### Large scale balancing from Norwegian hydropower







CEDREN

### PROGRAM

### <u>11th September</u>

- 14.40
- 16.00-19.00
- 20.00

### 12th September

- 8.30-12.30
- 13.30-18.30
- 20.00

### 13th September

• 9.00-12.00

Arrival in Sand. Lunch Results from CEDREN Dinner

National and international invited speakers from research, industry and authorities Excursion to Blåsjø reservoir and one of the Ulla-Førre hydropower stations Dinner

Workshop on research needs and requirements for future work Departure by boat to Stavanger



• 14.40

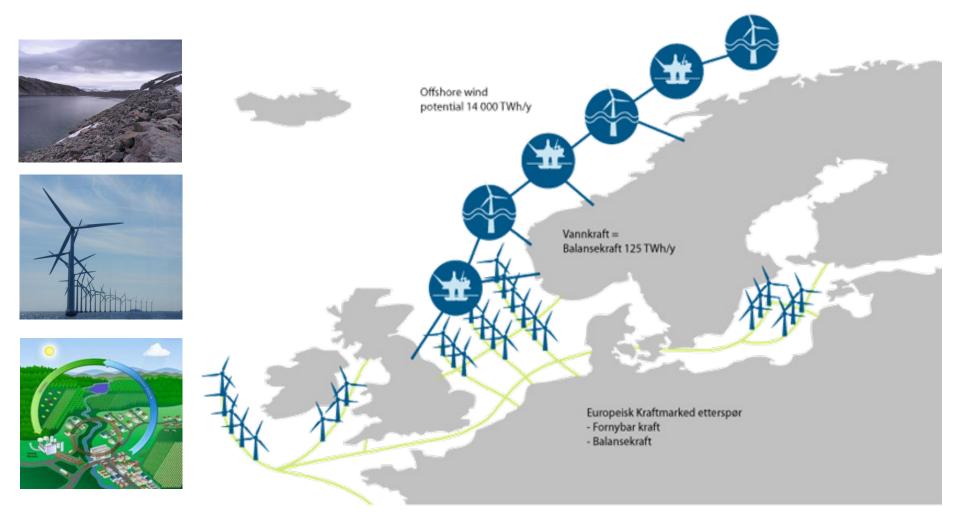
### **Tuesday 11 September**

- 15.45 Welcome and opening Atle Harby, CEDREN
- 15.50 *The potential for hydropower to mitigate climate change impacts* Ånund Killingtveit, CEDREN
- 16.10 CEDREN's activities and ambitions related to balancing power and pumped s torage hydropower Atle Harby, CEDREN
- 16.30 *How can Statkraft become "the green battery" of Europe?* Arne Sandvold, Statkraft
- 16.50 *Transition to 100 % renewable electricity in Germany the role of Norwegian hydro storage* Gesine Bökenkamp, University of Flensburg
- 17.10 Break
- 17.40 Simulating pumped storage operation in reservoirs used for balancing of wind power Julian Sauterleute, CEDREN
- 18.00 Impacts of pumped storage hydropower on the ecosystem of reservoirs Line Sundt-Hansen, CEDREN
- 18.20 Social acceptance of balancing power and pumped storage hydropower in Norway Helene Egeland, CEDREN
- 18.40 Opportunities and challenges for large scale balancing power seen from a regional and local point of view Trond Schrader Kristiansen, Vest-Agder County





### Energi21 and The Parliament → 8 new research centres on environmental-friendly energy







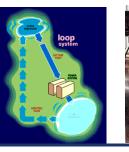
### **CEDREN - Renewable energy respecting nature**

- 8 large research projects
- 7 Norwegian research partners + many international
- 13 Industry partners and 2 management partners
- Budget: 36 MEuro (8 MEuro in 2012) financed by the Research Council and the Energy industry
- 16 PhD and 4 Post-doc positions



#### Hydropower technology







Environmental impacts of hydropower







Environmental impacts of wind power and power transmisson







How to reconcile energy and environment policy?









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.

