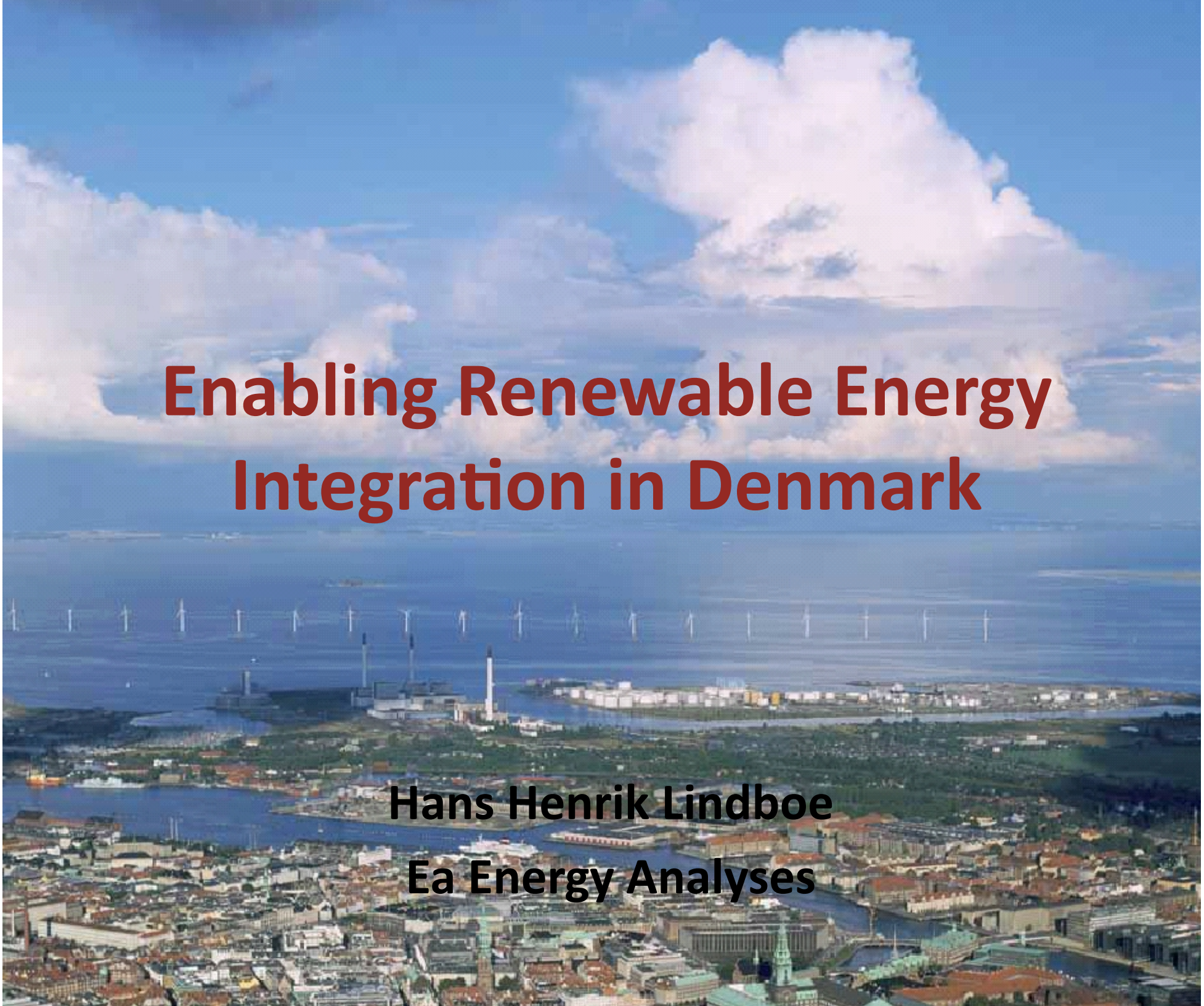


Enabling Renewable Energy Integration in Denmark

Hans Henrik Lindboe

Ea Energy Analyses

Ea Energy Analyses

Systems Analysis-Strategies-Markets -R&D

- Private Research and Consulting company based in Copenhagen. 34 employees.
- Partners have experience base in Utility, TSO, Regulator, University….

