STandUP for Energy Systems

Possibilities and challenges with generation of large amounts of renewable electricity

KTH, October 21, 2011

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Professor in Electric Power Systems, KTH

School of Electrical Engineering

- Automatic Control
- **Electric Power Systems**
- Fusion Plasma Physics
- Signal Processing
- Communication Networks
- Electrical Machines and Power Electronics
- Industrial Information and Control Systems
- Sound and Image Processing
- Communication Theory
- Electromagnetic Engineering
- Microsystem Technology
- Space and Plasma Physics

KTH
VETENSKAP
OCH KONST

Power Systems - personnel

- 1 Professor Lennart Söder, head
- 1 Administrator: Brigitt Högberg
- 1 Docent: Mehrdad Ghandhari
- 3 Assistant professors: Mikael Amelin, Luigi Vanfretti, Mohammad Hesamzadeh
- 4 researchers with PhD (Brolin, Eriksson, Hejri, Alvehag)
- 13 KTH-employed PhD students
- 7 not KTH-employed PhD students

- **In total at KTH: 30 (~34 2012)**

Electric Power Systems – research

Centra, International research cooperation

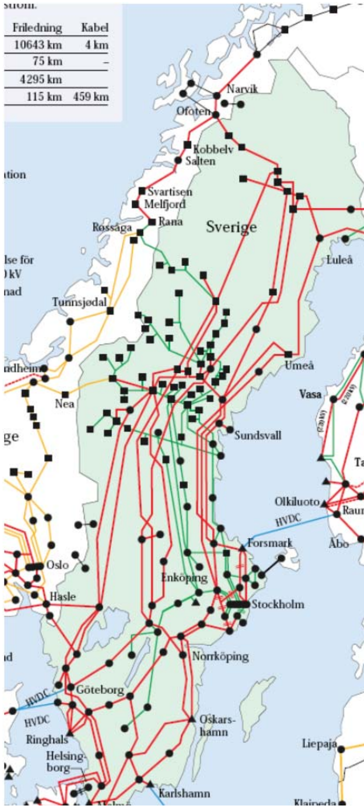
- EKC-2, Stand-Up, EIT, SETS Joint Doctorate (Sustainable Energy Technologies and Strategies), IEA, IEEE, Cigre, PSCC, program Energisystem, NEPP, PV-ERA, iTESLA, STRONgrid

Results from research

- Control methods for smart grids, economic regulations, integration of wind power, 2009: highest ”Crown-index” at EE-school

Future potential

- The division will grow, 3-4 PhD students per year only from SETS, increasing interest for wind power and smart-grids, around 80 applicants per PhD position. Need of more seniors.