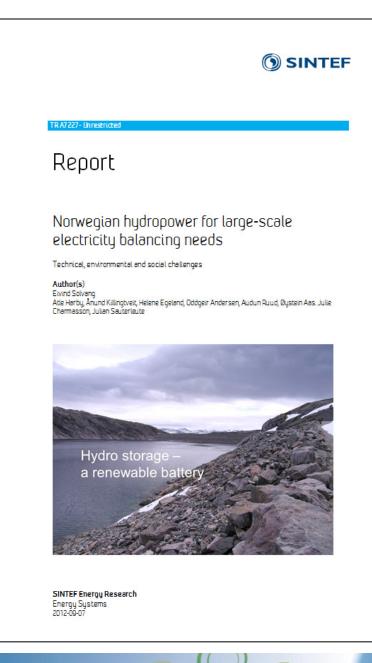
Statkraf

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

# Hydro storage – a renewable battery

### Norwegian hydropower for large-scale electricity balancing needs

- Balancing needs from variations in wind power production
- 20 000 MW of increased capacity
  - Using existing reservoirs between HRWL and LRWL
  - New tunnels and new hydropower and pumped storage plants
- Societal legitimacy
  - Stakeholders' interest and concerns
- Impacts on water volume, stage and area in reservoirs
  - Model description, three cases, results
- Impacts on CO<sub>2</sub> emissions
- Grid development challanges
- GIS-based method for evaluation of plant sizes and locations





### Large scale balancing from Norwegian hydropower







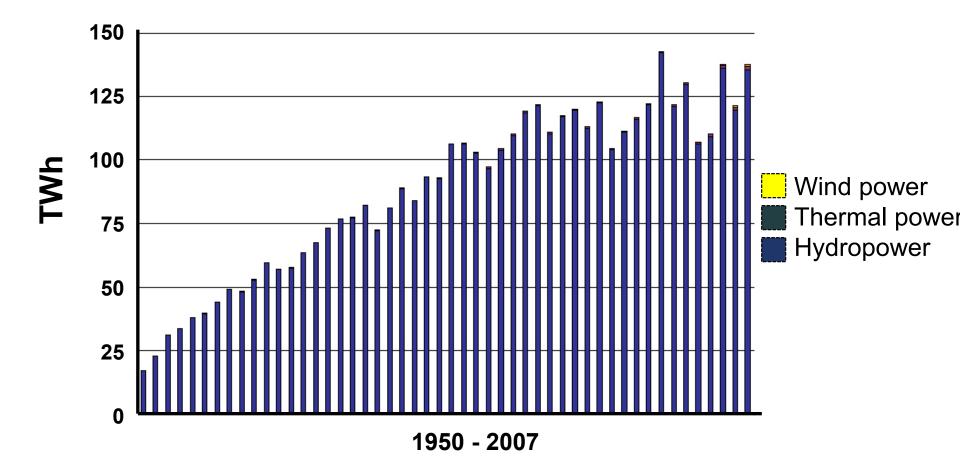
CEDREN

# Some facts about the Norwegian hydropower system

**MINISTIN** 

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# **Electricity production Norway**