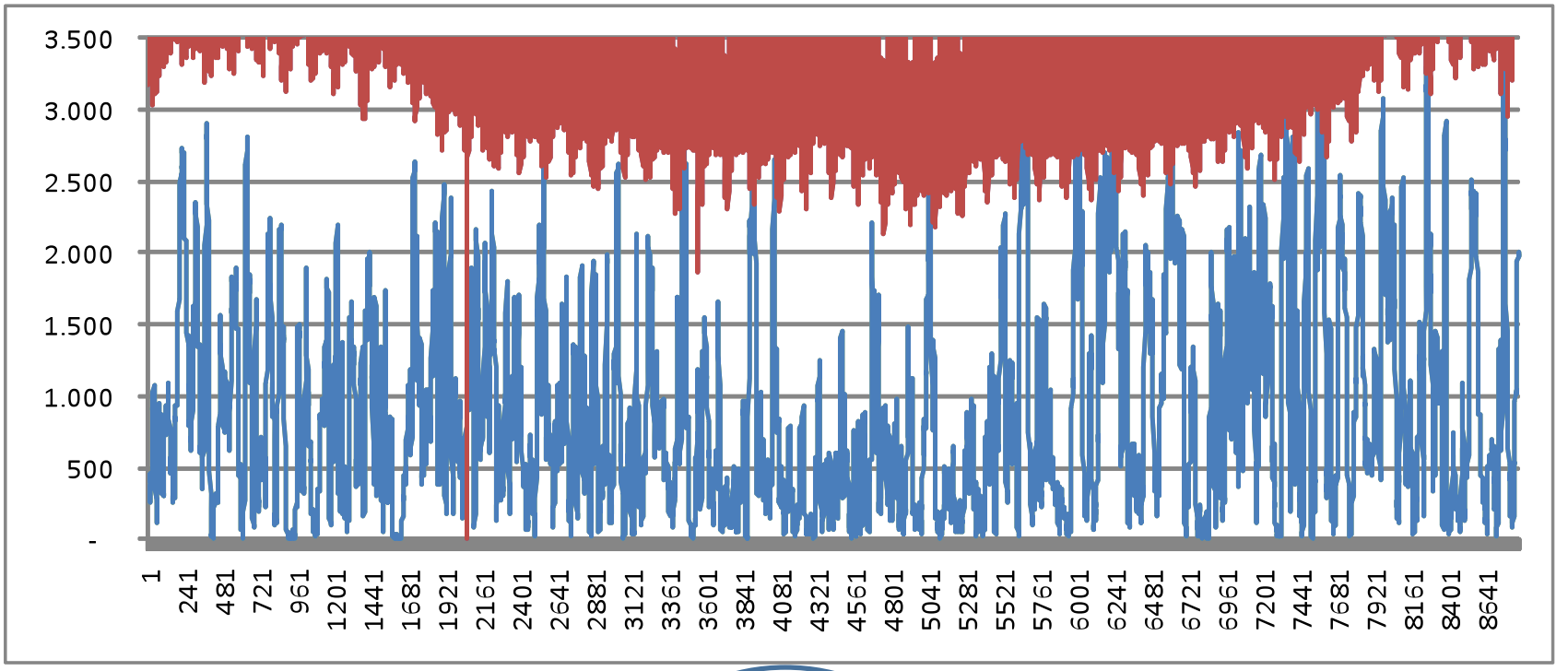
- Linear modeling of electricity, gas and district heating systems and markets.
- Our projects are often financed by Energy Companies, Utilities, Authorities and R&D funds.
- We also cooperate with universities as visiting lecturers and as mentors for thesis writers in our fields.

Ea Energianalyse

Wind and consumption 2010

22% wind (compared to consumption)

