Integrating more wind power into the Danish Power System

Hans Abildgaard

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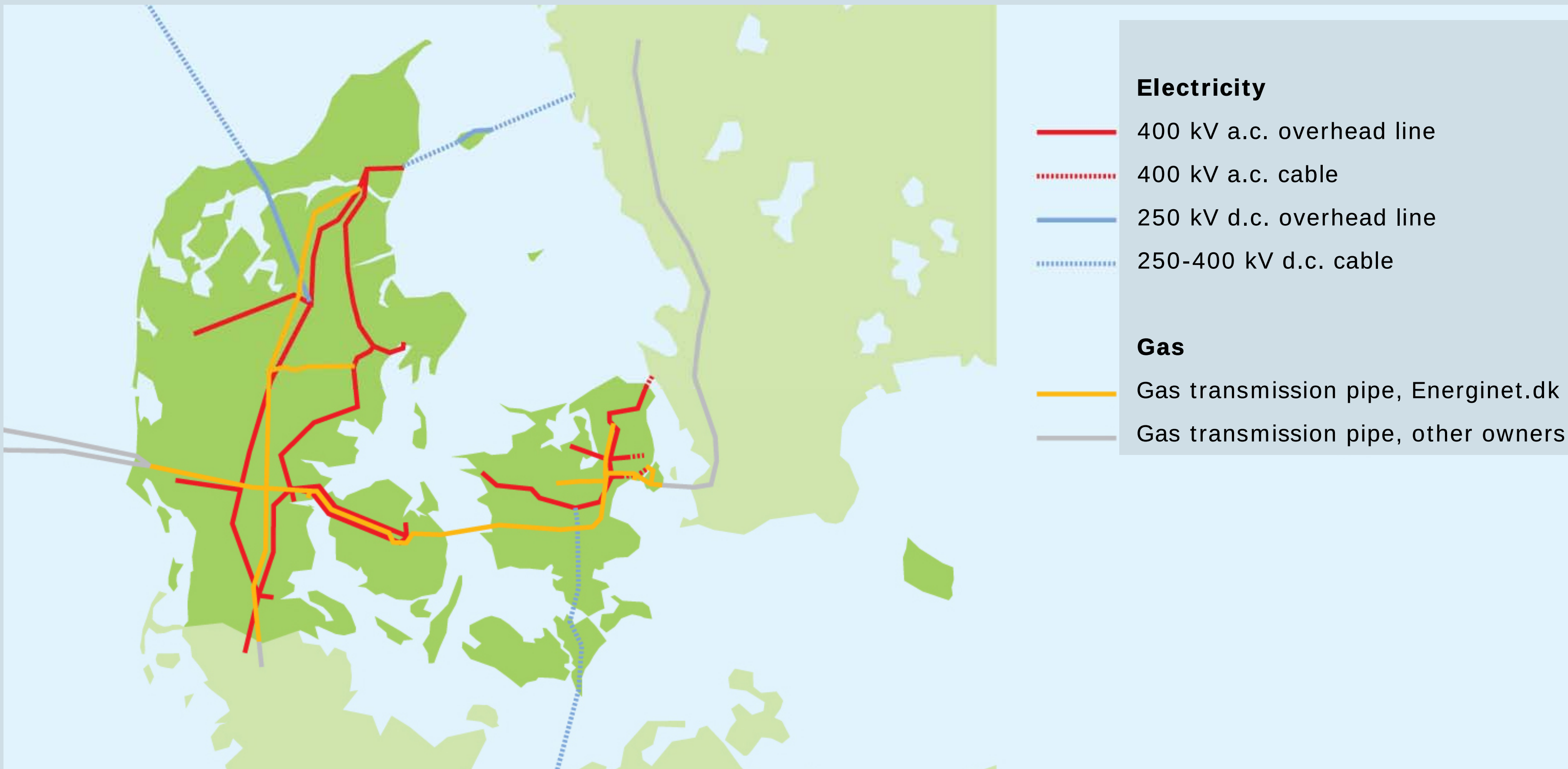
The Danish transmission system for electricity and gas