Source: Norwegian Energy and Water Directorate



# Norwegian hydropower



Natural lakes used as reservoirs





#### Multi-year reservoirs







### Norwegian hydropower

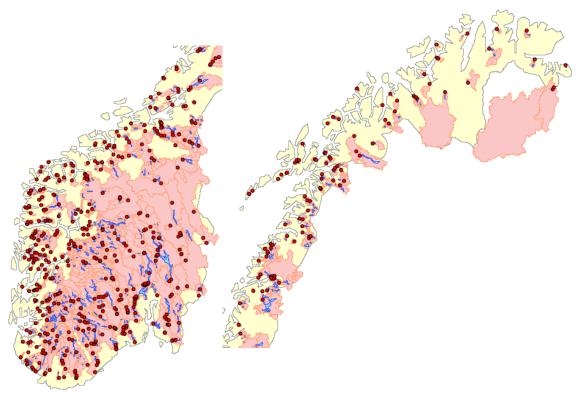


# Solid rocks providing great opportunities to hide penstock and power plants inside the mountains





### Norway





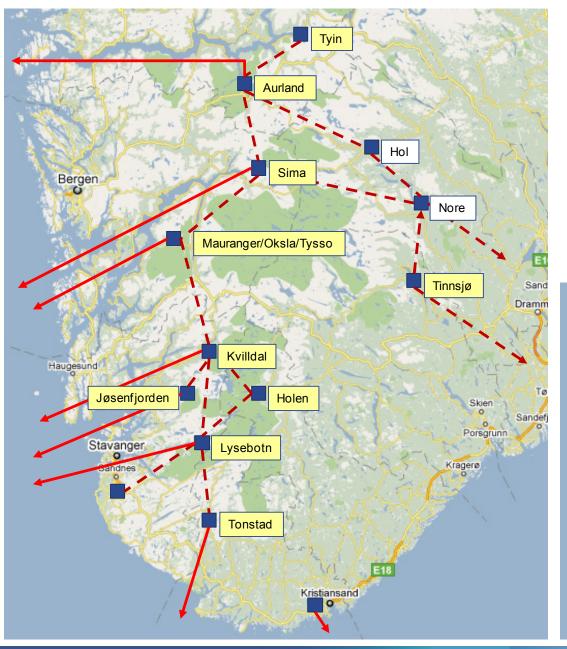


- Hundreds of large reservoirs
- 20 reservoirs with more than 100 Mm<sup>3</sup> both up- and downstream