2 hours overflow



2025:
50% wind
932 hours
overflow

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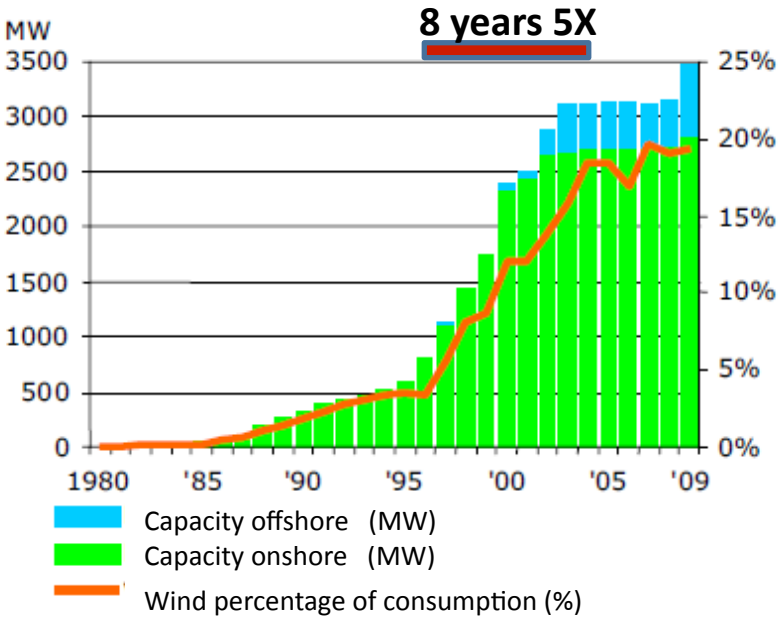
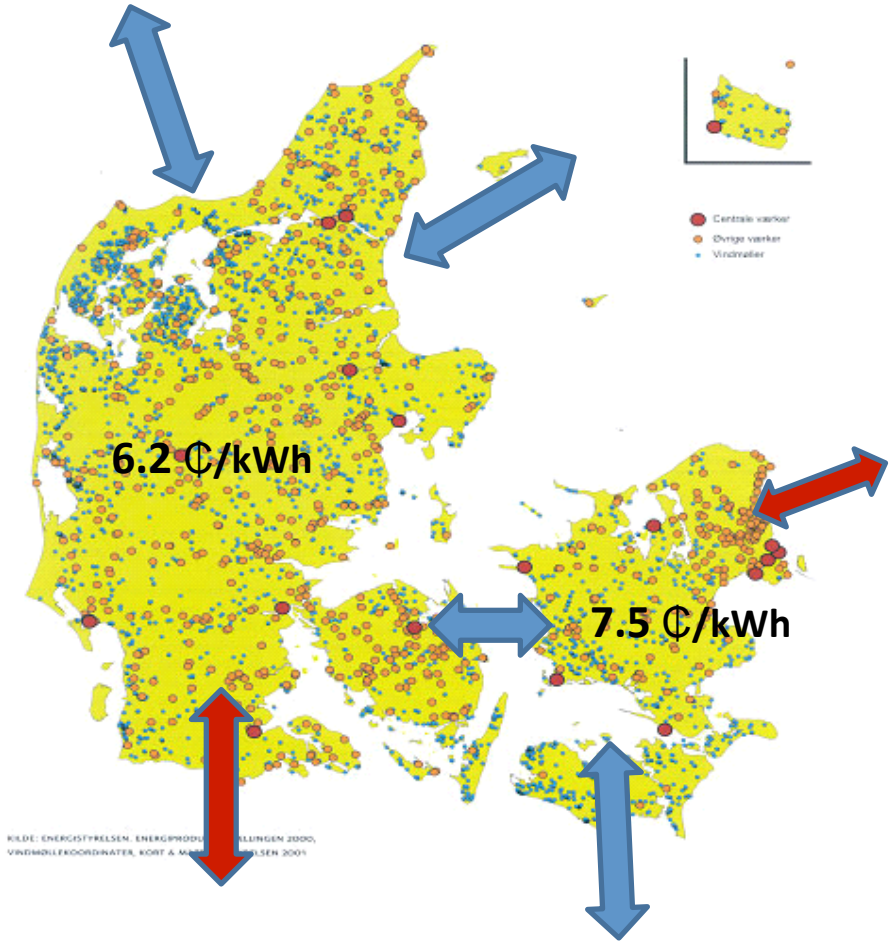
Denmark 2010

5,5 mio people, 35 TWh elec (22% wind), 36 TWh DH

	W (MW)	E (MW)
Load	2380	1585
Central C	3400	3800
DG	1700	650
Wind	2600	970
Trans	3240	2300