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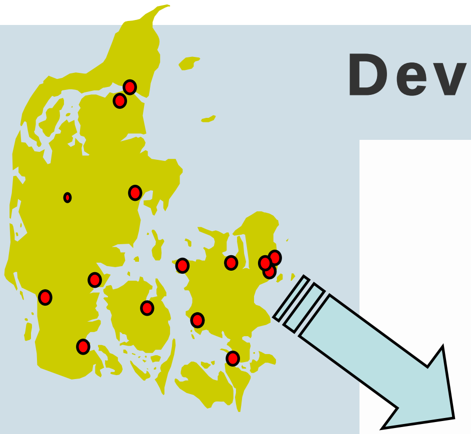
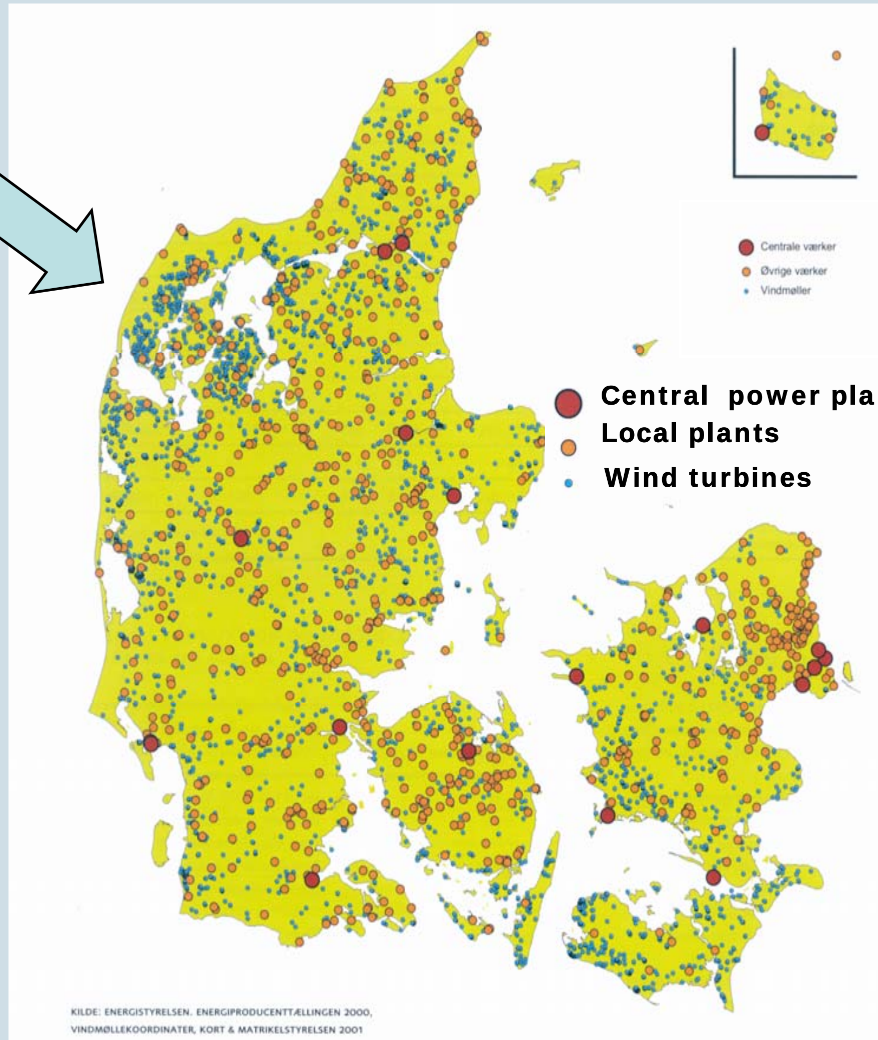
Development from the 1980s





2005	DK West	DK East
Peak demand	3 797	2 737
Generation <100 kV	3 902	1 215
Generation >100 kV	3 562	4 007

so far so good…

- but can we integrate more wind power?

Challenges for integrating more wind power into the Danish Power System

- The system costs of wind power
- Keeping the system in balance
- Planning for the future

