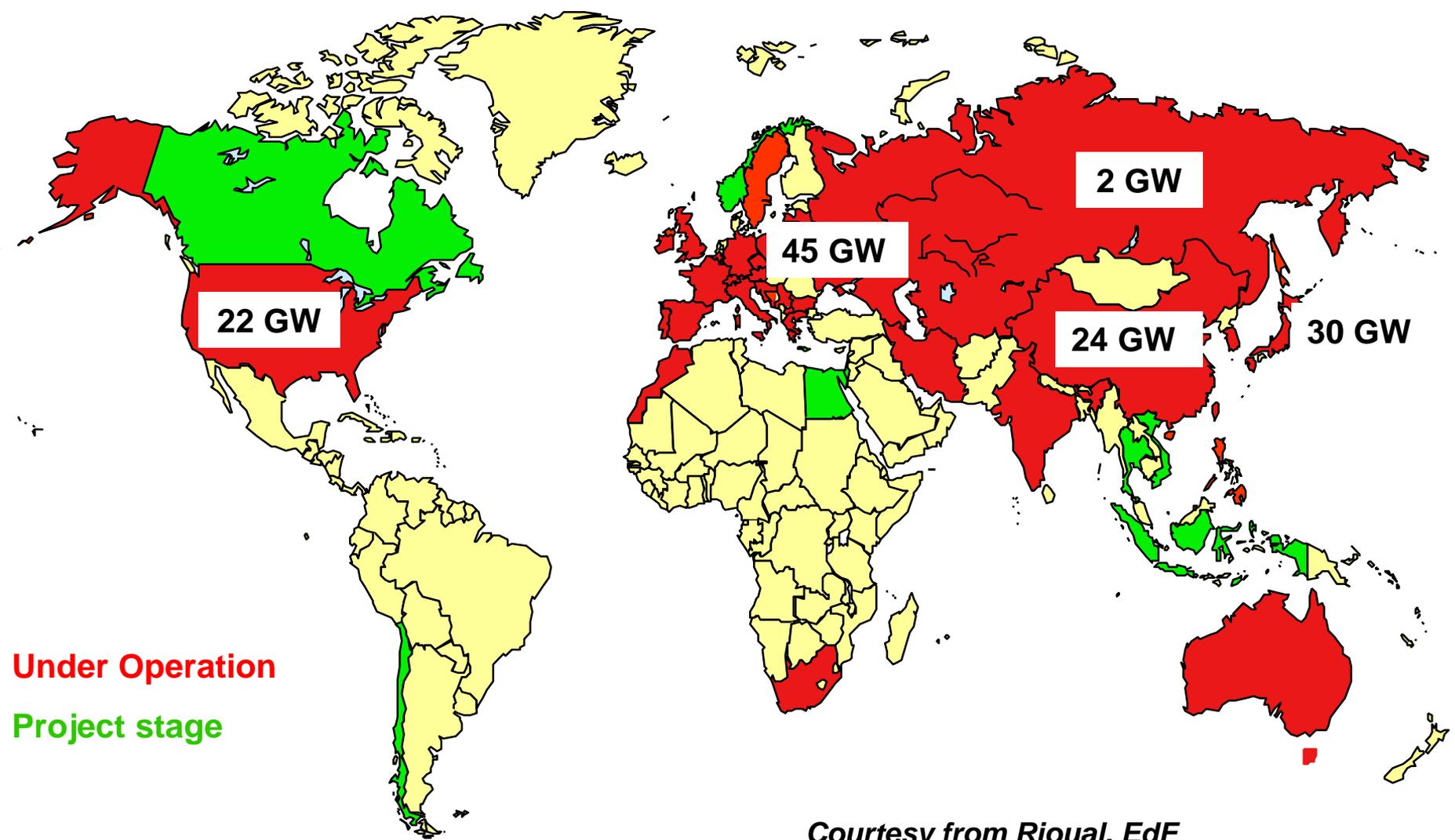
Hydro, Flywheels, Compressed Air

## 5) Superconducting Magnetic Energy Storage

99 %



# Installed PSH world-wide: ~140GW



Under Operation

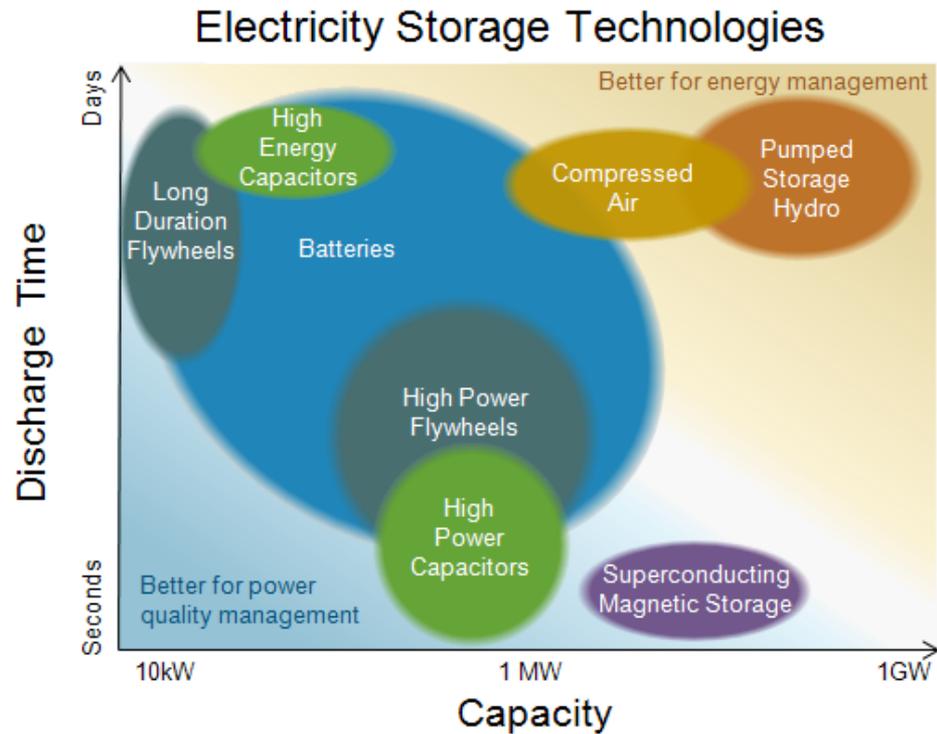
Project stage

Courtesy from Rioual, EdF

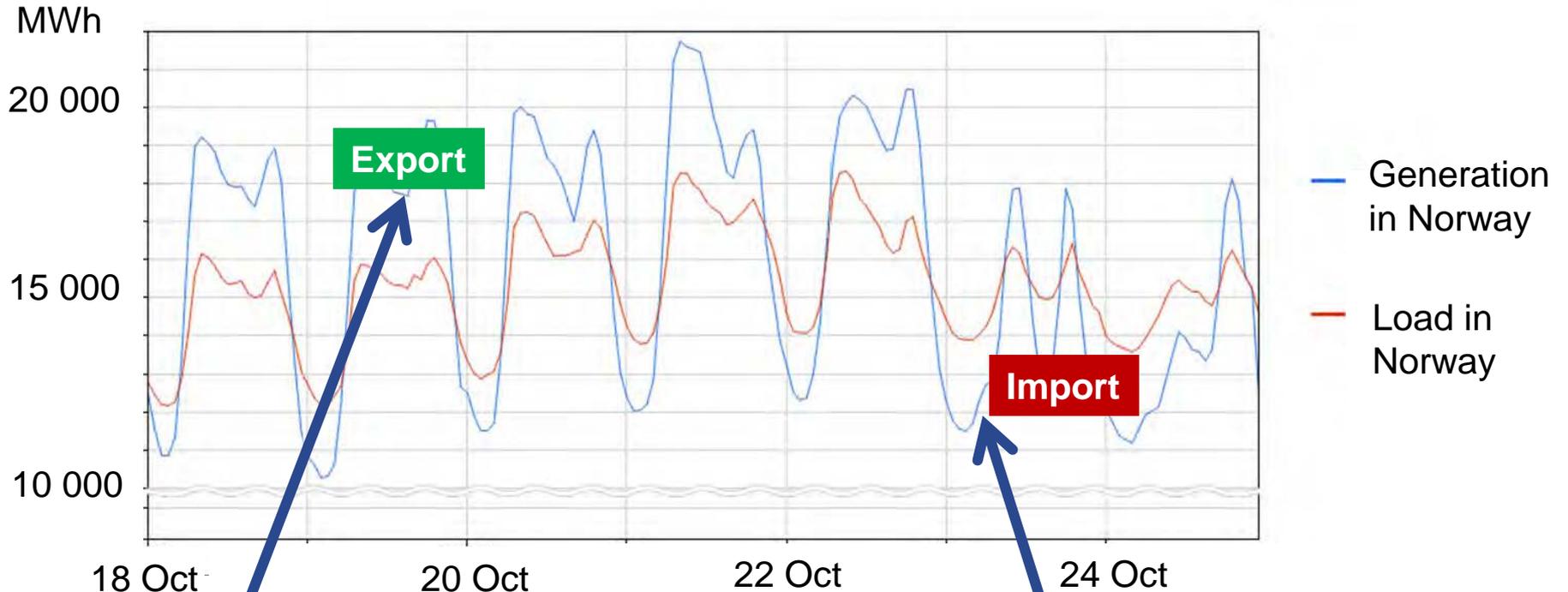
# Conclusions

## Energy Storage

- We need more energy storage – better grid cannot solve all lack of storage
- We need all technologies for energy storage - plus some future ones
- Different technologies operate on different time scales with different volumes of storage  
→ There is no "one size fits all"
- Use a combination of many storage options
- Reservoir and pumped storage hydro are the most efficient and cheapest large-scale storage option



# Norwegian hydro and Danish wind





# 10<sup>th</sup> International Symposium on Ecohydraulics 2014

Norwegian University of Science and Technology  
Trondheim, Norway, June 23<sup>rd</sup> - 27<sup>th</sup>



#ecohyd



[www.cedren.no](http://www.cedren.no)

Contact: [atle.harby@sintef.no](mailto:atle.harby@sintef.no)



NATURHISTORISK MUSEUM  
UNIVERSITETET I OSLO