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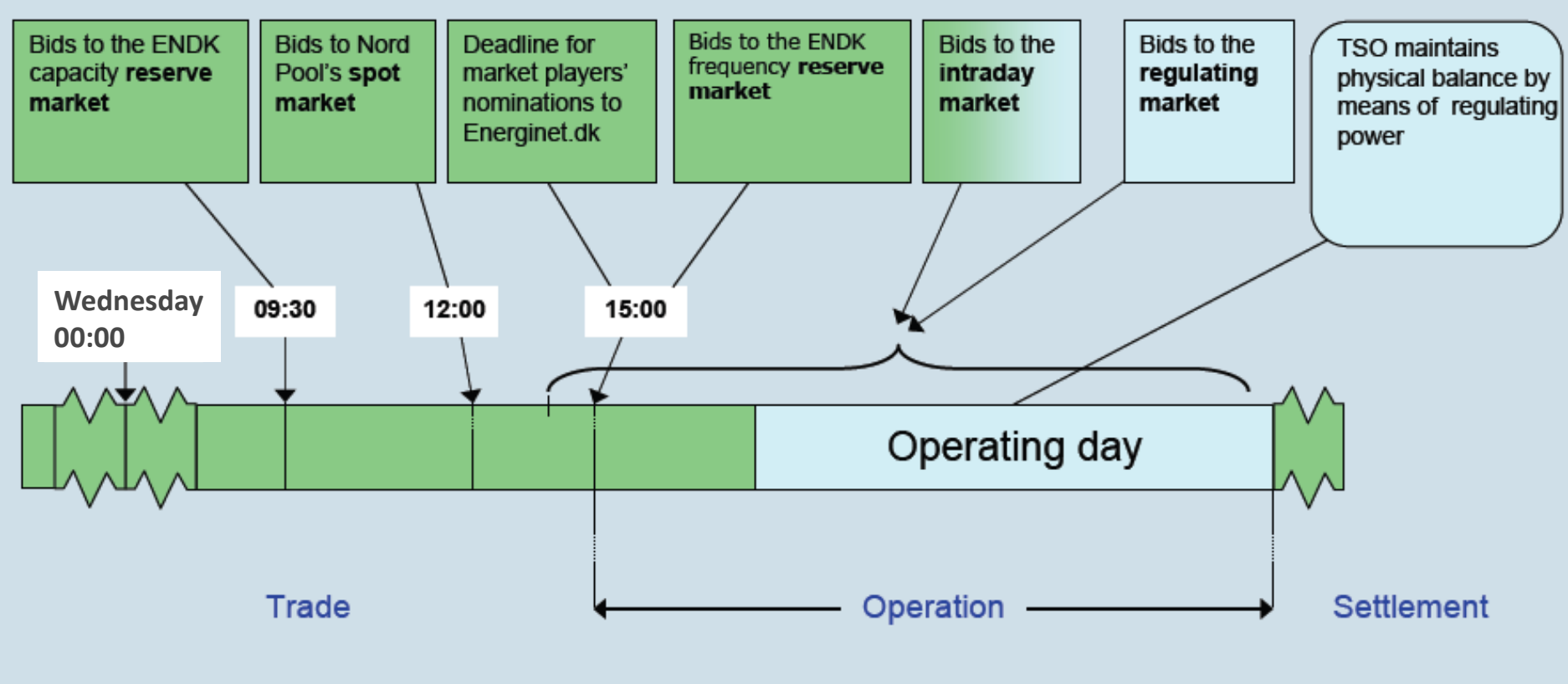
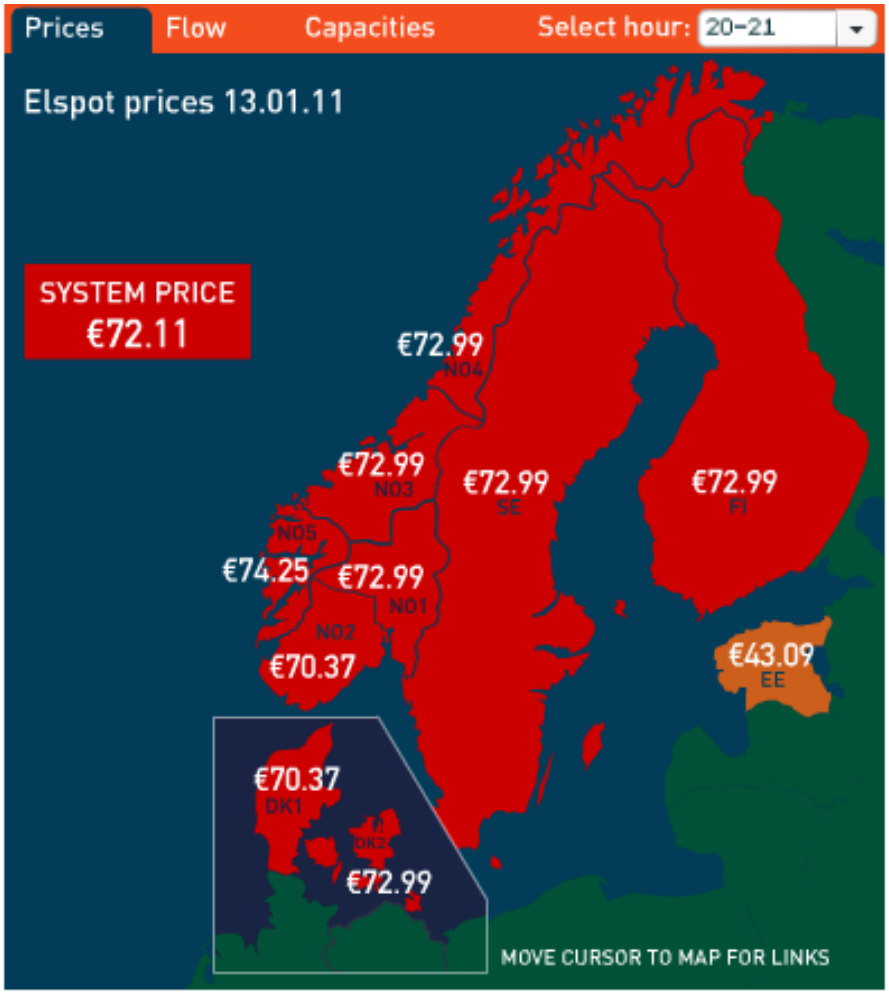
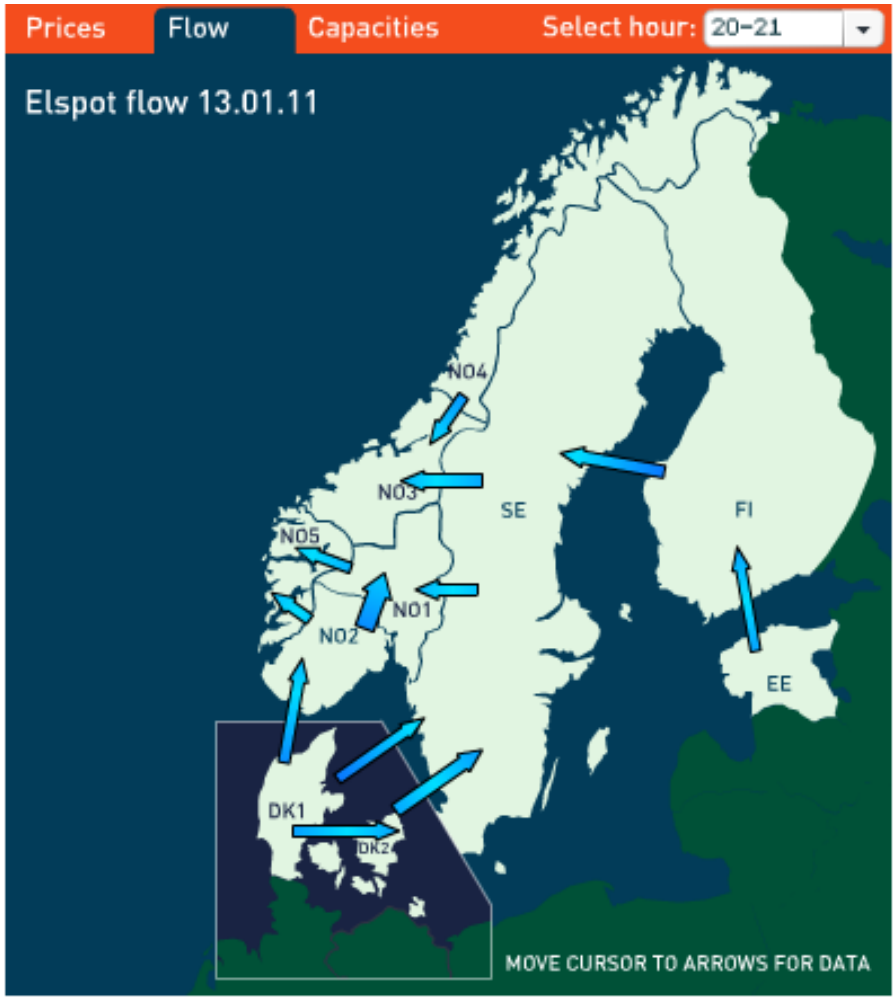
The physical markets