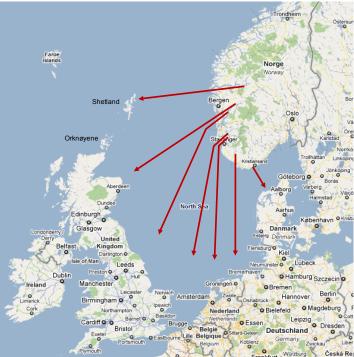






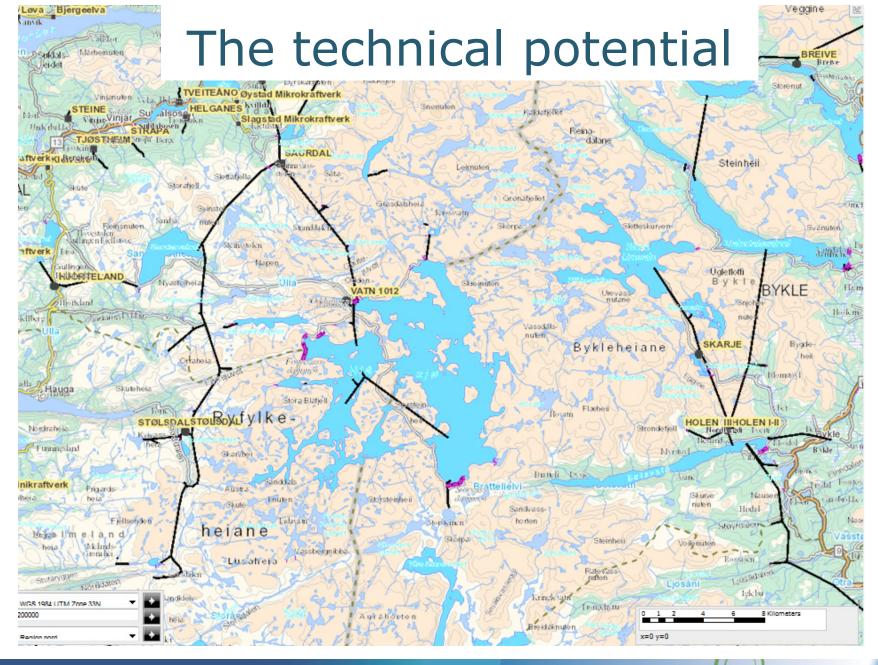


### CEDREN Case study 2030



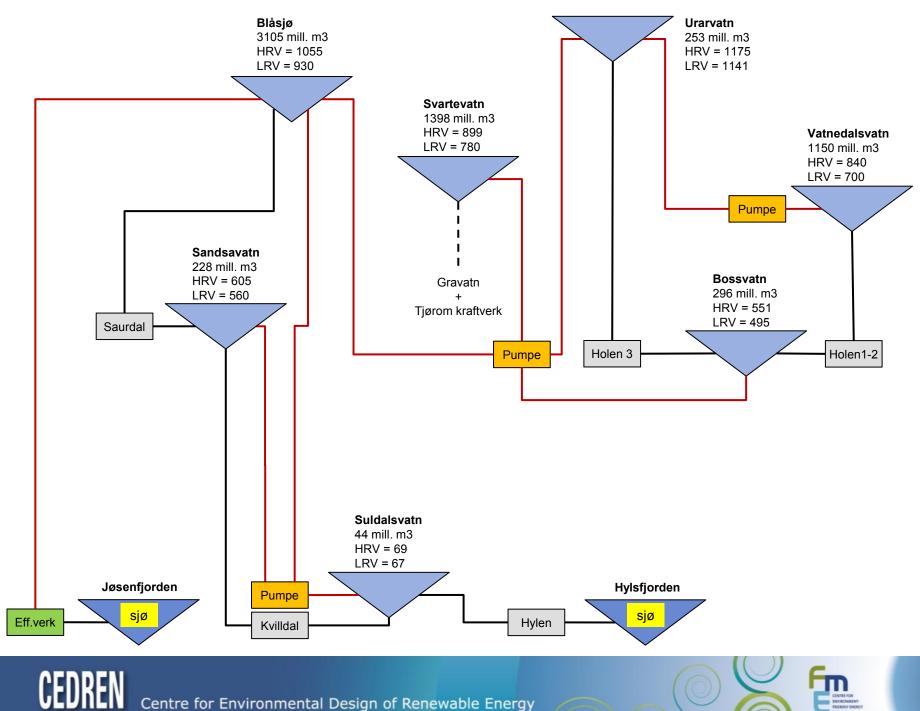












#### Veggine The technical potential Märbeinuten

Leinnuter

Skielinuten

Ressam

Kaldafjellet

Gronafjellet

Skorpa

Reina-

datane

Slotteskurven

Upeyass

Snonuten

Graodalsheia

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Storenut

BYKLE

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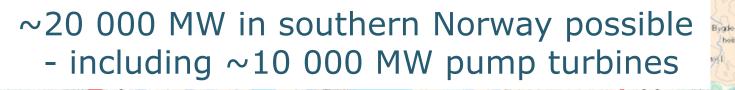
OID.

Florm

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为出华的







Løva Bjergeelva

Subbala

Jeidet

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Skuta

Sullingen

Hioricland

Hayga

Hovestolen Gallingen Fiellstore

HUNR TELAND

Aller

Vinjanuten Vela II-lan

TJØSTHEM MOTO BARA

Feinsnuten

Vinne Vinjar Su' alsos HEL

STRAPA

Storafic

**Vyastolhe** 

Sandsa

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Slettabell

Skinsstokn

Napen

ANES Miller

Slagstad

likrokraftverk

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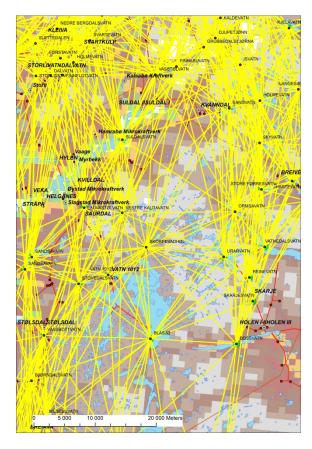
RDAL

Sata

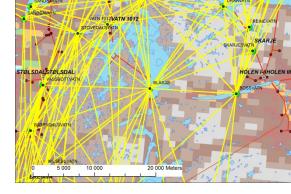
VA'

1012

anvik



Distance criterium



DIUPETIC

BRE

KVANNE

VASSTOLVATI

Keftver

bø Mikrokraftver

+ Terrain criterium

NEDRE BERGDA

TAVADTEVAT

SPARTKULP

**Ovstad Mikrokraftve** 

SAURDAL

ad Mikrokraftver

KLEIVA

100.