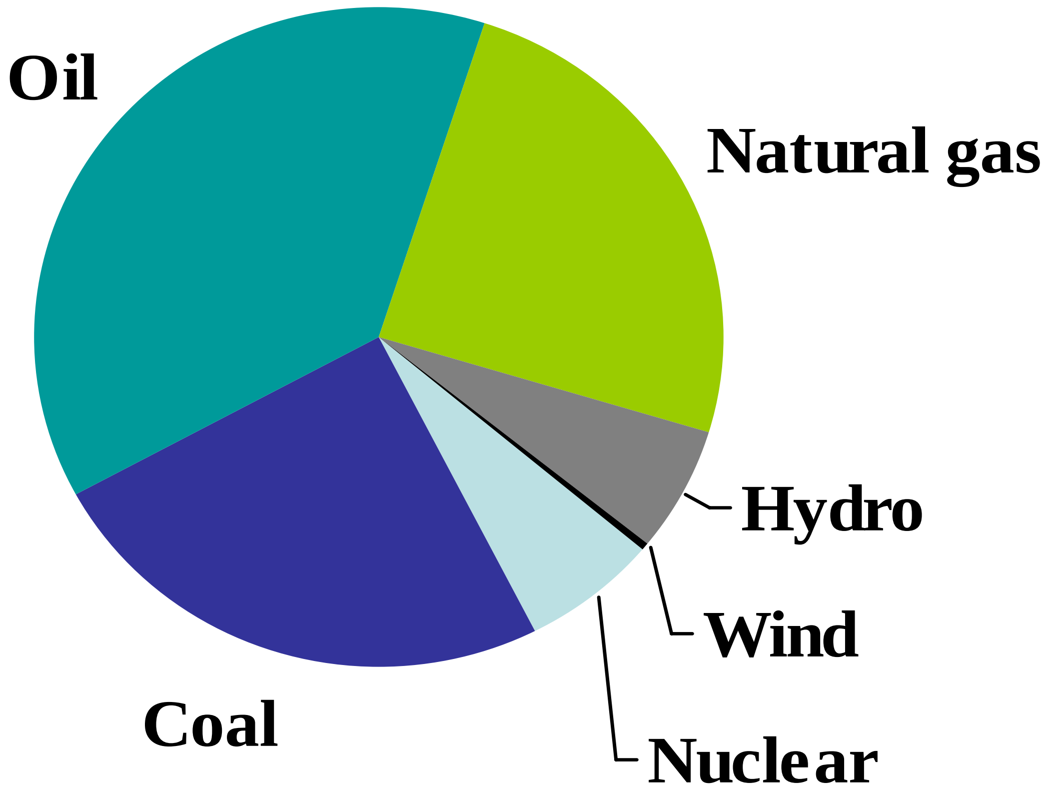


Power Systems - research

- **Power System Dynamics and Control**, 12 projects
- **Electricity Market and Production Planning**, 8 projects
- **Power System Network Planning**, 6 projects