Source: Energinet.dk

The Spot market just now !





370 MW wind in DK

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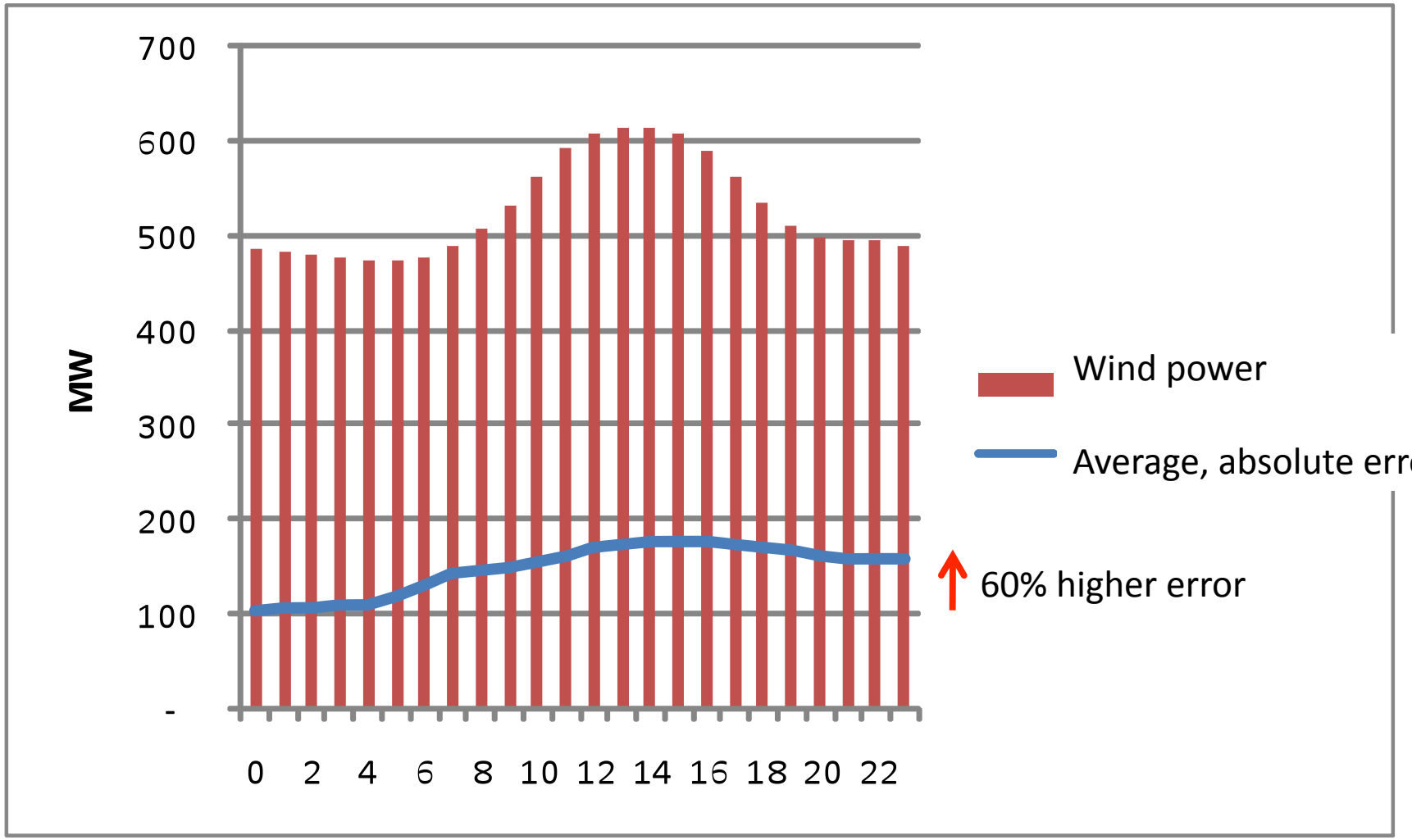
West Danmark (2008)