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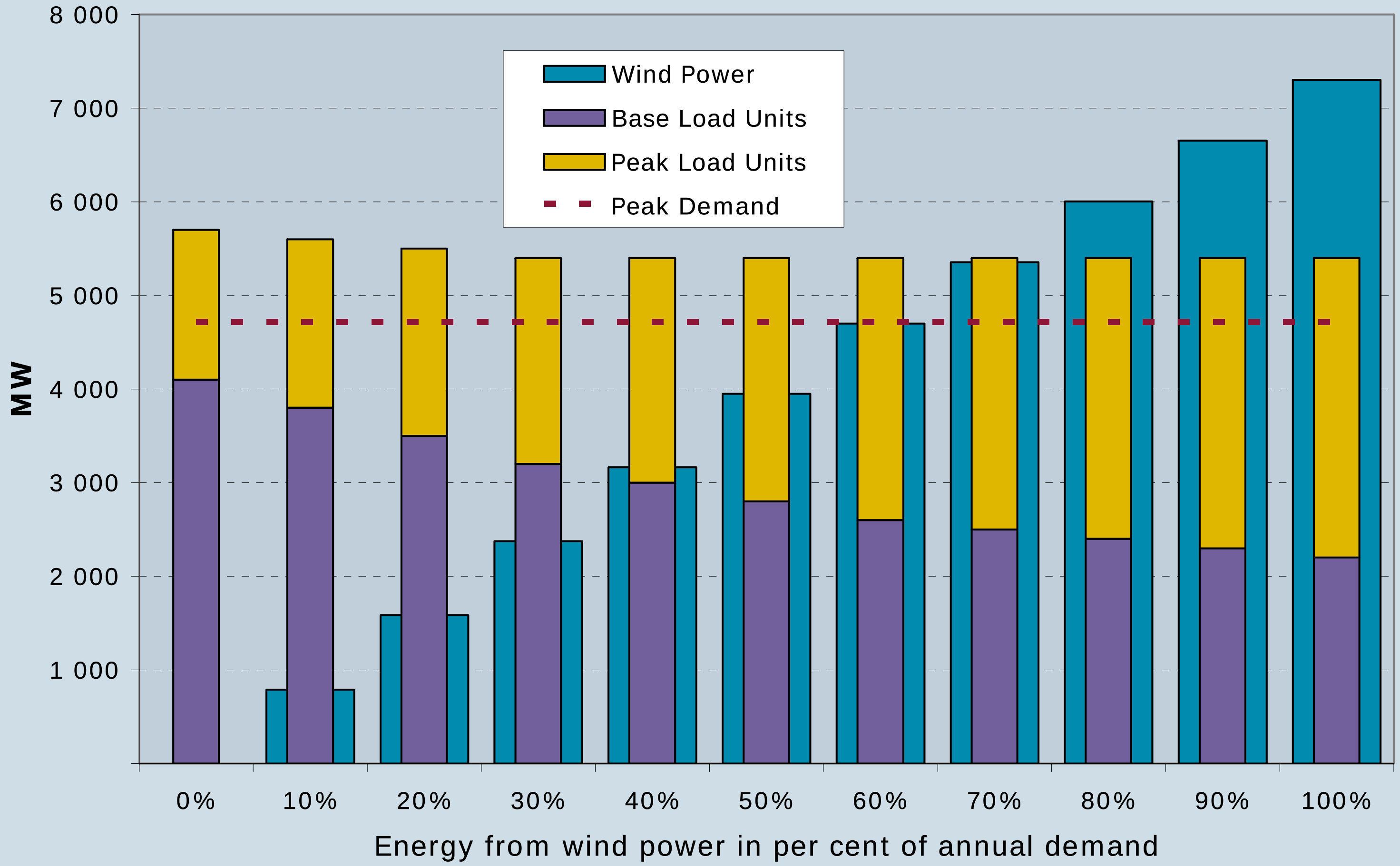
What are the system costs for wind power?
- a simulation on a fictitious power system

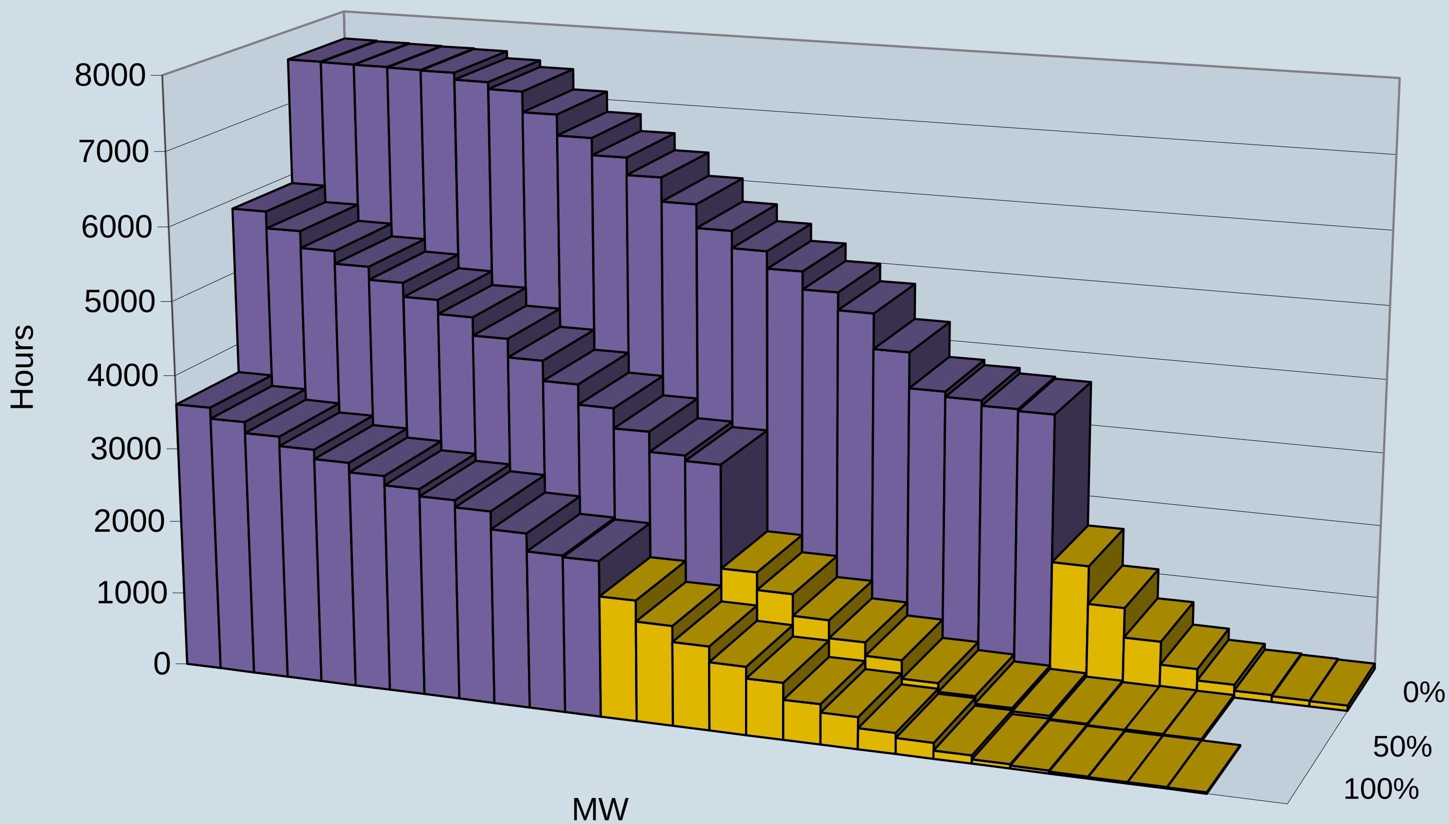
0-100 per cent of the energy demand covered by wind power assuming:

- isolated power system
- demand 26.3 TWh/year, 4 715 MW peak
- the production mix is adjusted depending on the amount of wind power
    - 2 500 MW onshore – the rest is off shore
    - same security of supply
    - coal fired base load units (utilisation time >2000 h)
    - natural gas fired peak load units (utilisation time <2000 h)
- forced and scheduled outages included
- 5%, 30years annuity=0,0651
- CO_2 emission 6.7 €/ton

Generation mix at different levels of wind power



Equivalent full load hours for base- and peak load units



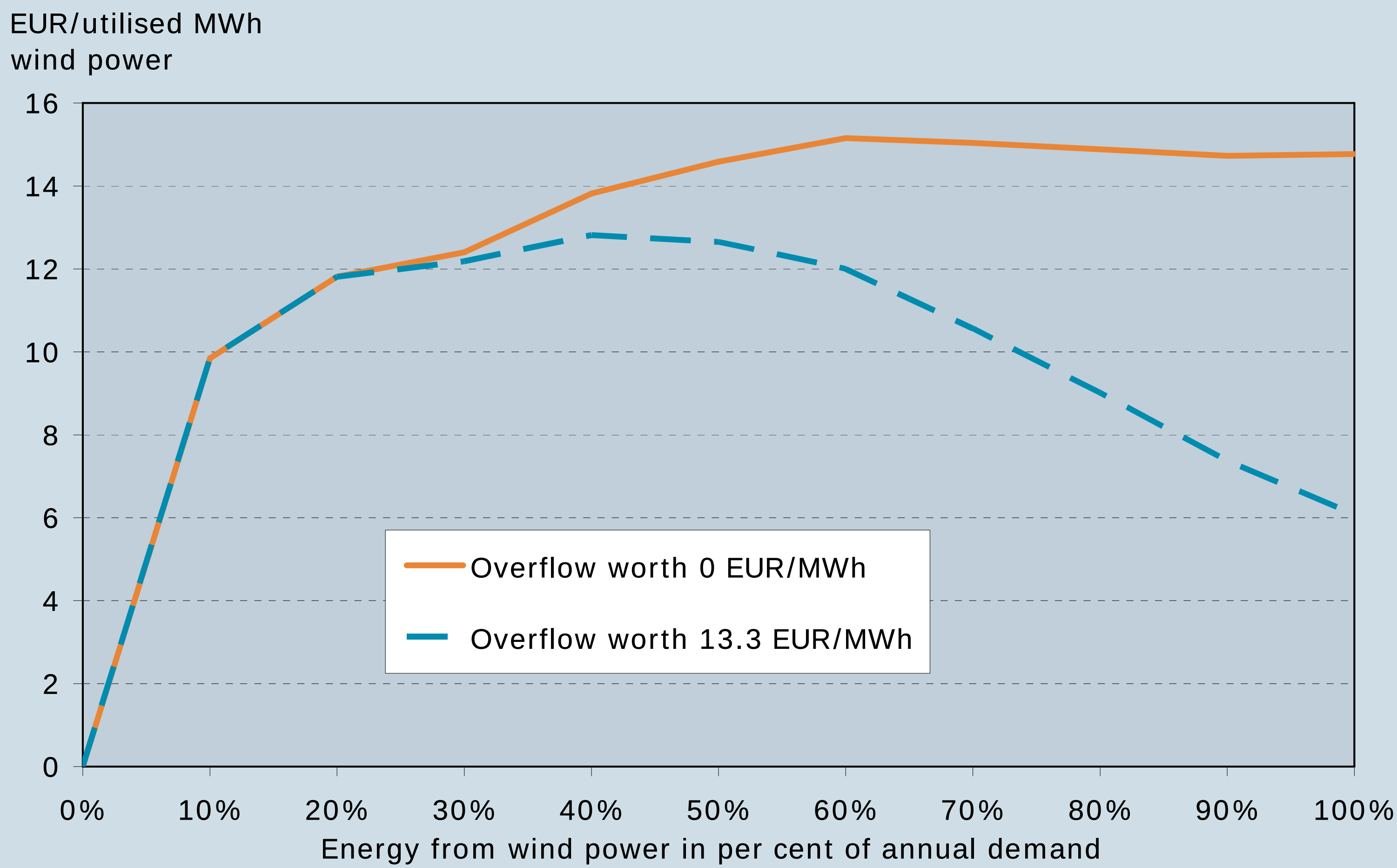
Energy produced and consumed

Wind Power Penetration		0%	50%	100%
Production				
Wind power	TWh	0.00	13.14	26.30
Base load thermal power	TWh	25.49	12.76	6.58
Peak load thermal power	TWh	0.81	1.27	1.51
Consumption				
Demand	TWh	26.30	26.30	26.30
"Overflow"	TWh	0.00	0.91	8.13

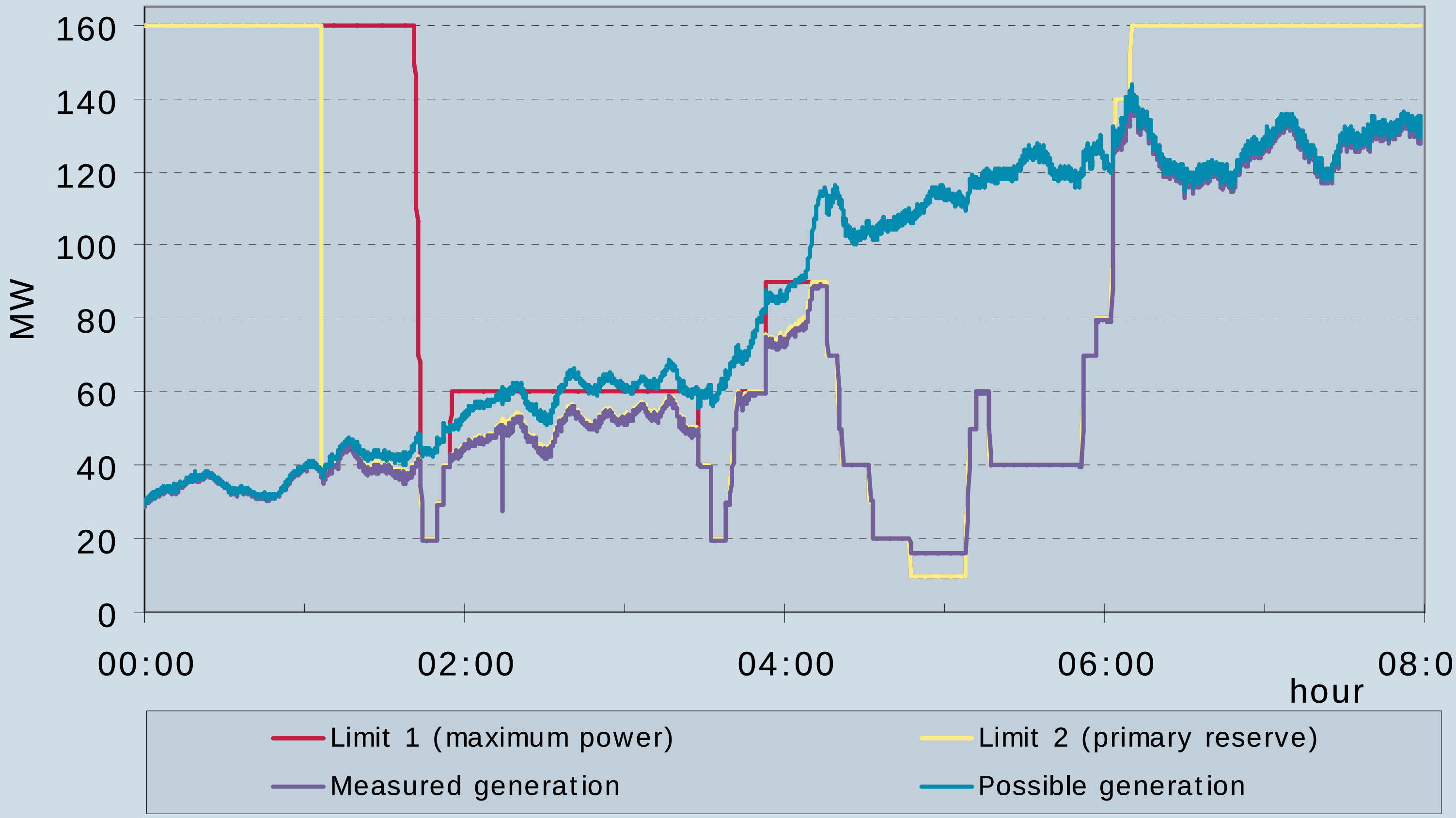
System related costs of increasing wind power

