

# Integration of Wind Power in the Danish Energy System

Wind Integration Forum  
July 29th – 30th 2010, Portland

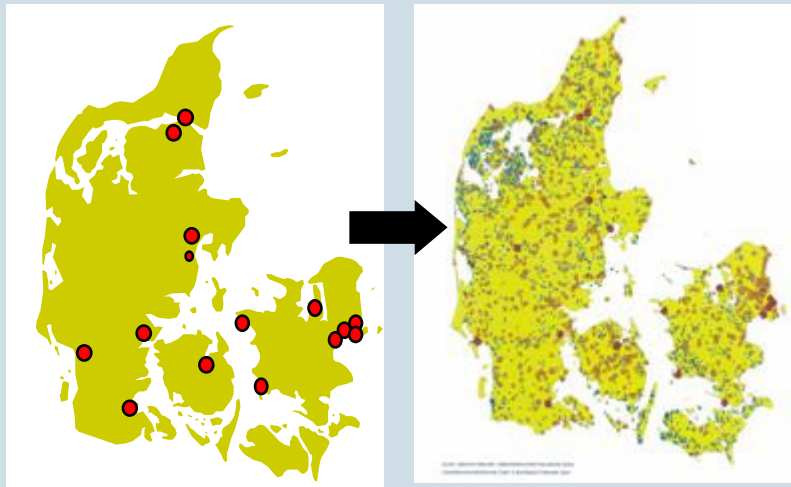
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*Senior Engineer*  
*Energinet.dk*



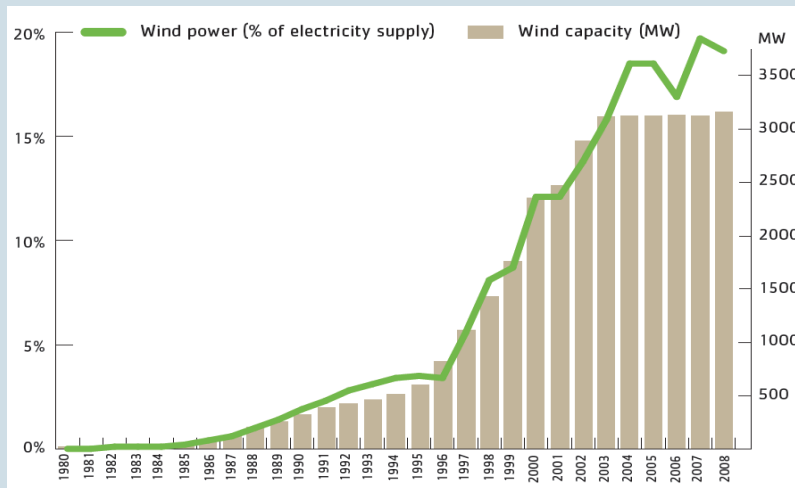
## Agenda

- Wind power in Denmark - status and plans
- Wind power in the electricity market
- Wind forecasting
- Efficient integration of wind power
  - Strong international transmission grid
  - Coherent and flexible energy systems
  - Active control - SmartGrid
- Conclusions

# The Danish electricity system – development and policy



From primary to local generation



Danish wind power – capacity and supply

## Danish energy policy:

### Long-term vision:

- Fossil-fuel independent

### Energy agreement 2008-2011 (2008):

- 1.300 MW of new wind-power capacity ~ +40%!

### EU 20-20-20 target – 30% renewables:

- Power system may have to handle 50% wind power!

# Power balance July 1st. 2010

## Two synchronous areas

West:

Consumption	1400 - 3700 MW
Primary power stations	3400 MW
Local CHP plants	1700 MW
Wind turbines	2740 MW

**4400 MW**

East:

Consumption	900 - 2700 MW
Primary power stations	3800 MW
Local CHP plants	650 MW
Wind turbines	885 MW