12 hours prediction

36 hours prediction

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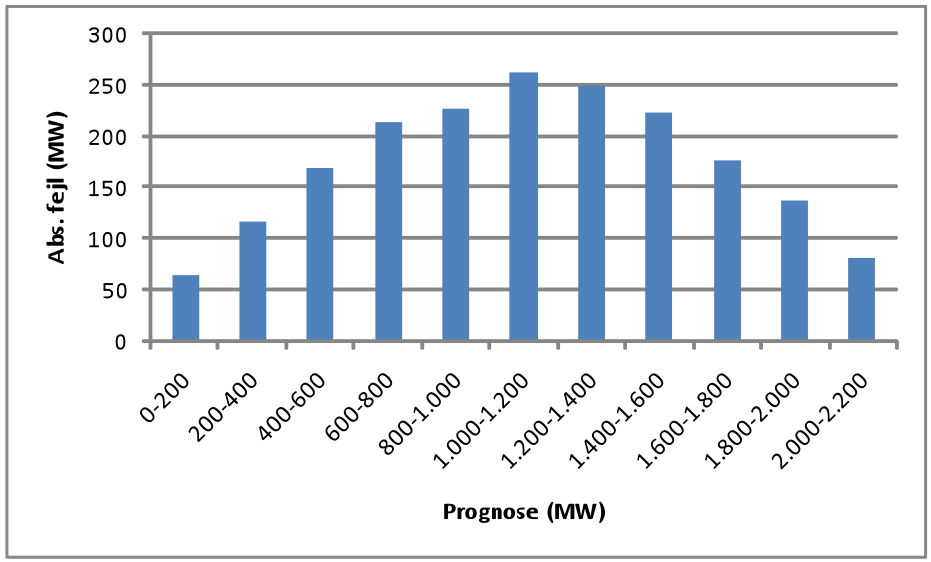
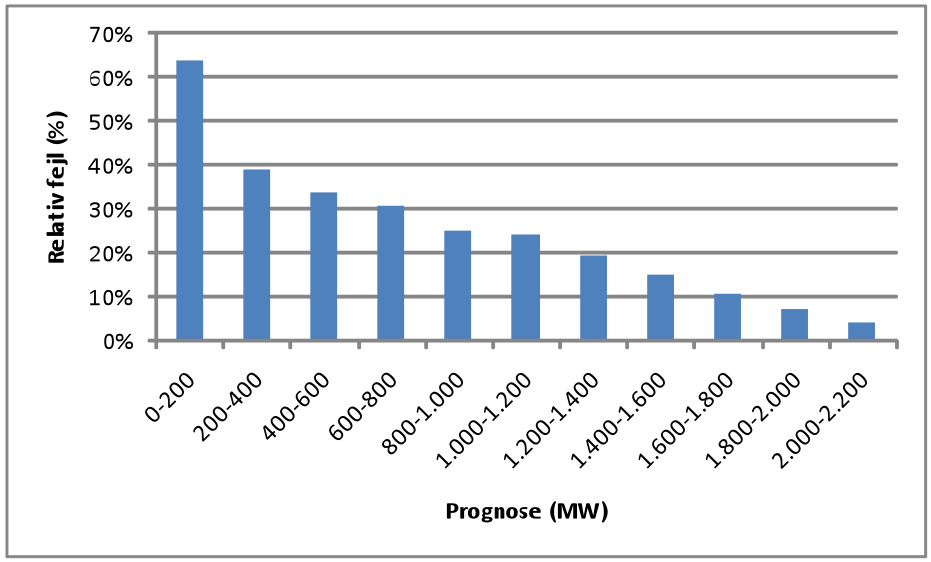
Prognosis error (Western Denmark 2006)