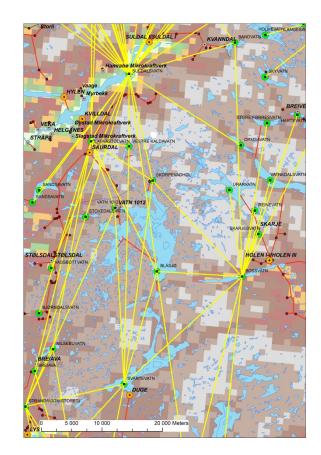
STORLIVATNDALVATN

VERA

STRAPA

HELG/

EDALEN



+ Power plant criterium

Blåsjø-area: GIS-based suitable connection lines





# **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



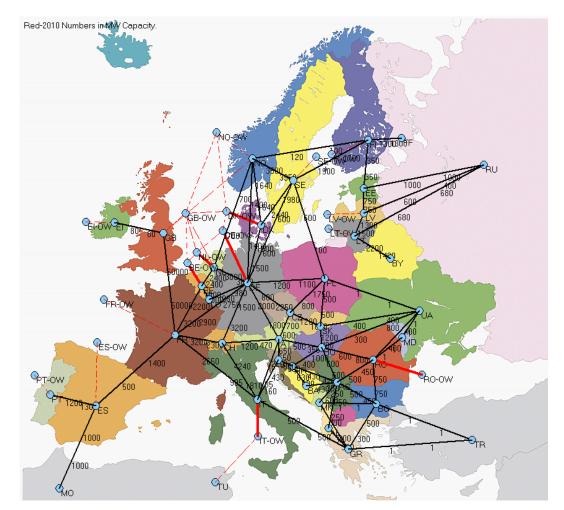






# Market design

- Inter-governmental agreements
- Benefit for all parties:
  - Reservoir owner
  - Cable connection owner
  - Energy company on the continent
  - Local communities
  - ....and climate!