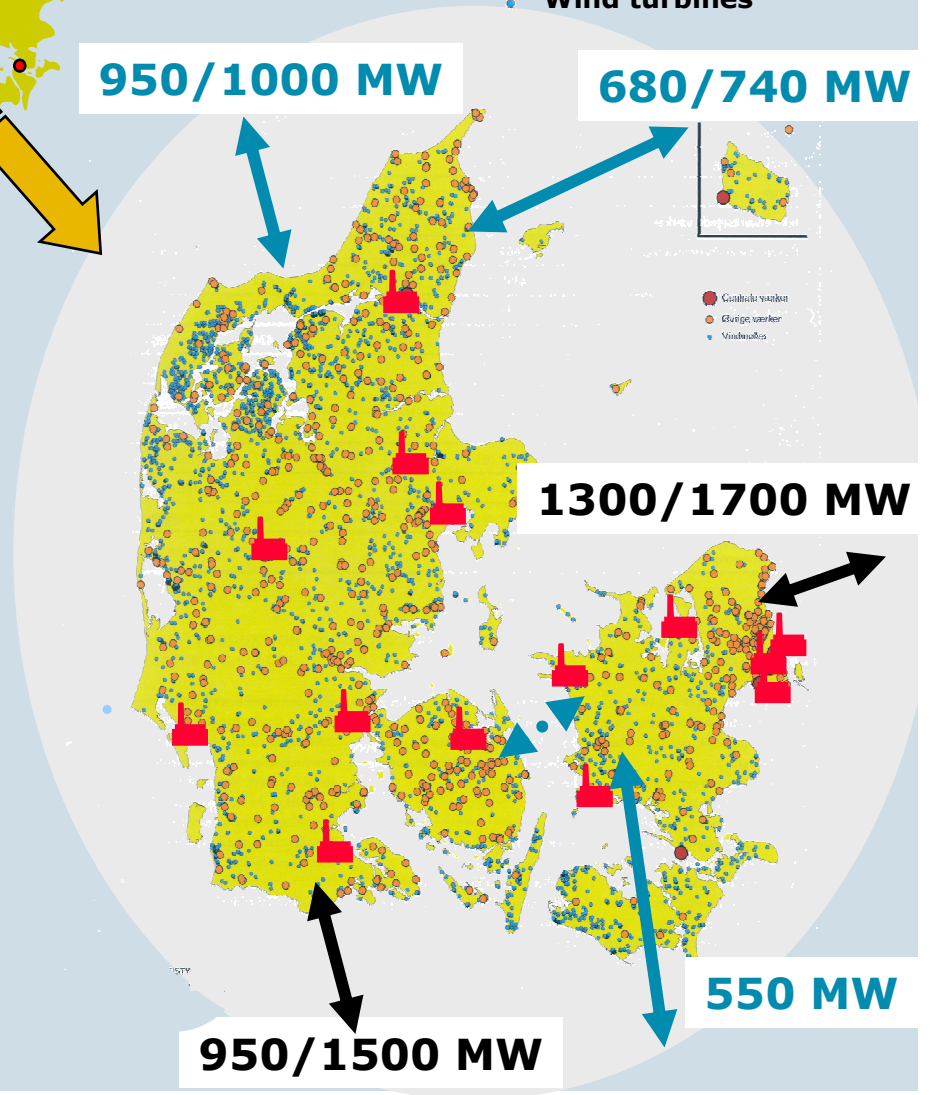
**1535 MW**



**950/1000 MW**

**680/740 MW**

- Primary power station
- Local CHP plant
- Wind turbines

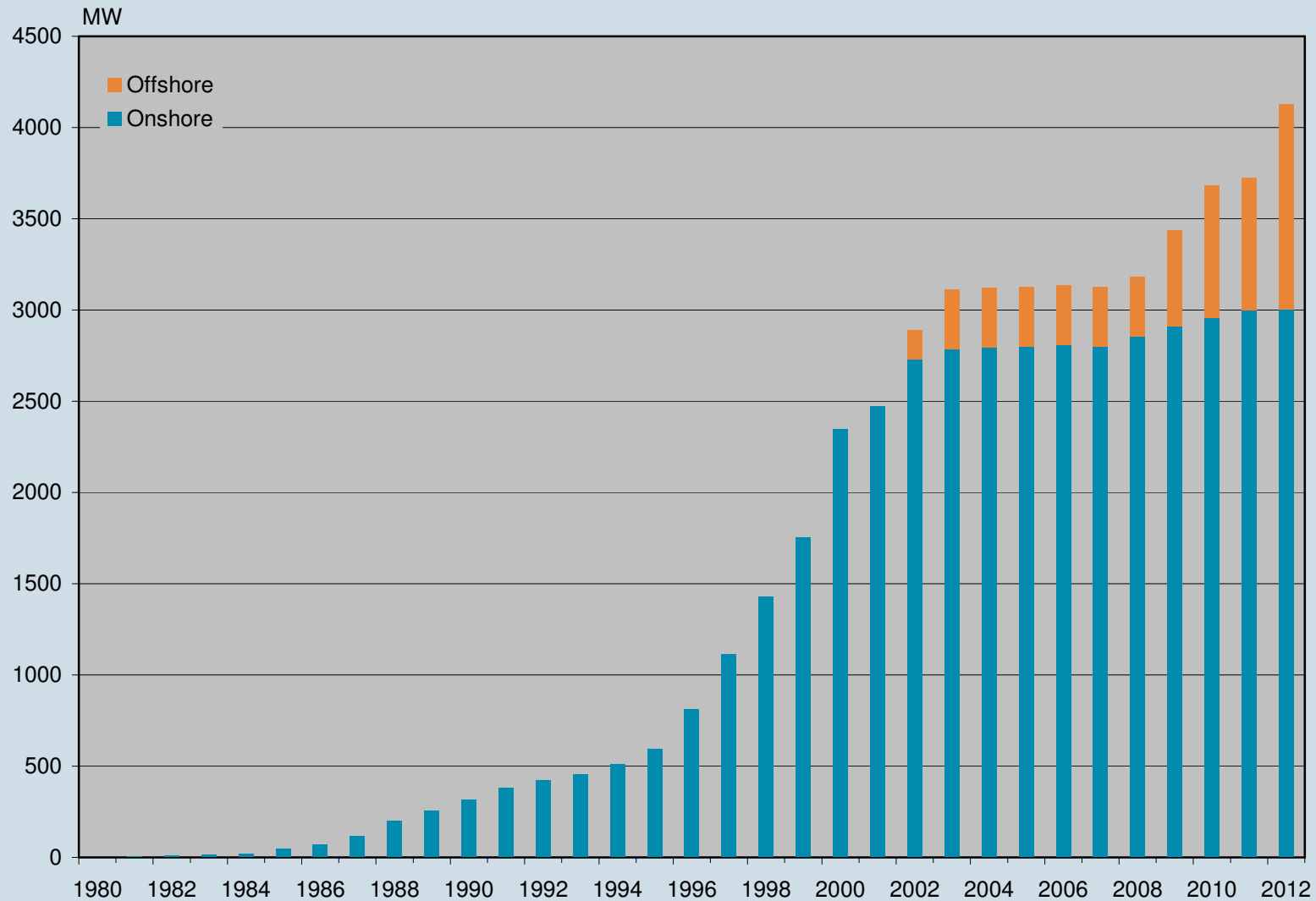


**1300/1700 MW**

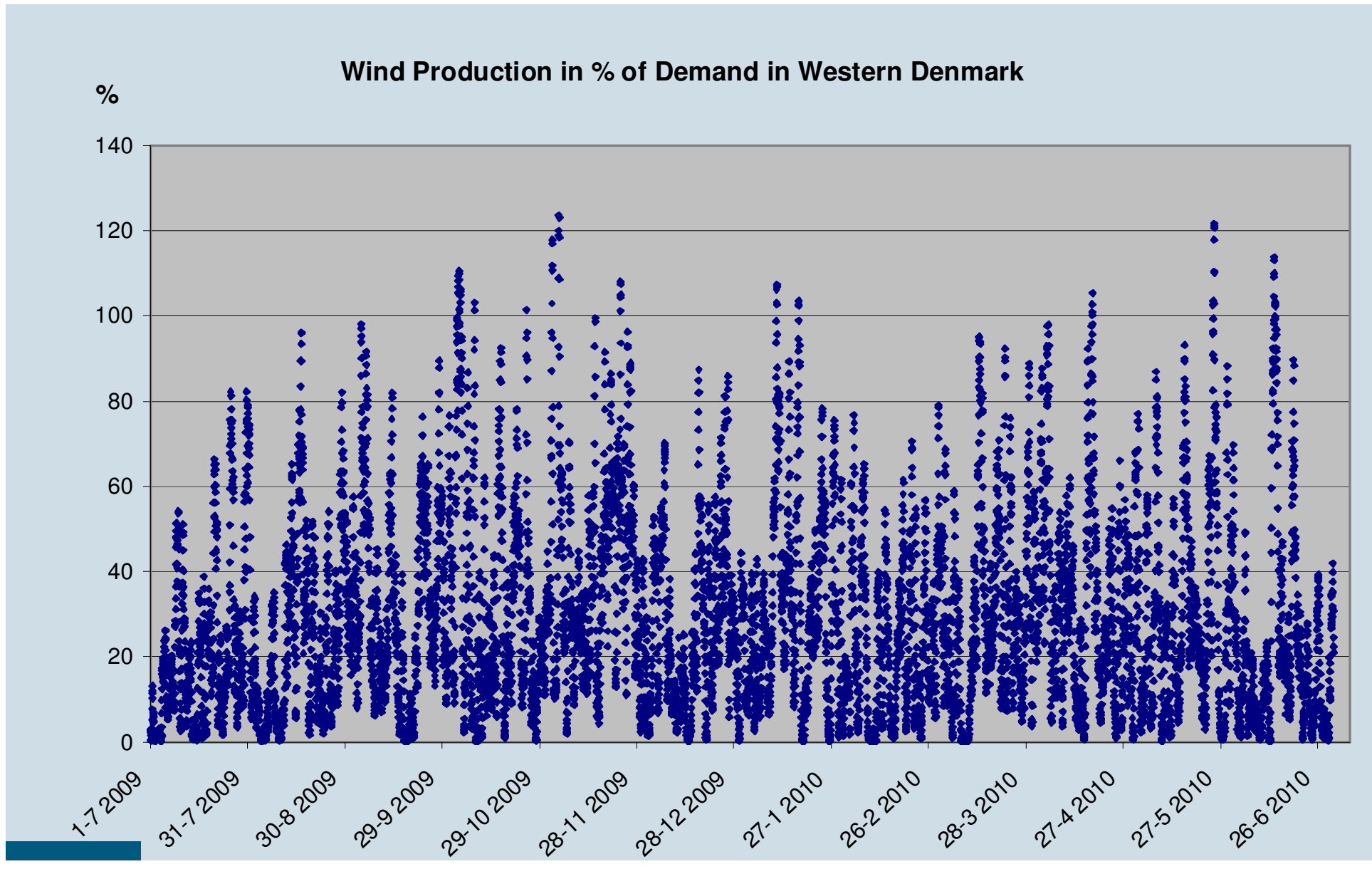
**950/1500 MW**

**550 MW**

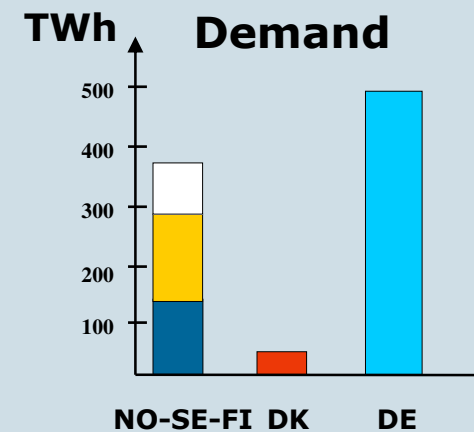
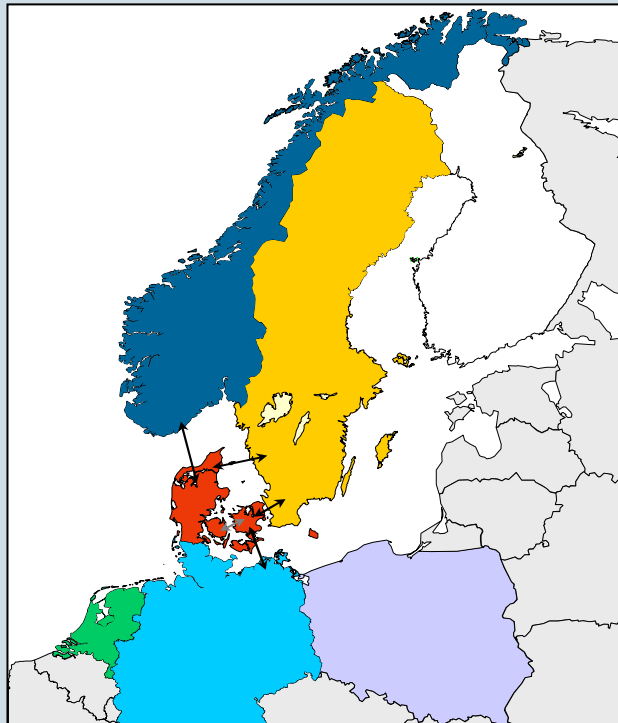
## Wind power in Denmark 1988-2012



# Wind power already exceeds hourly demand today!



## Wind power balanced in a large market area



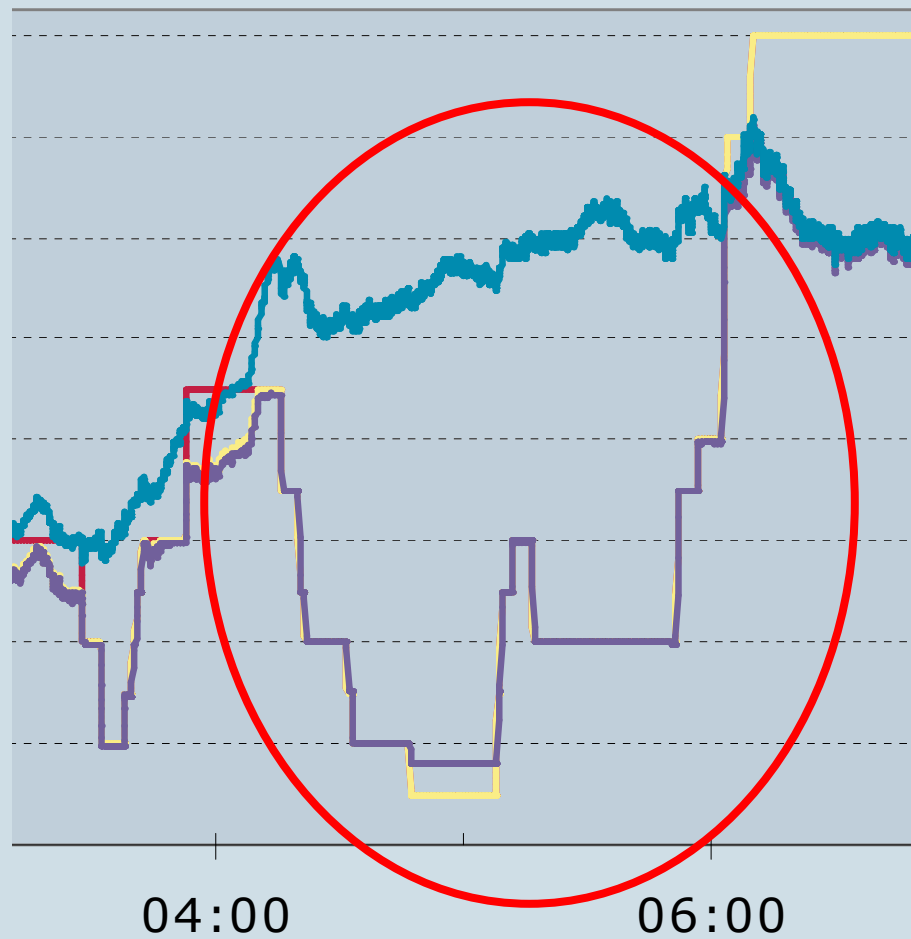
- Strong transmission grids and interconnectors
- Coherent electricity markets