- Depends on total production (due to wind turbine power curve)
- Relative error large for little wind power production

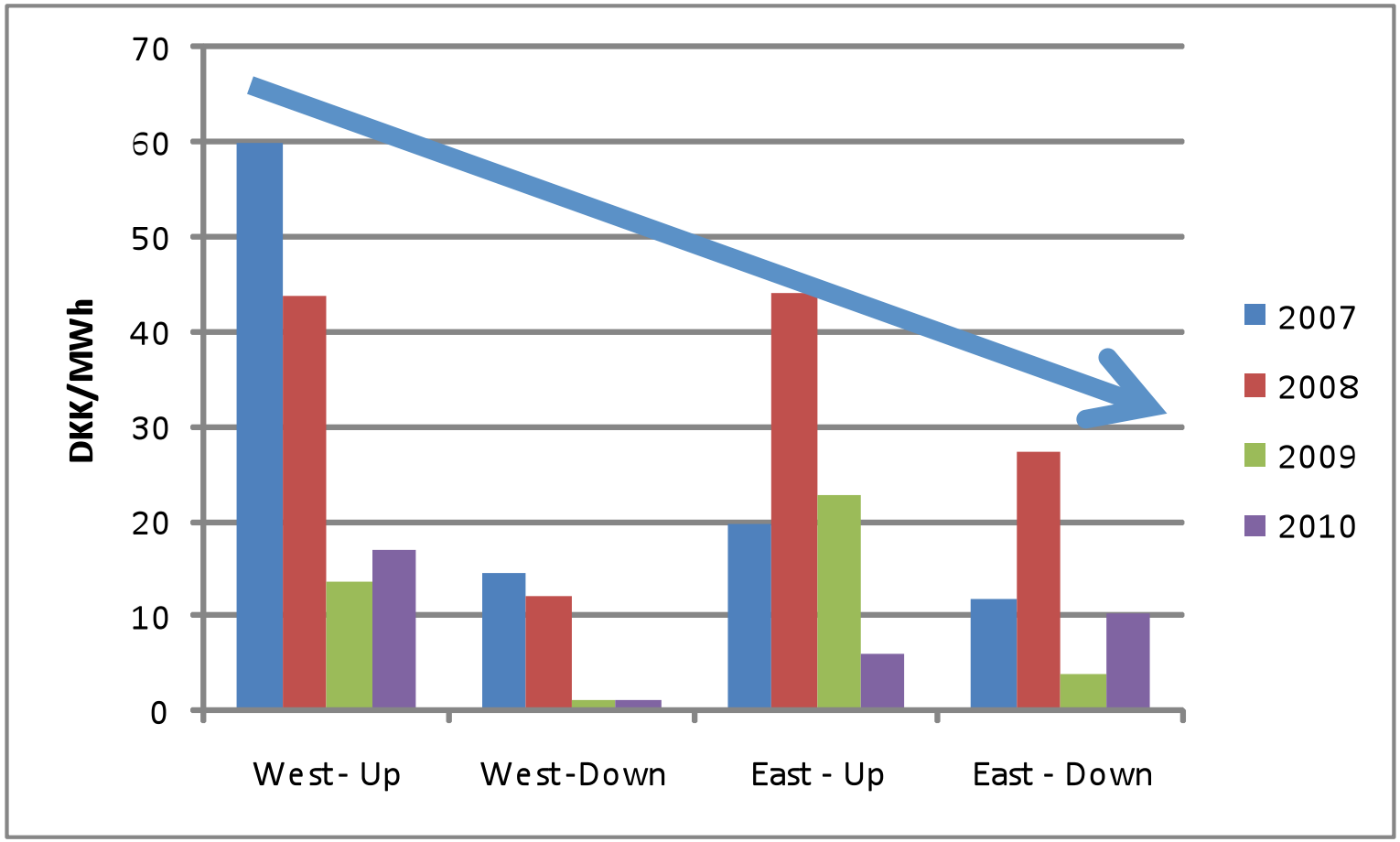
Main challenges

- Variable
- Difficult to predict

The solutions

- Efficient international electricity market. Both day-ahead and intraday. Full use of geographical spreading & Hydro storage.
  - Negative prices since 2009
- Strong grid. Interconnectors are integrated in the market
- Open flow of information and Co-operation between TSO´s
- Quick operational response to changes
- Improved wind forecasting. Data transparency
- Common grid planning – and the will to invest
- Increased flexibility in centralised plants.
- DG resources (with heat storage) contribute with manual and frequency reserves
- Modern grid codes ensure ability to regulate
- Price signals and ICT make demand resources available

Decrease in regulation price (Standby)