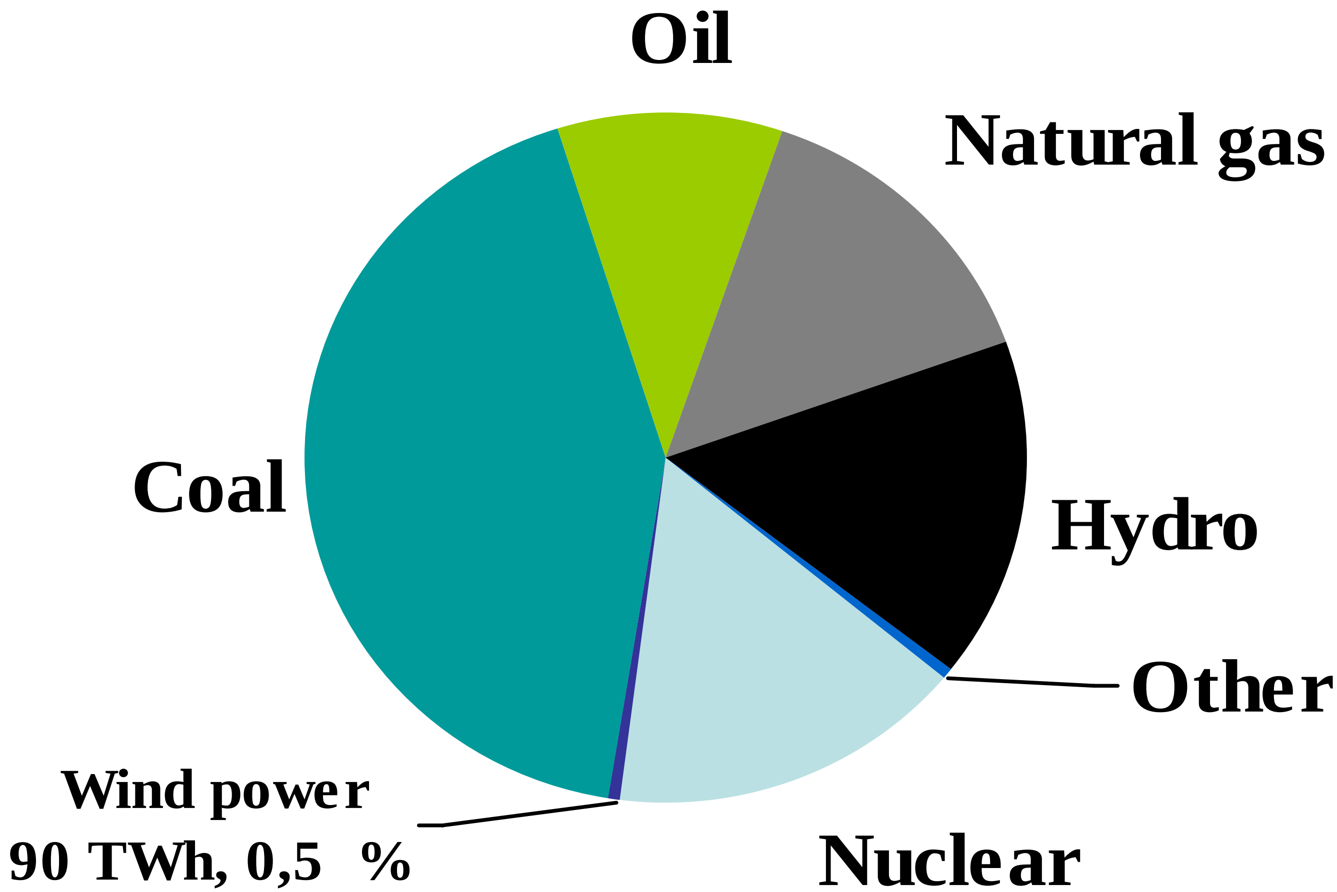
World energy consumption 2003

114 000 TWh

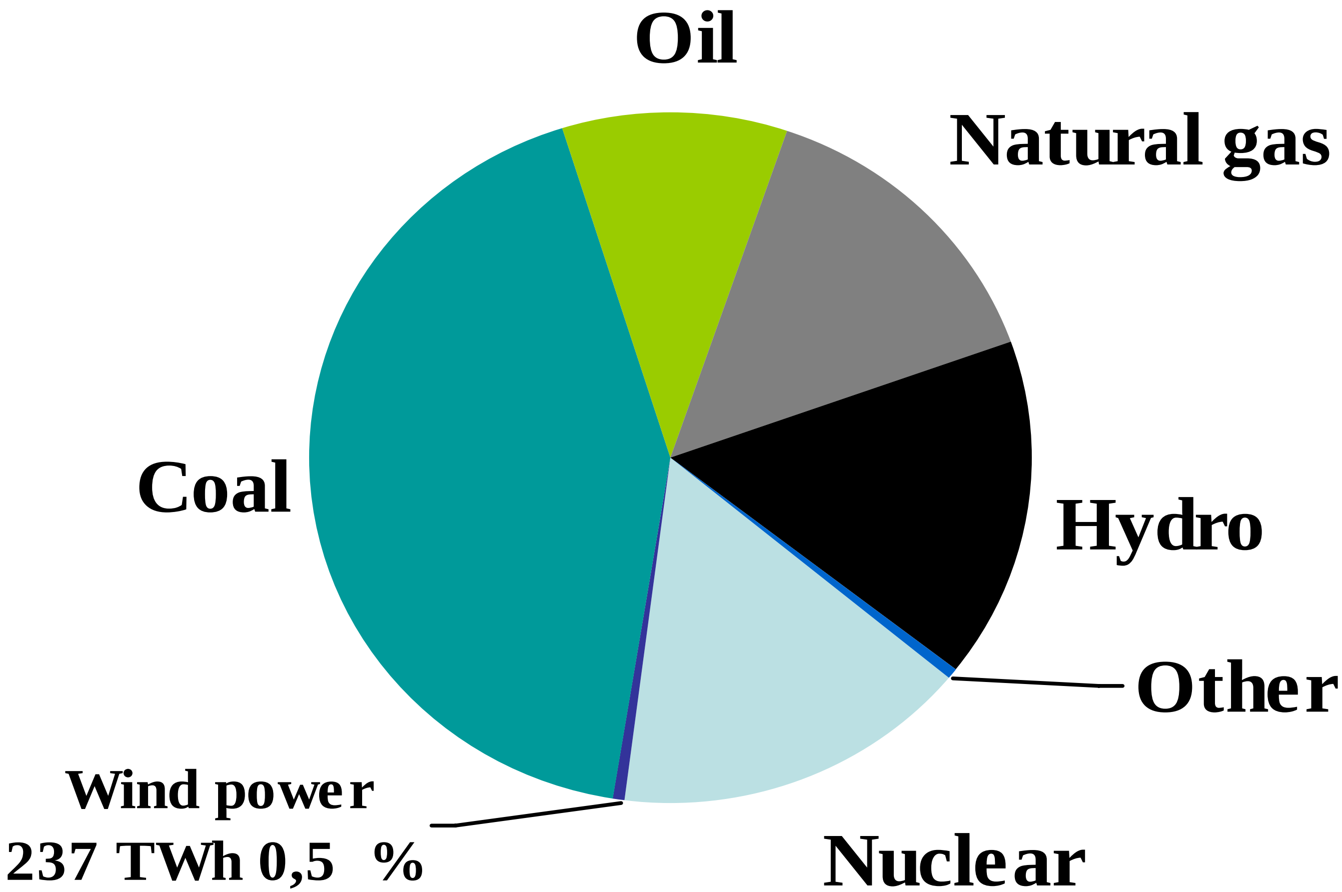


Hydro, wind, nuclear:
Replaced thermal energy, 38% efficiency

World electric power production 16 700 TWh



World power production as thermal equivalent 43 850 TWh (39% of all)



Aim of a power system:

1. Supply consumers with electricity when they want

   = keeping the continuous balance between production and consumption