# **Environmental impacts**

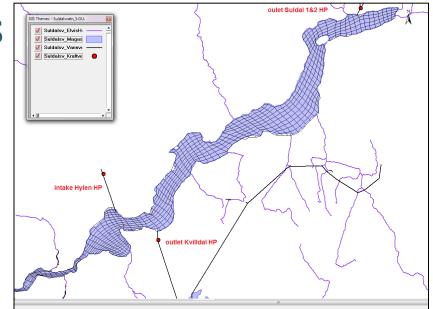


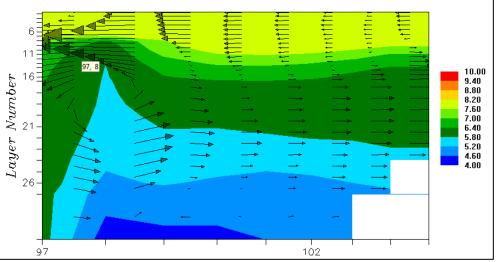
# **Unsafe ice conditions ?**

### **Detailed simulations** of PSP with outlet into Suldalsvatn



#### Simulations with GEMSS

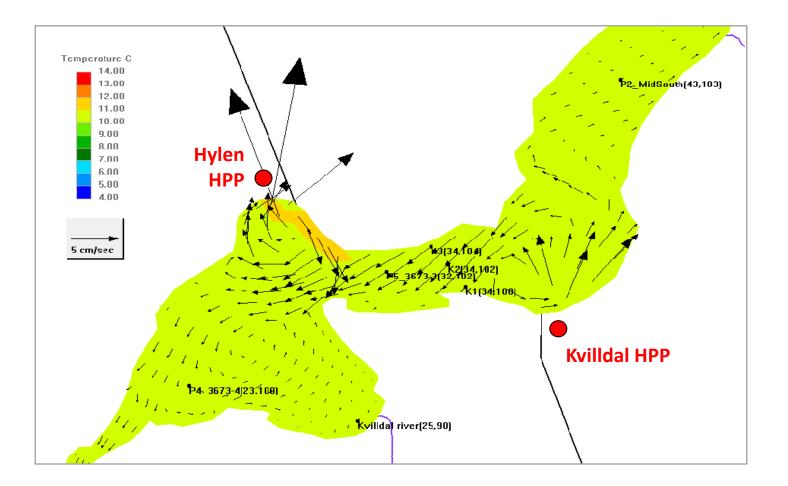




Temperature C

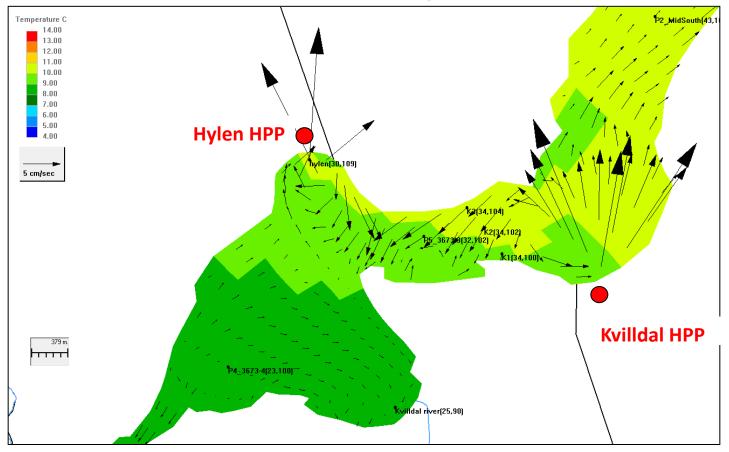


# 10 m depth in summer - today



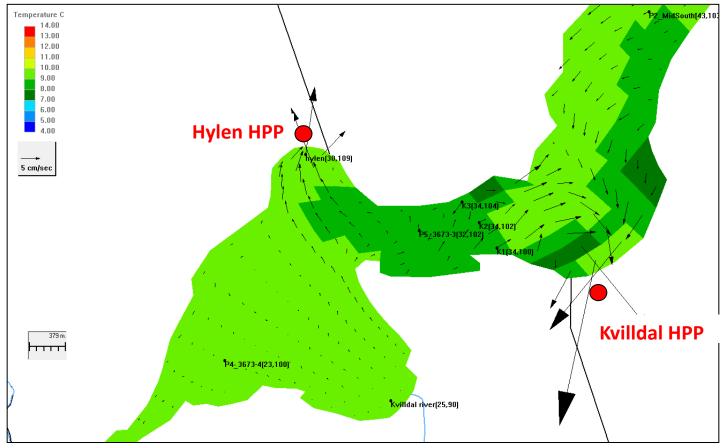


### 10 m depth in summer – with PSP Production phase





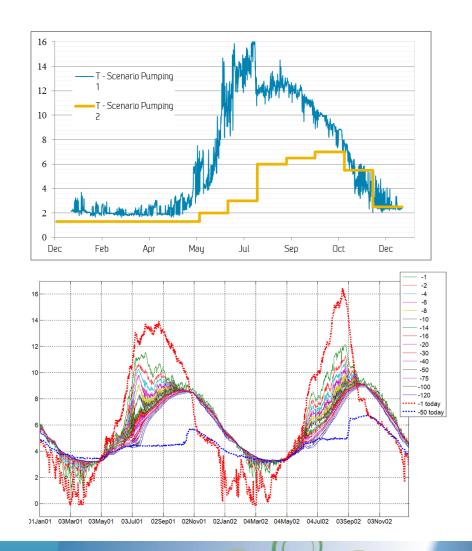
### 10 m depth in summer – with PSP Pumping phase





# Results

- Intense vertical mixing through the water column
- Colder temperature in the downstream river Suldalslågen during summer and autumn if water comes directly from Blåsjø
- Strong currents appear next to the new power plant





### Social acceptance









### www.cedren.no

### Contact: <a href="mailto:atle.harby@sintef.no">atle.harby@sintef.no</a>



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