## Wind power balanced in a flexible generation system

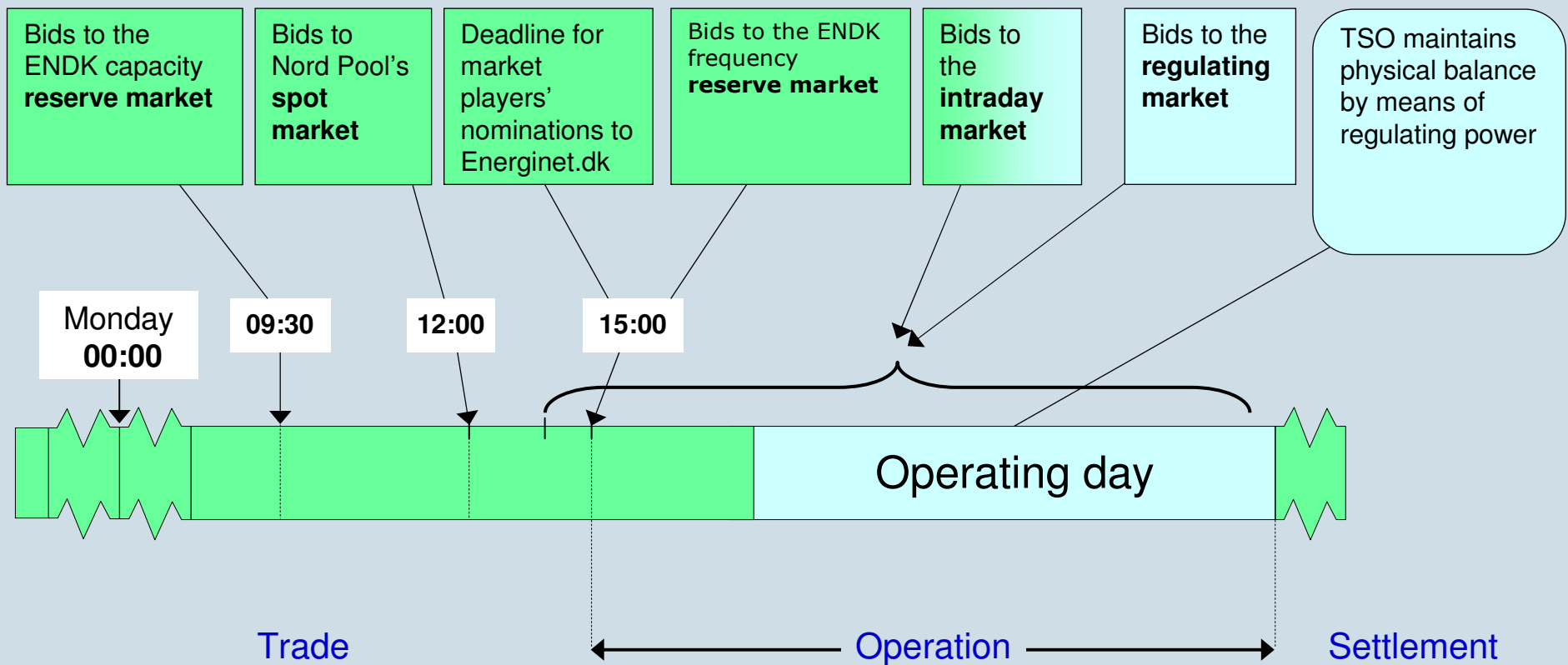
- Coal fired power plants:
  - Required to operate down to 35% of rated power
  - Some are capable to operate down to 10%
- Combined heat and power plants:
  - Heat accumulators decouple electricity and heat demand
  - Electric boilers give flexible demand
- Wind farms:
  - Grid codes ensure capability to regulate



## Wind power can contribute to system balancing!



# The phases of the power market

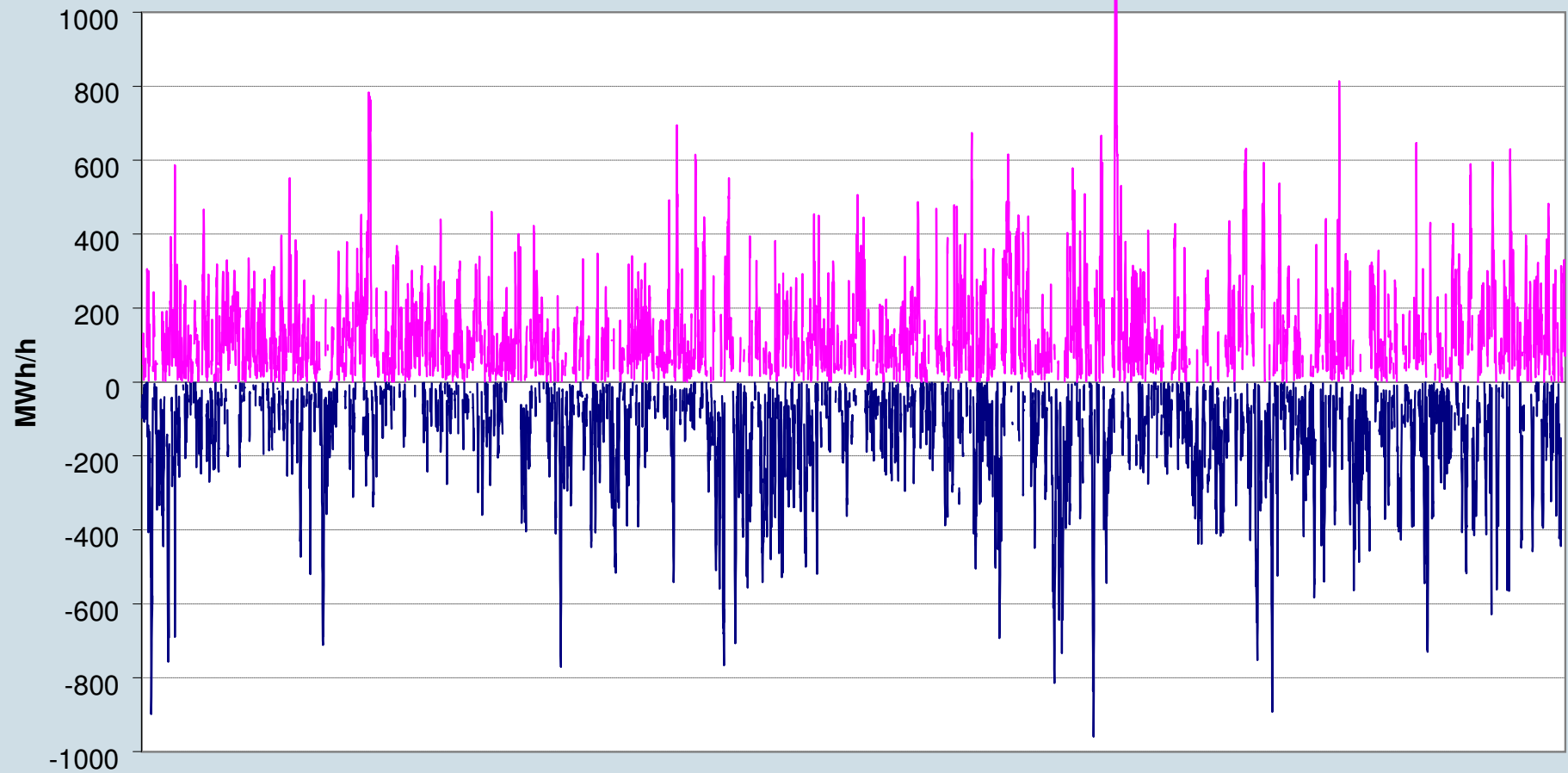


## The regulation market (real time market)

- Energinet.dk is part of a common Nordic regulating power market which operates along the same fundamental principles as the spot market.
- Regulating power bids are collected from all Nordic countries and listed in price order (NOIS = Nordic Operational Information System).
- Bids are activated in accordance with the price list (cheapest first) and the marginal bid in one hour determines the price for all suppliers
- To secure a minimum volume in the regulating market Energinet.dk buys reserve capacity.

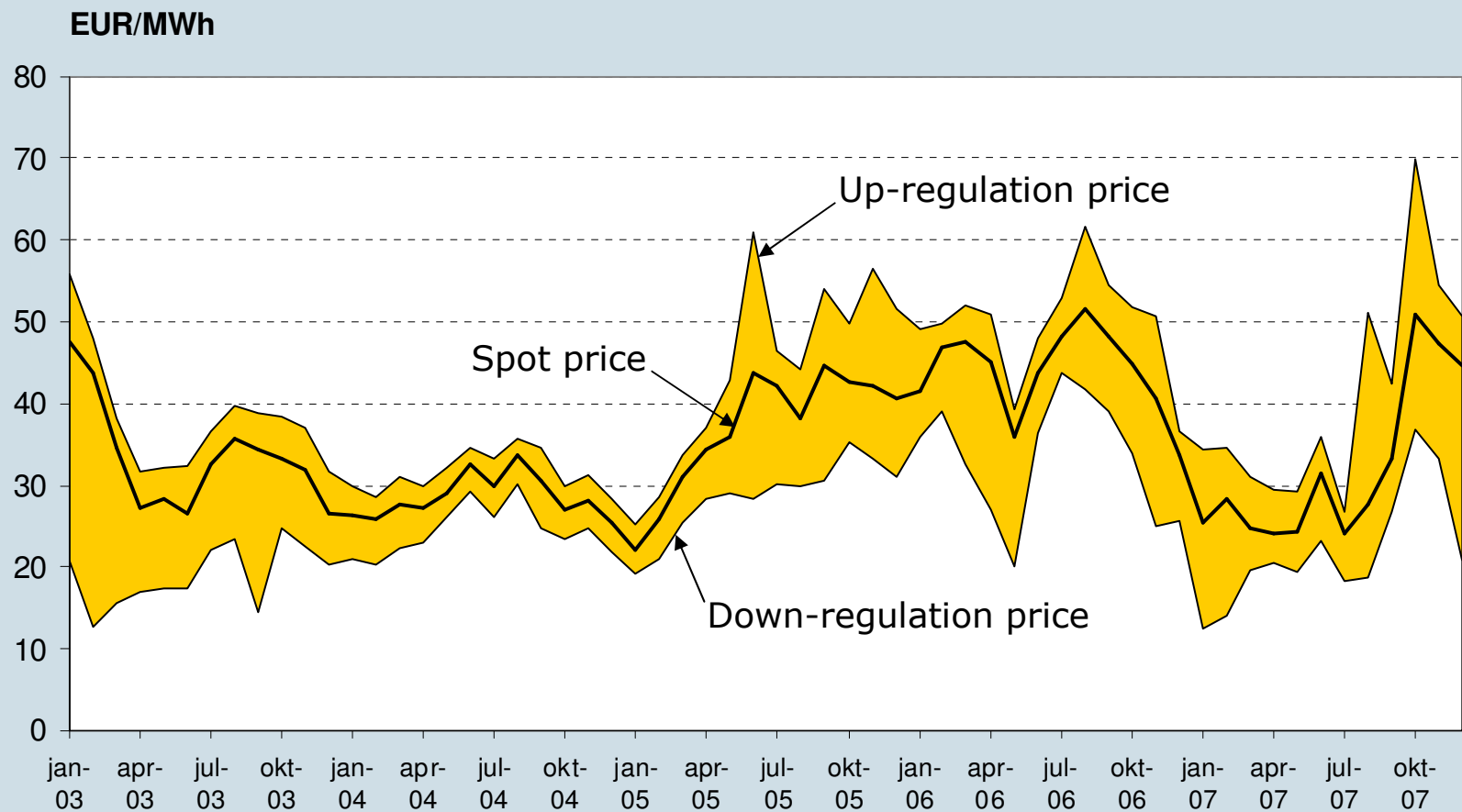
## The need for regulating power in Denmark - West