   (deregulated → competition)

2. Keep the voltage for the consumers

   (regulated monopolies)

unbundling

Power = current · voltage

Renewable energy systems

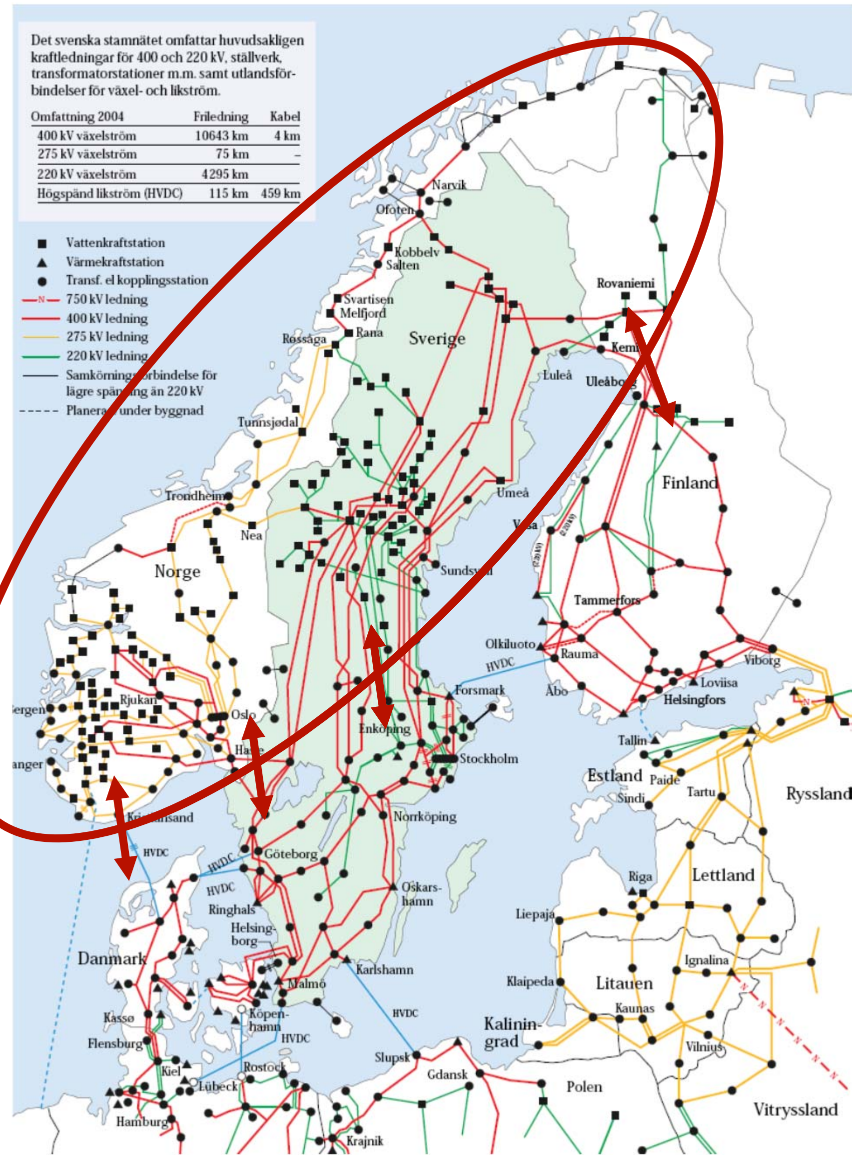
- Energy is ”produced” where the resource is
- The energy has to be transported to consumption center
- The energy inflow varies, which requires storage and/or flexible system solutions