Wind Power Penetration		0%	50%	100%
Total cost thermal power	M€/year	1157	796	624
Avg. cost thermal power	€/MWh	44.0		
System costs with optimal use of thermal power	M€/year	1157	617	356
Overflow worth 0 €/MWh				
Additional system costs for wind power	M€/year	0	178	268
Avg. additional cost of wind power	€/MWh	**0.0**	**14.6**	**14.8**

Additional costs for the system by introducing wind power



Waste of energy?

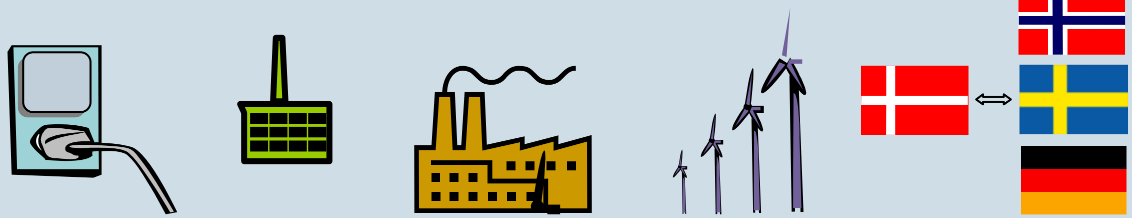


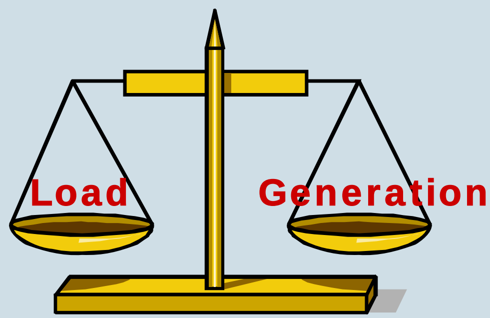
Lessons

- The specific costs of the thermal power plants will increase when the wind power level increases
- Large wind power penetration leads to additional costs of 6-15 €/MWh per utilised MWh wind power
- New demand types are needed to utilise the power overflow
- Not considered
  - ancillary services including regulating power
  - transmission capacity
  - stability aspects
  - district heating which will increase the overflow
  - wind power installation cost