1. April 2007 - 31. March 2008



# Prices in the regulating market

Western Denmark: January 2003 – December 2007



## Wind power in the electricity market

- Wind power can be integrated in a liberalized electricity market
- Wind power has marginal costs of almost zero, and will therefore always get its bids accepted in the spot market
- The fixed feed-in tariffs for existing wind turbines are decreased over time to market price + a subsidy
- Newly build wind turbines will get market price + a subsidy
- In Denmark, the consumers pay the subsidies to the wind power producers
- The redistribution of money from the consumers to the wind power producers is handled by Energinet.dk



# Wind power forecasting

We use two forecasting tools – one external and one internal

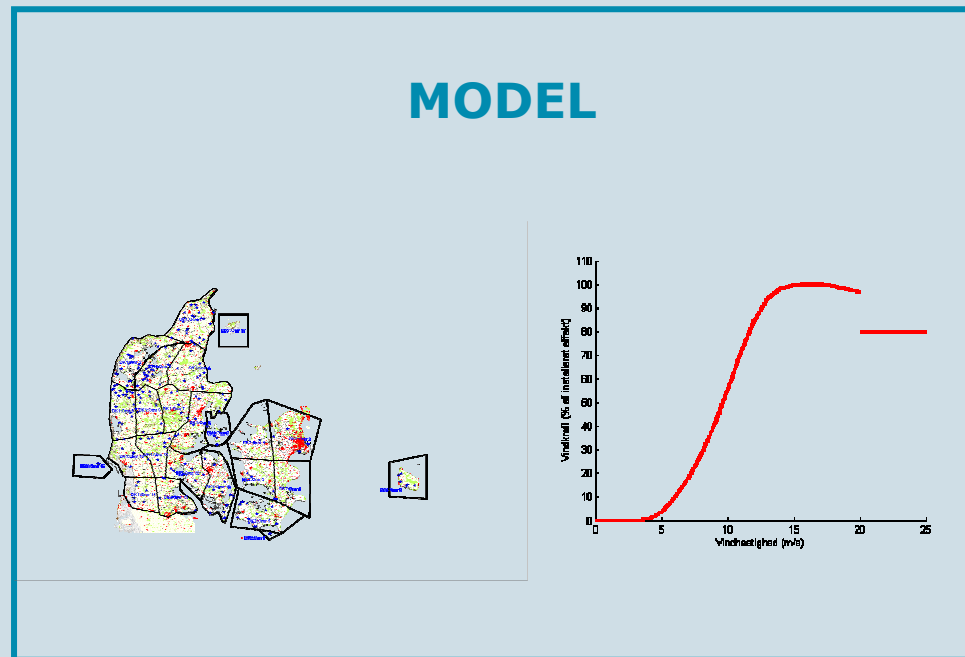
- External forecast:
  - Current provider: energy & meteo systems GmbH
  - Combined forecast based on 4 meteorological prognoses.
  - 0-48 hour forecast
  - Hourly deliverance
  
- Internal forecast:
  - combined forecast based on 3 meteorological prognoses.
  - day ahead (12-36 hour) and short term (0-6 hour) forecast

We are constantly looking for new competitive forecast providers

# Internal forecast

- Wind speed
- Production data
- Installed capacity
- UTM coordinates
- Telemetric data

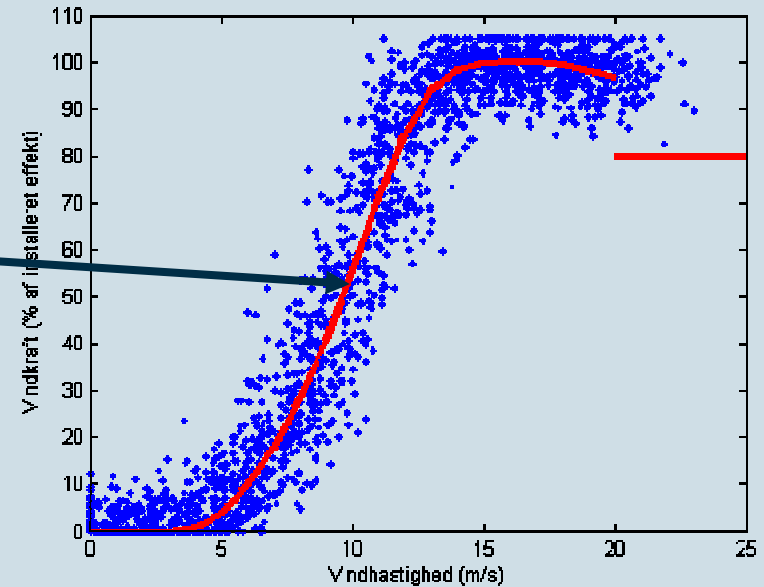
Wind power  
forecast





# Challenges

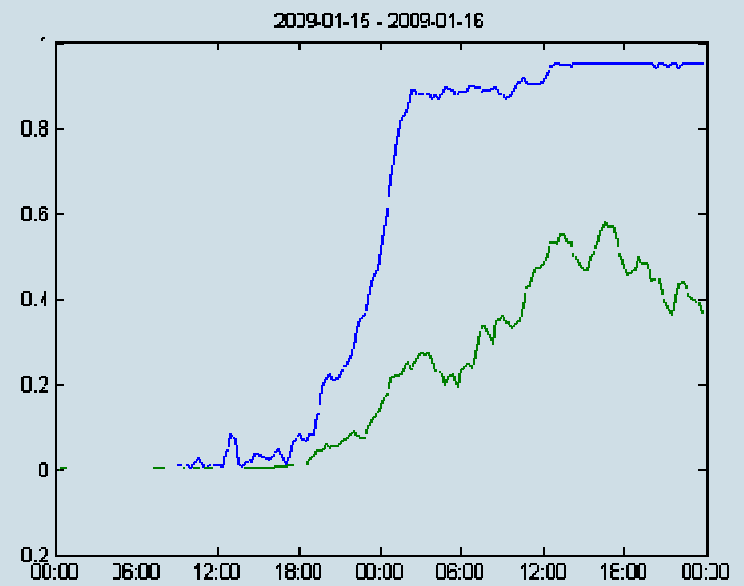
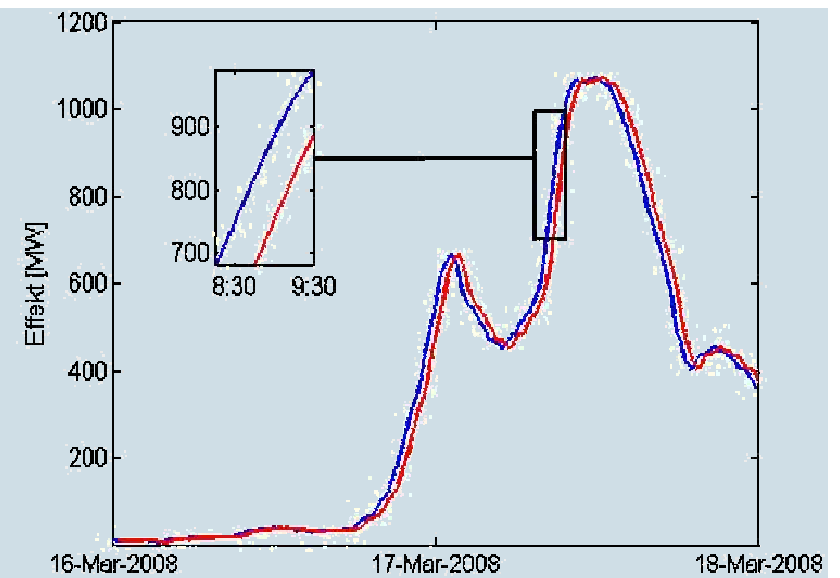
- Having 3,2 GW wind power installed in the system, a change of **1 m/s** in wind speed can result in a change of **450 MW** power production.



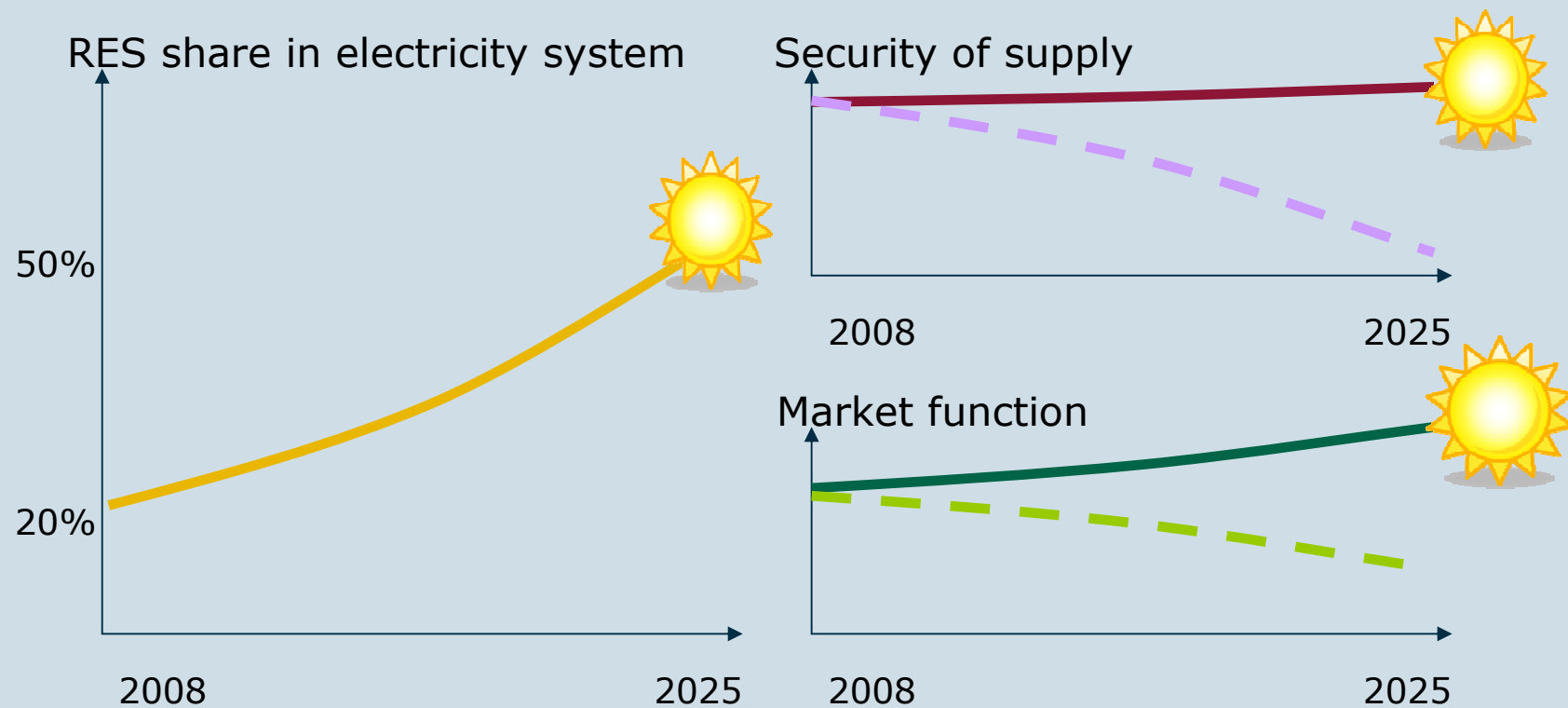
- The meteorological forecasts rarely agree on the same wind speed. Thus we constantly look for the best combination.