5,5 DKK = 1$

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The winds of change

Independence of fossil fuels

Horns Reef Offshore. 160 MW owned by Vattenfall & DONG Energy

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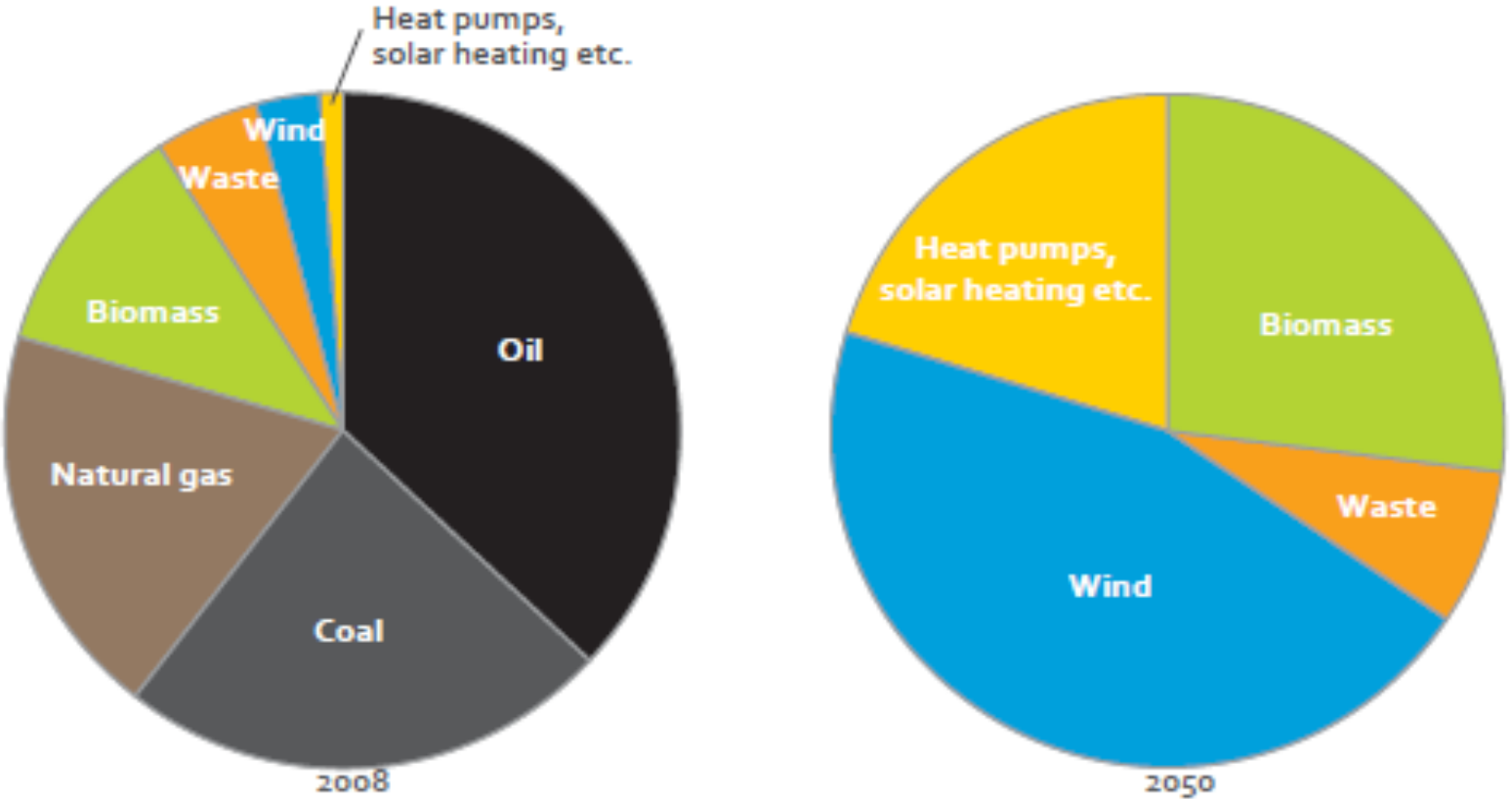
Denmark independent of fossil fuels

Commission states: 2050 is a realistic target



www.Klimakommissionen.dk

Calculated in linear optimization model

Electricity consumption	Volume	Handled in the model
Classic consumption	30 TWh	Not flexible
EV´s	20 TWh	Substantial flexibility
Biofuels/Hydrogen	12 TWh	Substantialflexibility
Individual heat demand	5 TWh	Not flexible
District heating	6 TWh	Flexible. CHP and energy storage
Industry –high temperature	16 TWh	Quite flexible – toggle between electric boilers and biomass
Total	**90 TWh**	

Production from wind, sun & waves: ~ 85 TWh
Thermal production: ~ 9 TWh
=> Demand side emerges as the primary supplyer of flexibility.

The future solutions

For large scale integration of wind

- **International solutions – increased capacity in interconnectors (Supergrid). Nordic hydropower with storage is valuable**
- **Large scale electrification of land transport**
- **Increased coherence between electricity, heat and transport.**
  - **It is cheap to store energy as hot water**
- **Flexibility and ICT (Smart grids)**
- **Research, development, demonstration, incentives**


Thank you for your attention