Balancing the power system

Sources for imbalance

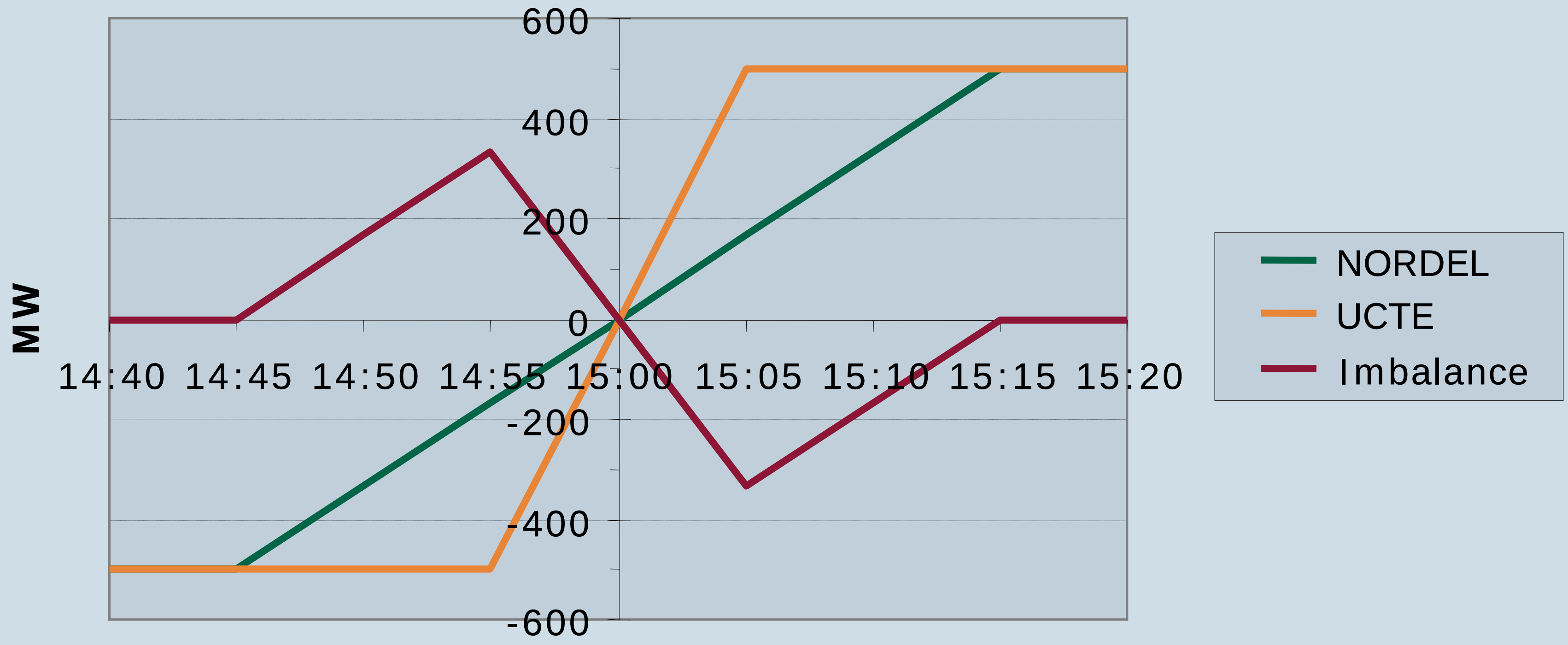




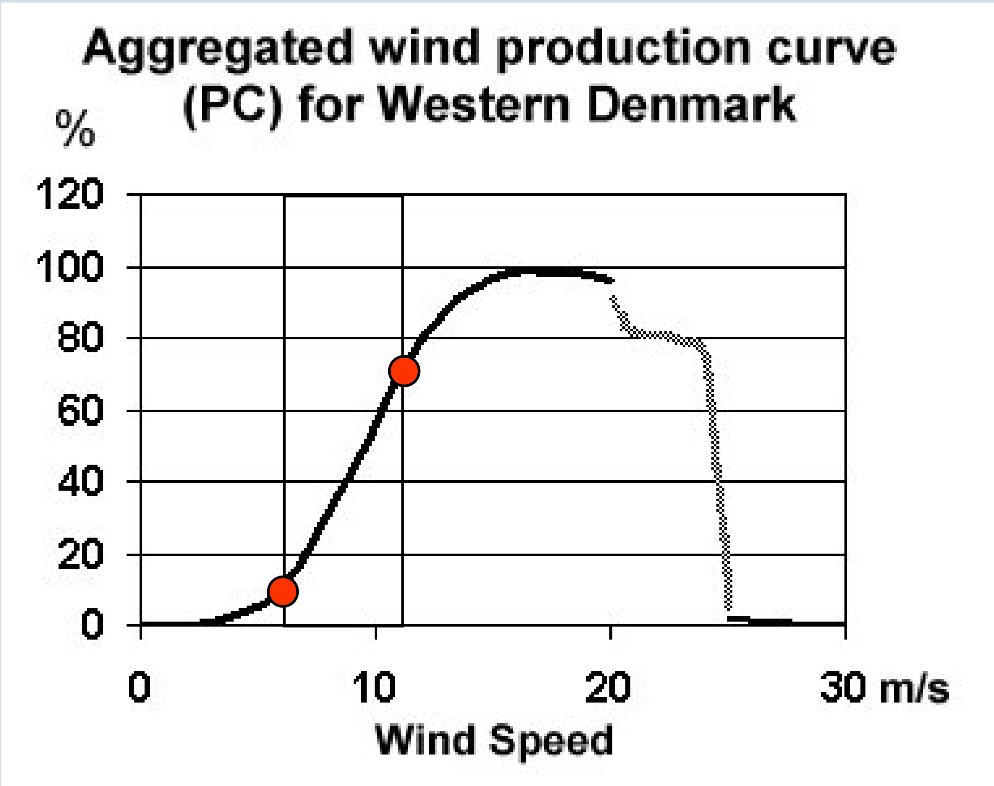
Handles

AGC **NOIS** **a.c. tie lines** **Emergency plan**

Ramp rates change of schedules



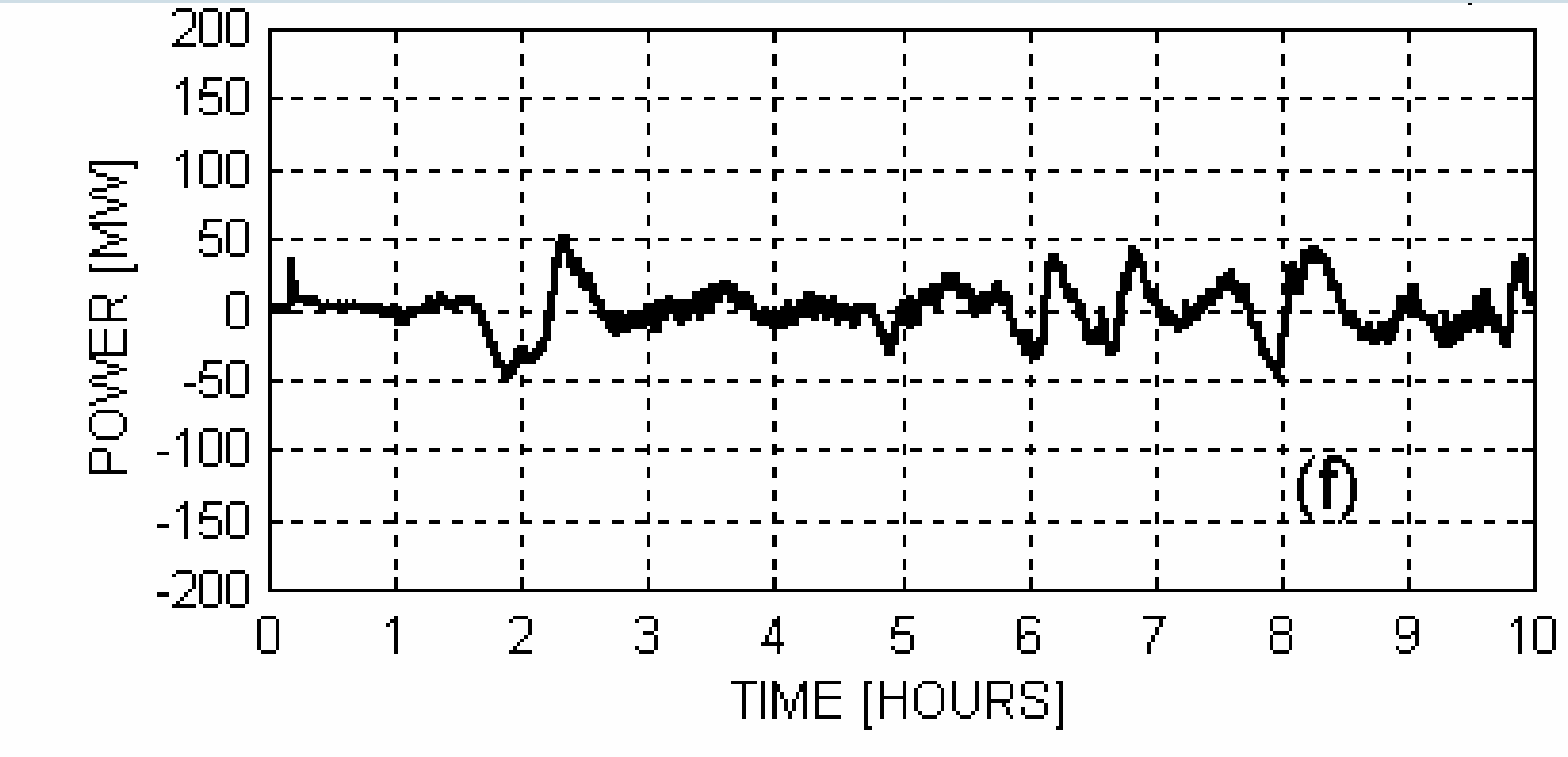
The Challenge of Wind Power Forecasting



"Fresh breeze" means somewhere between 200 and 1 600 MW

A deviation of just ±1 m/s may have an impact of ± 320 MW (With a 2 374 MW installed base).

Computed power imbalance for HRA+HRB



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Present regulating resources are close to being exhausted

new handles are being examined

- local CHP on the regulating market and reacting on market signals
- common regional regulating market
- interconnection of the Danish power system
- price dependent demand
- reduction of positive power gradients from wind farms
- direct communication with the local generation
- improved wind forecasts

Planning for the future

- ETSO / UCTE wind study
- activating the domestic regulating abilities of the power system
- promoting price dependent demand
- building autonomy into the power system by redesigning the system architecture
- adding more transmission capacity