# Challenges

- A weather front passing the country 30 min late can easily mean a lack of several 100 MW.
- Off shore production can result in very steep production ramps.



## Main challenges for the Danish electricity system



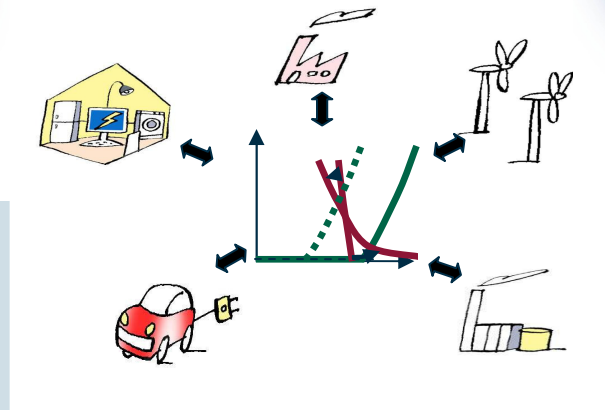
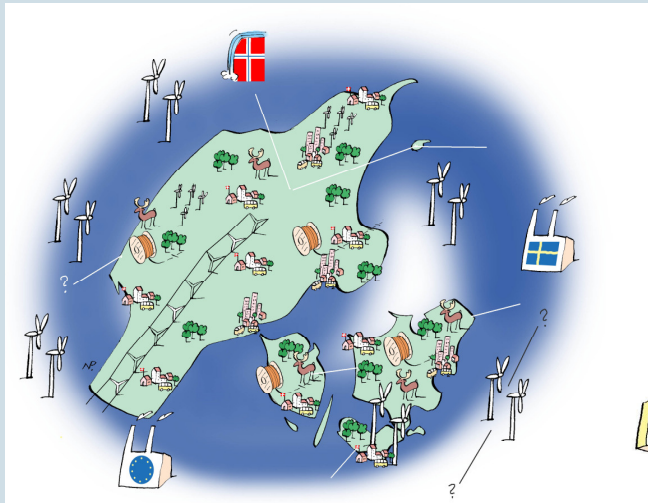
## 50% wind power in a “traditional” electricity system!

- System balanced through:
  - import/export
  - regulating available generators
  - stopping wind power



- Wind power stopped 1.000 hours/year
- 22% of marginal wind power wasted
- Market value of wind power reduced to 72% of remaining Danish electricity generation

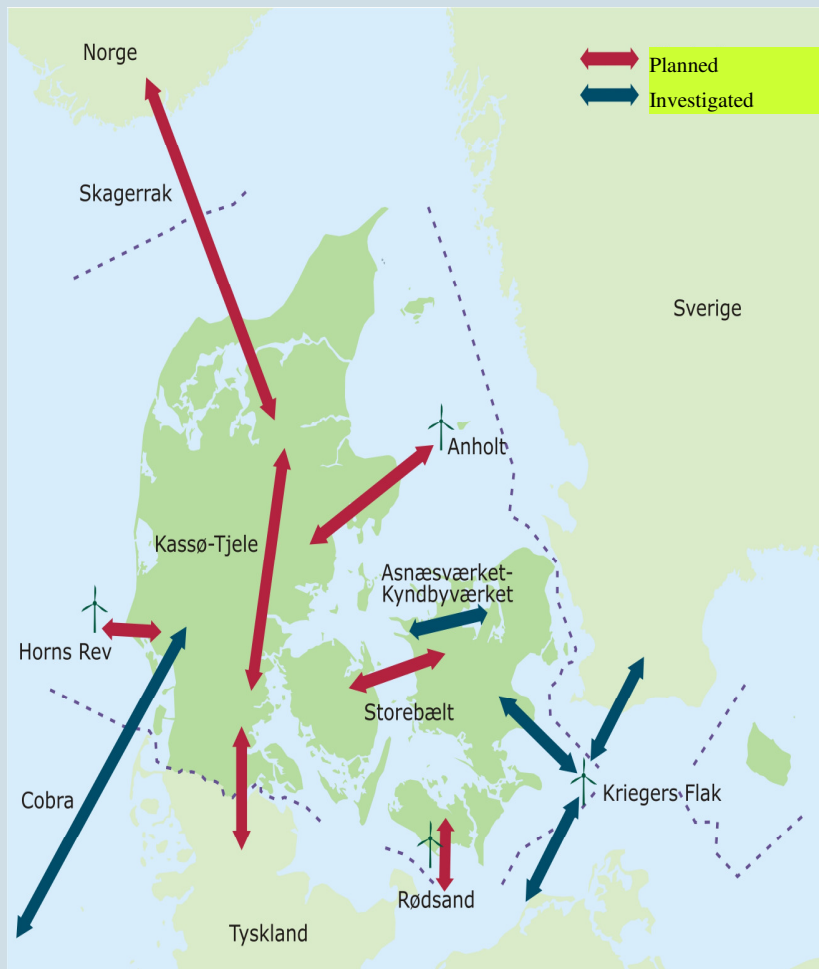
## Preparing for 50% Wind Power



### Efficient integration of wind power through:

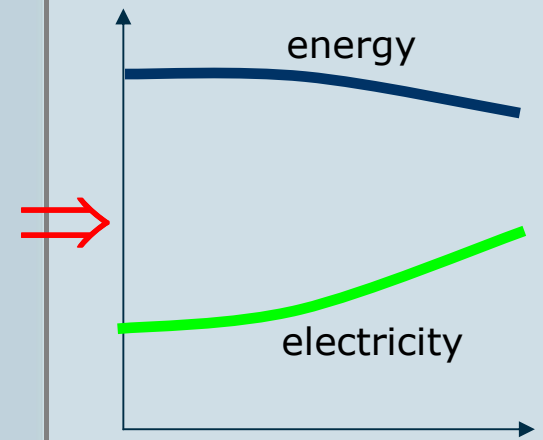
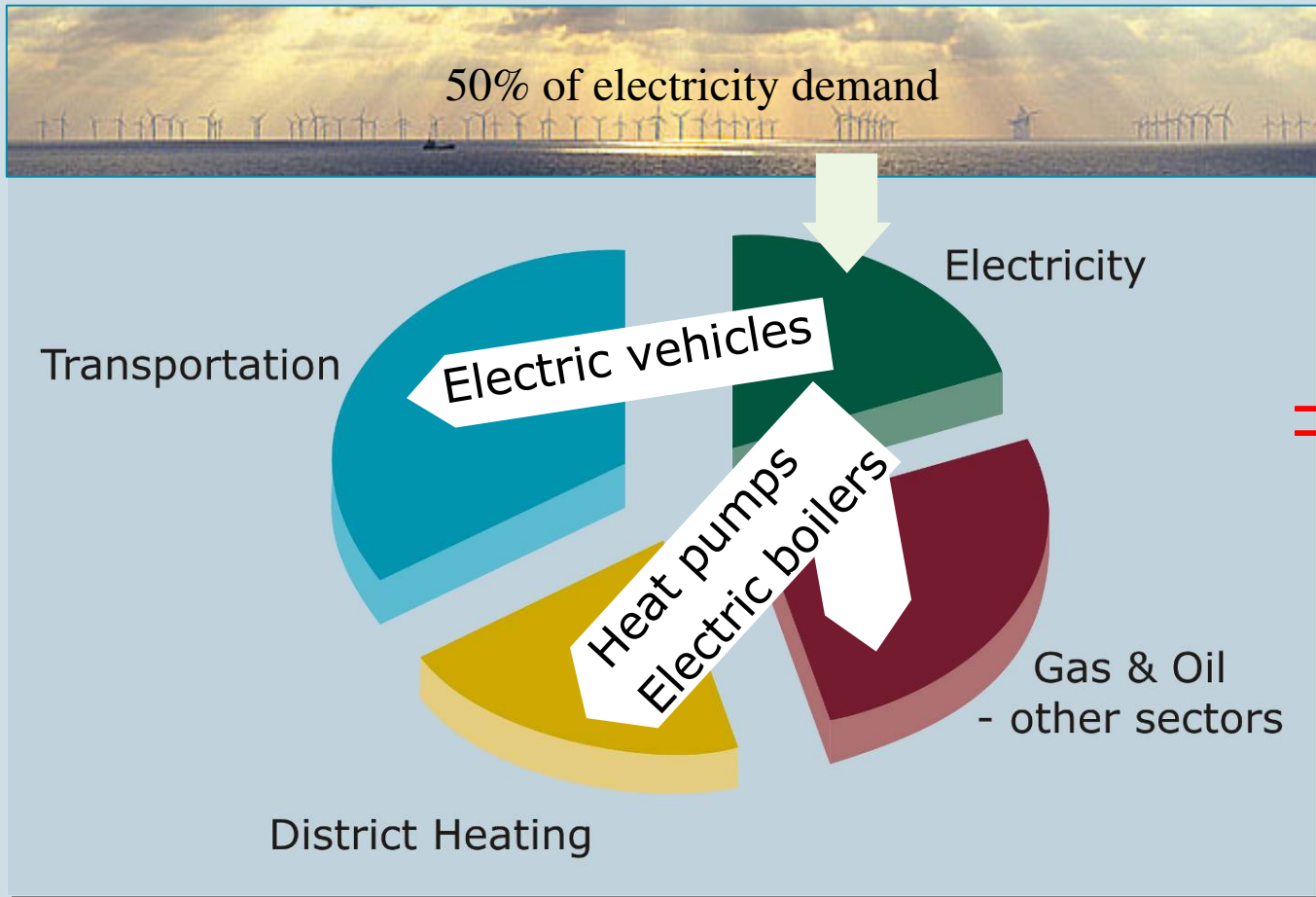
- A strong international transmission grid
- Coherent and flexible market based energy systems
- Active control - SmartGrids

## A strong international transmission grid

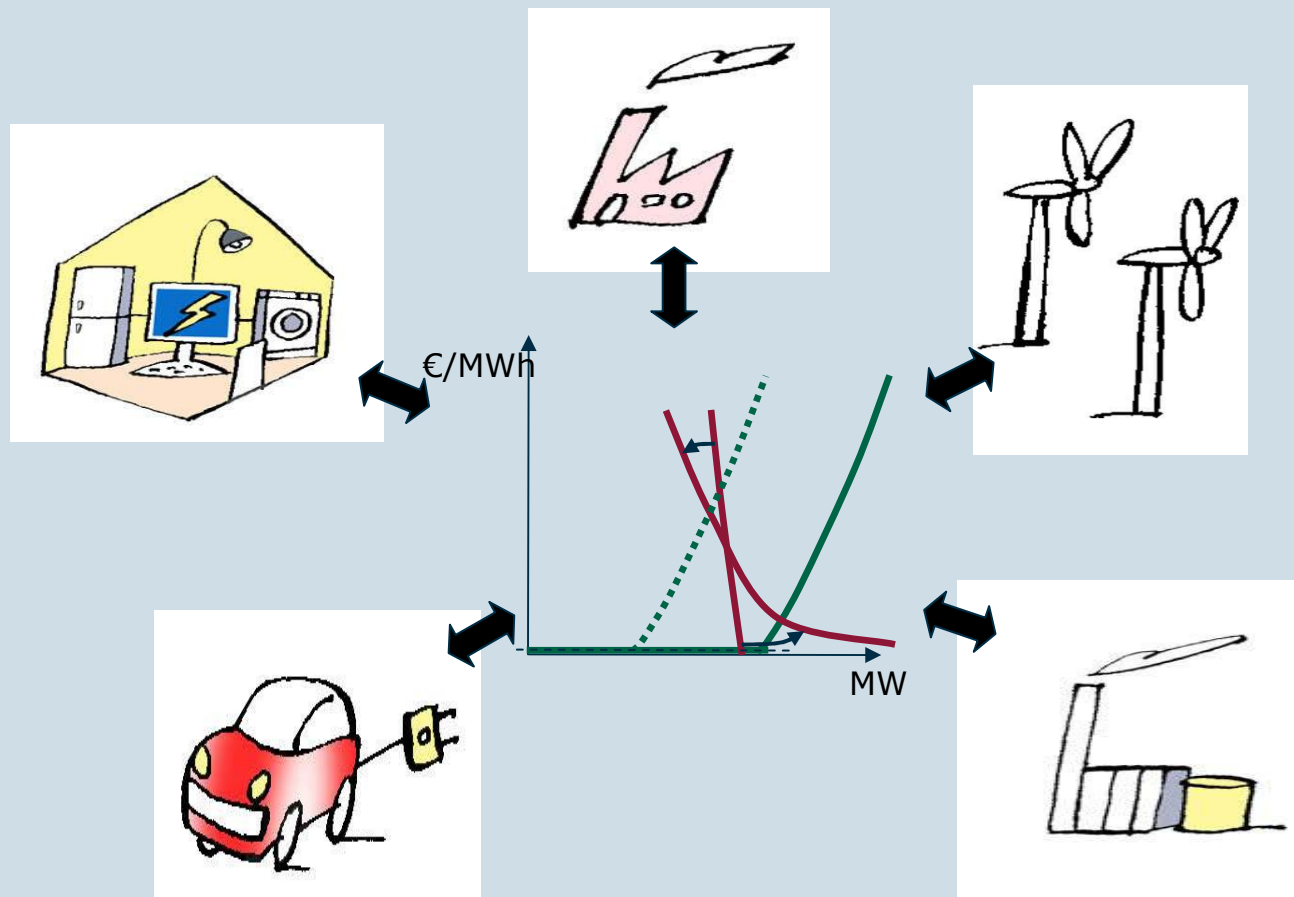


- **Wind power balanced in a larger area**
  - mutual support from geographically dispersed wind power
- **Diversities between systems utilized**
  - e.g. synergy between wind and hydro power
- **Robustness increases operational security**
  - secure handling of changing energy transports

## Coherent and flexible energy systems



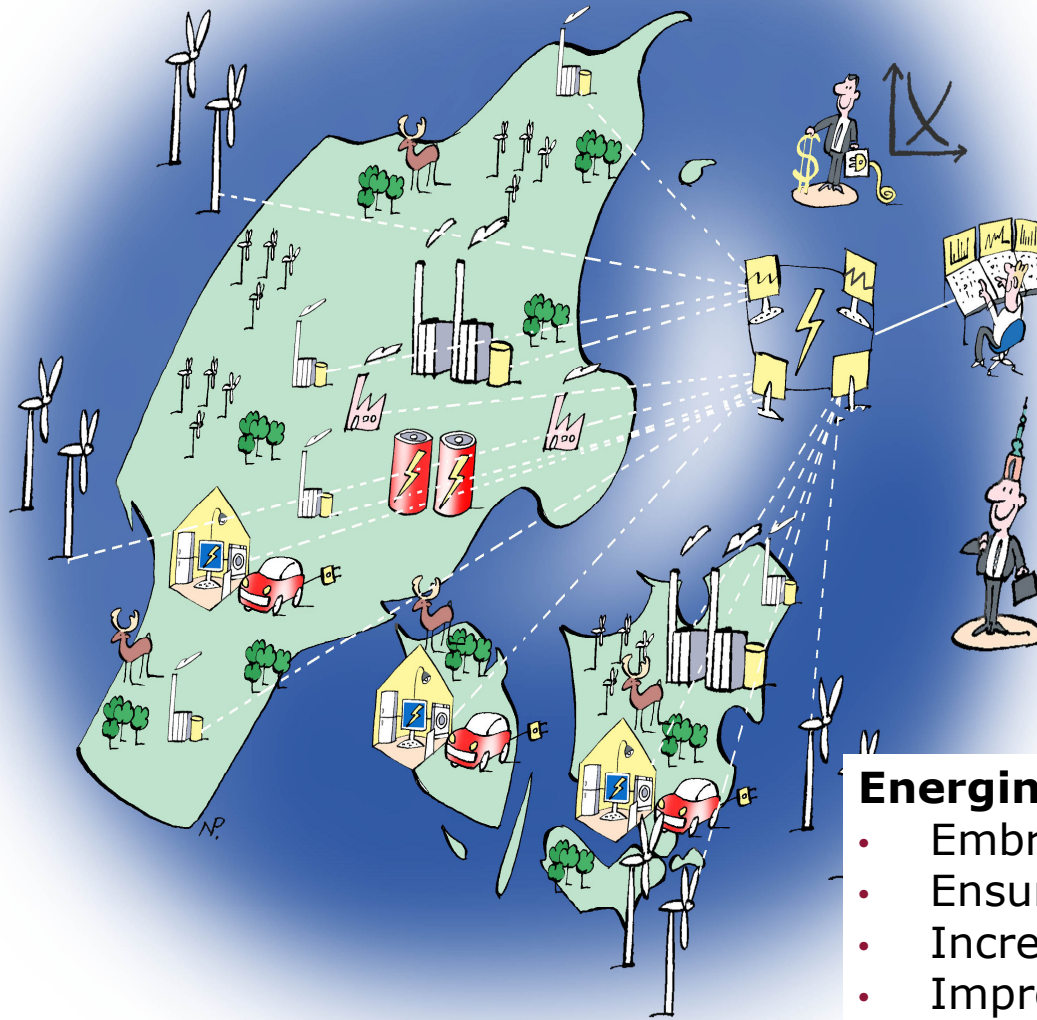
## Market based mobilisation of all flexible resources



flexible generation and inflexible demand → fluctuating generation and flexible demand



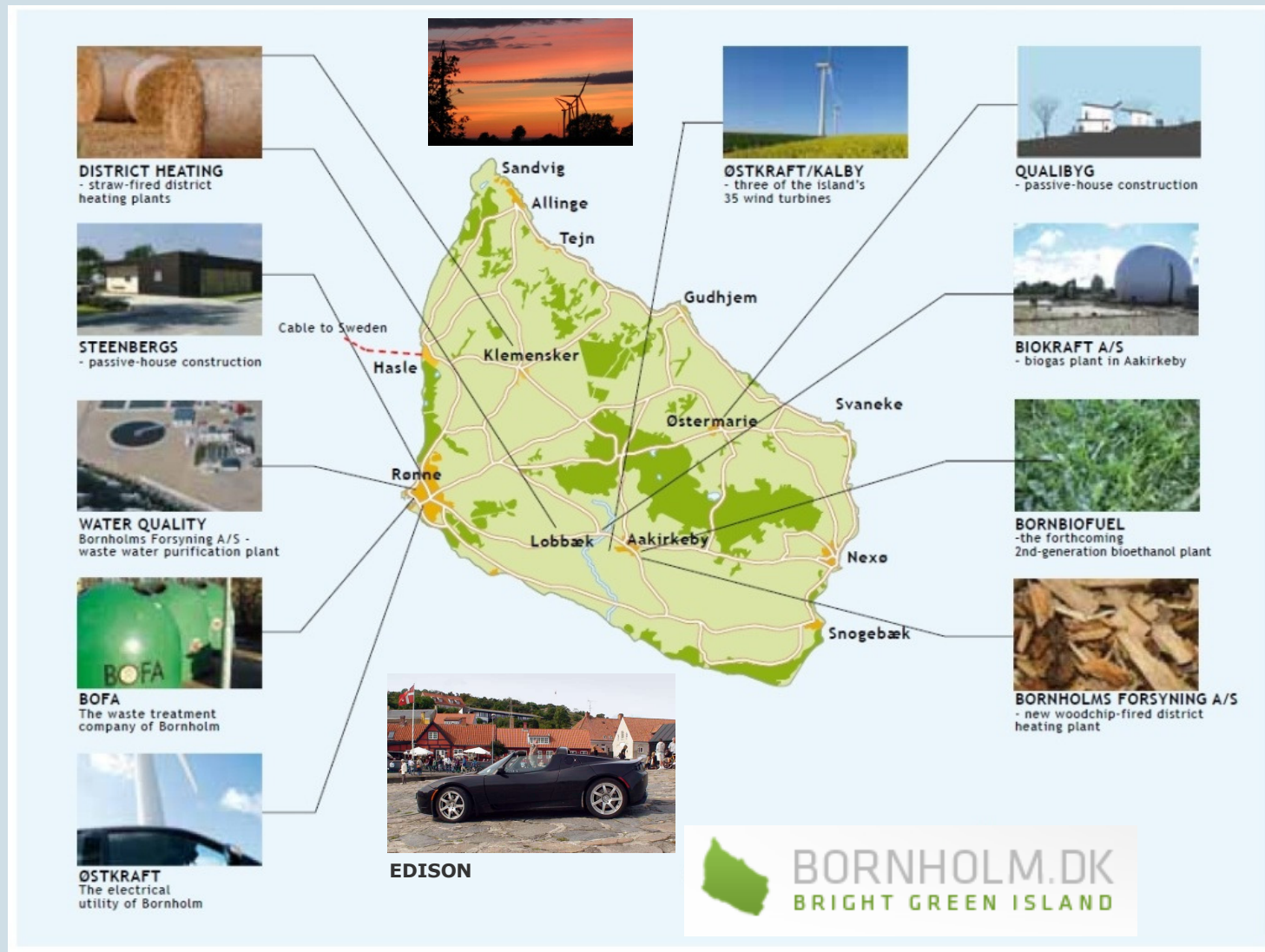
## Active control of distributed resources - SmartGrids



### **Energinet.dk prepares a concept to**

- Embrace the whole system
- Ensure optimal utilization of all resources
- Increase security of supply
- Improve market functioning

# Demonstration on Bornholm



## Conclusions

Efficient integration of large-scale wind power through:

- **A strong international transmission grid**
  - to trade and balance in a wide geographical area
- **Efficient international electricity markets**
  - with clear price signals and trading close to real-time
- **Coherent energy systems**
  - to increase flexibility and economic efficiency and reduce environmental impact – electricity, heat and transportation
- **High flexibility in generation and demand**
  - with technical connection requirements for all resources – Grid Codes
- **A revised power system control architecture**
  - for active control of distributed resources - SmartGrids

.....latest offshore platform launched in December!



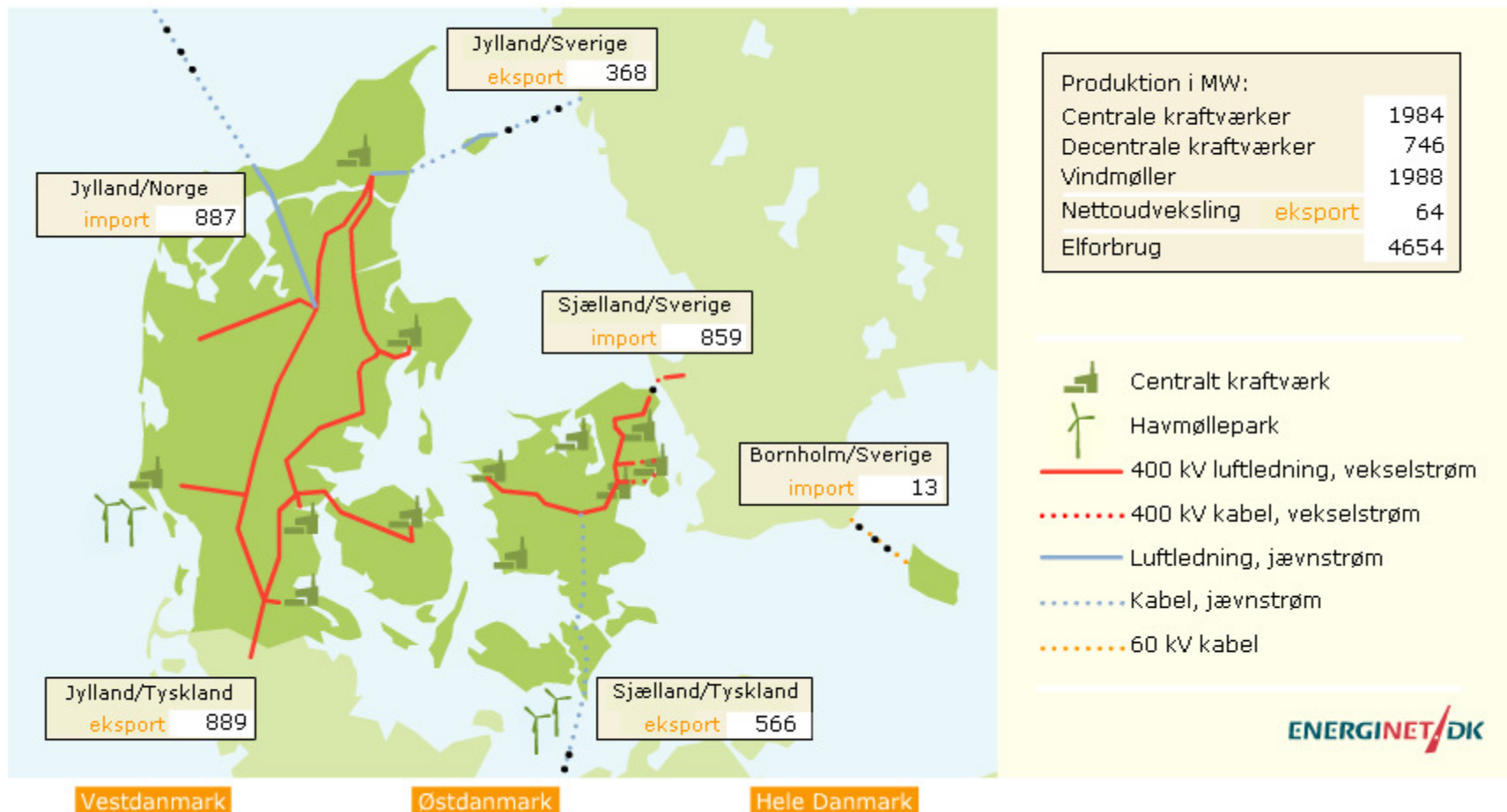
**Thank you for your attention!**

[www.energinet.dk](http://www.energinet.dk)

# Extra slides

# The power system right now

Elproduktion og elforbrug lige nu: 22/09/2009 10:19

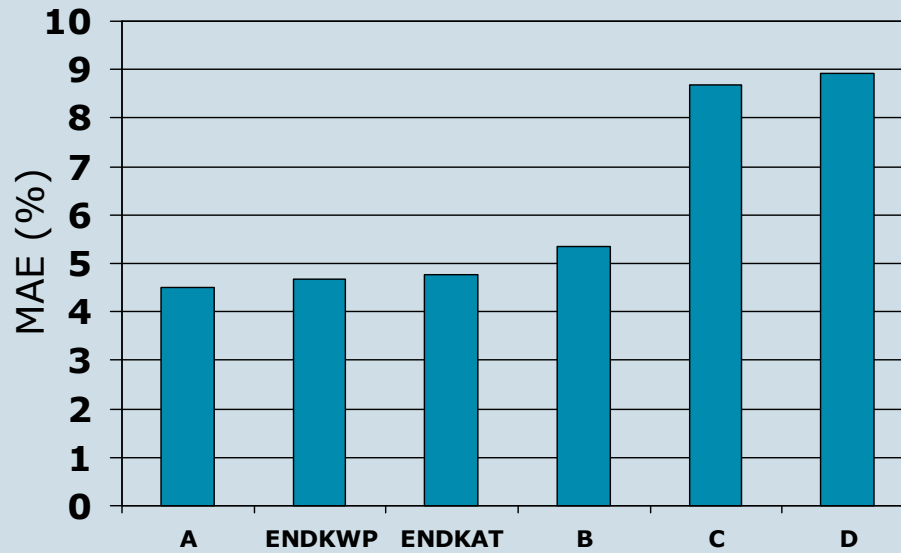


## Long term planning – available sites for 4.6 GW

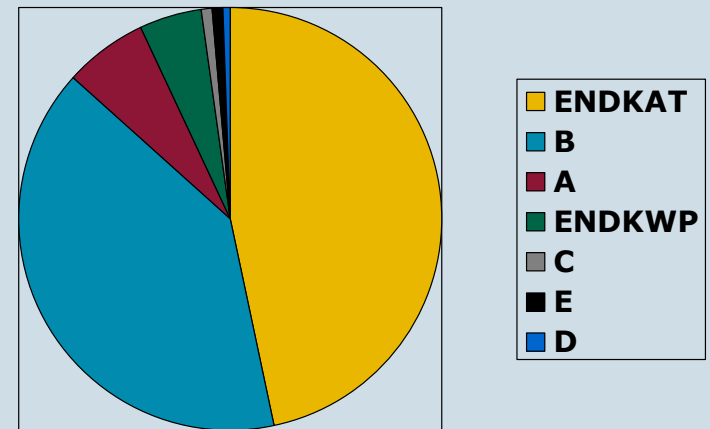


# Wind Power Forecast Performance per PBR

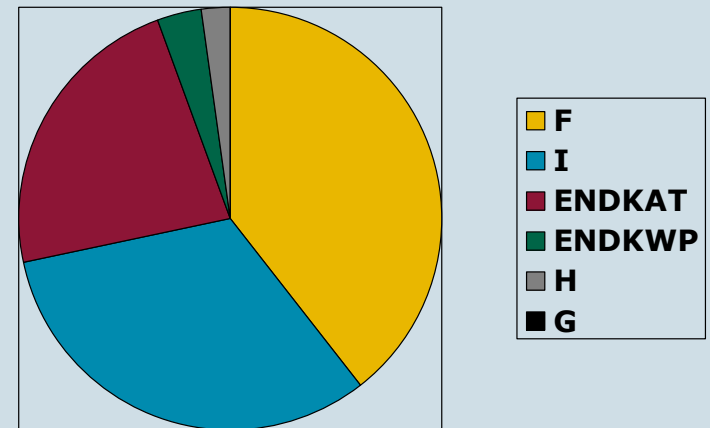
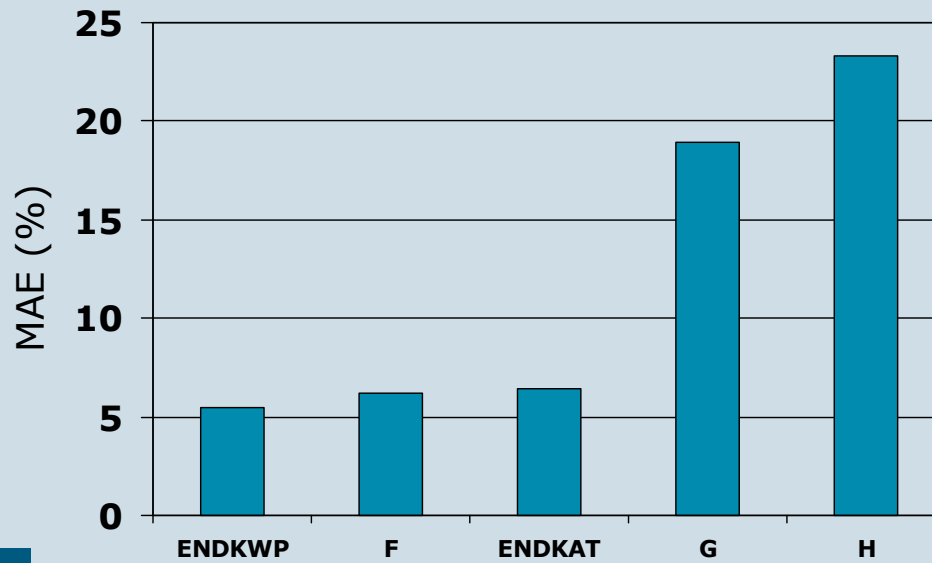
DK1



Share of installed wind power











DK2

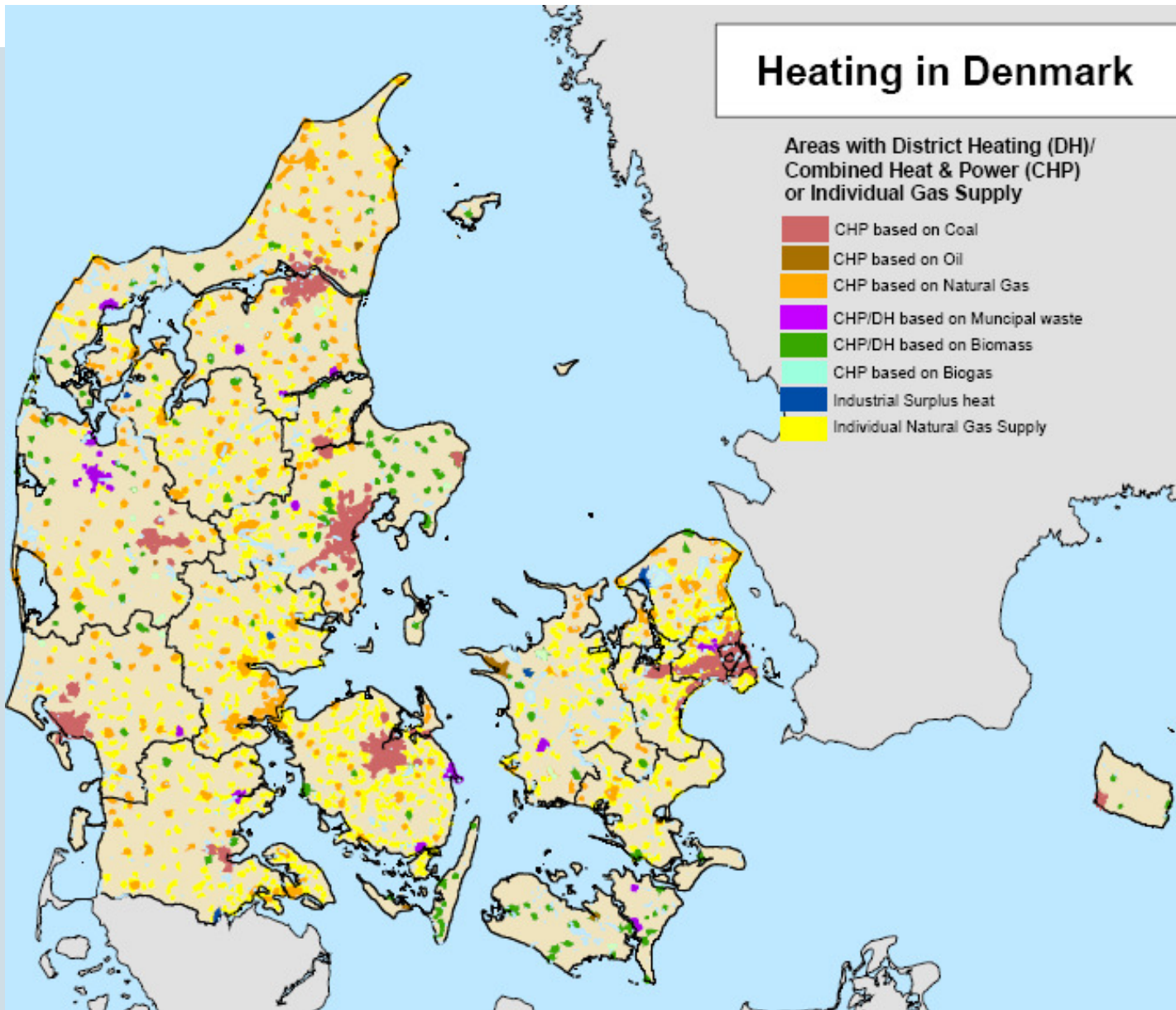




## Heating in Denmark

Areas with District Heating (DH)/  
Combined Heat & Power (CHP)  
or Individual Gas Supply

-  CHP based on Coal
-  CHP based on Oil
-  CHP based on Natural Gas
-  CHP/DH based on Municipal waste
-  CHP/DH based on Biomass
-  CHP based on Biogas
-  Industrial Surplus heat
-  Individual Natural Gas Supply



## The intraday market

- Continuous power trading up to one hour prior to delivery
- Bid types: hourly bids (MWh/h) and block bids
- Transmission capacity allocated according to "first-come-first-served"
- In the Nordic area Nord Pool's Elbas has monopoly

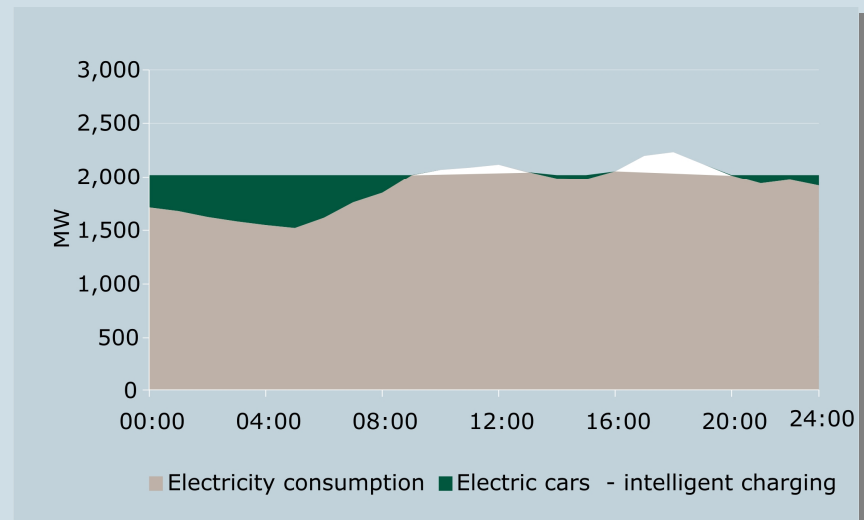
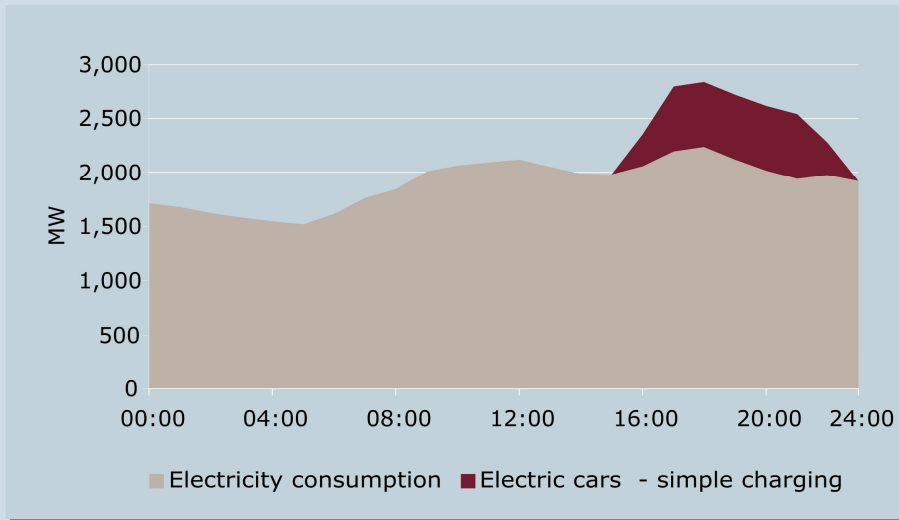




# New means for integration wind power

Means	Short term	Medium term	Long term
<b>Primary focus: Power system balancing</b>	<ul style="list-style-type: none"> <li>• Expansion of interconnections - cross-border electricity trade</li> <li>• Reinforcement and expansion of existing grid</li> <li>• Downward regulation of production through negative spot prices</li> </ul>	<ul style="list-style-type: none"> <li>• Geographical spread of offshore wind farms</li> <li>• Demand response</li> <li>• Flexible electricity generation</li> </ul>	<ul style="list-style-type: none"> <li>• Electricity storage in hydrogen for fuel cells</li> <li>• Compressed Air Energy Storage</li> <li>• Electricity storage in batteries</li> </ul>
<b>Primary focus: Electricity integration in other energy sectors</b>	<ul style="list-style-type: none"> <li>• Heat pumps in power stations</li> <li>• Electric boilers in power stations</li> </ul>	<ul style="list-style-type: none"> <li>• Heat pumps in private households</li> <li>• Plug-in hybrid cars</li> <li>• Electric cars</li> </ul>	<ul style="list-style-type: none"> <li>• Use of (electrolysis-based) hydrogen in transport sector</li> <li>• Use of (electrolysis-based) hydrogen in natural gas grid</li> </ul>

# Electric cars – simple or intelligent charging



# Efficient use of Wind Power in Denmark

Our main conclusions – key figures on EU’s 2020 targets:



	RE share of total energy consumption	CO <sub>2</sub> emissions in sectors not subject to emission allowances Million tonnes/year	RE share of transport	Energy efficiency
Target for Denmark, see the EU 2020 targets	+13 percentage points	-7.5	+10%	-20%
Heat pumps and electric vehicles 2020	+5 percentage points	-3	+4%	-7%

*Note: The table includes handwritten annotations in yellow circles: '- 40 %' is written over the RE share of total energy consumption and RE share of transport values for the 'Heat pumps and electric vehicles 2020' row. '- 40 %' is written over the CO<sub>2</sub> emissions value for the same row. '- 35 %' is written over the Energy efficiency value for the same row.*