- This is valid for hydro power, **wind power**, solar power

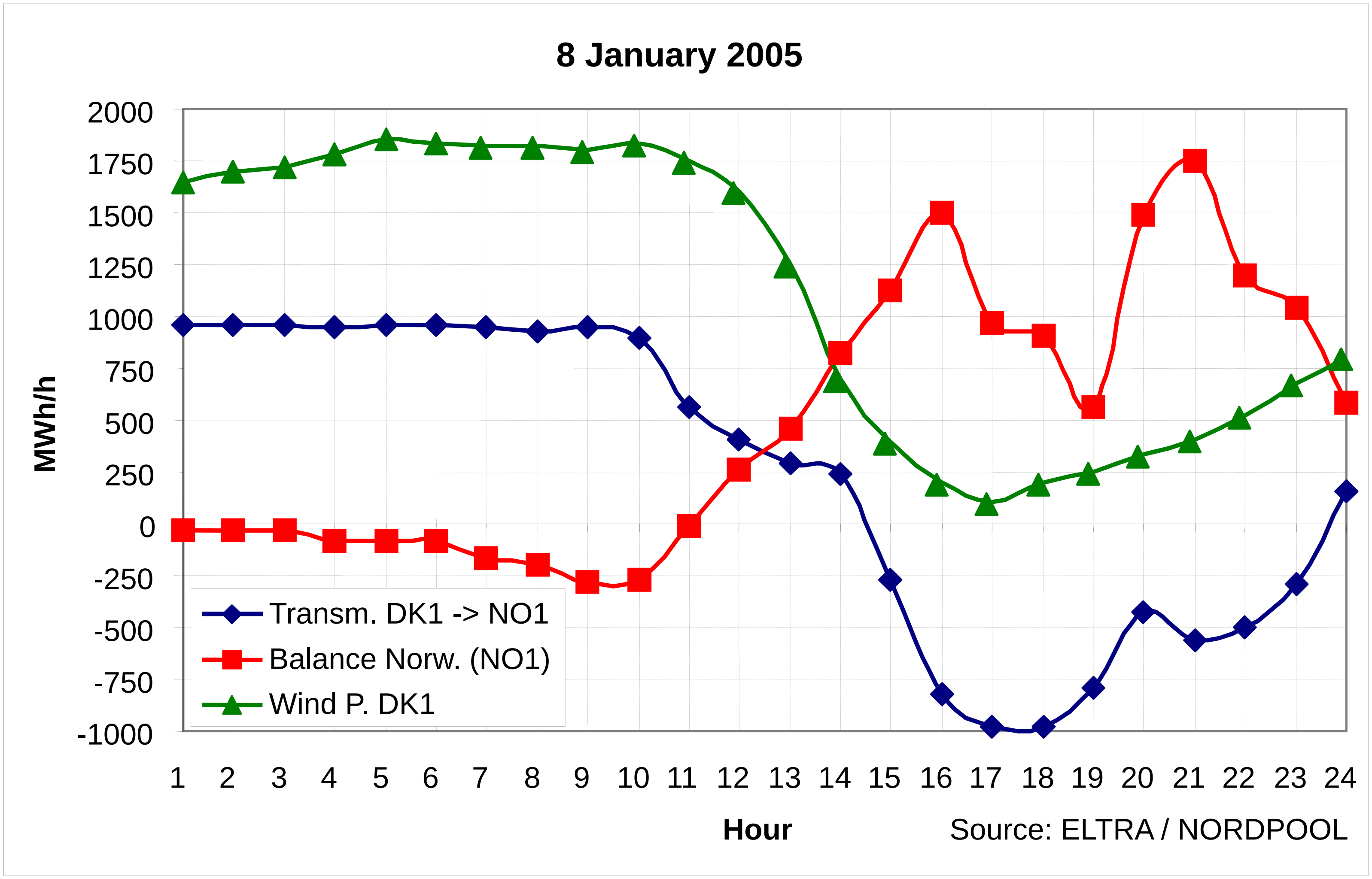
Example

- Nordic hydro inflow can vary 86 TWh between different years (1996, 2001)
- Transport from north Sweden to south Sweden
- Energy **balancing** with thermal power in Da+Fi+Ge+EE+Pl+NL

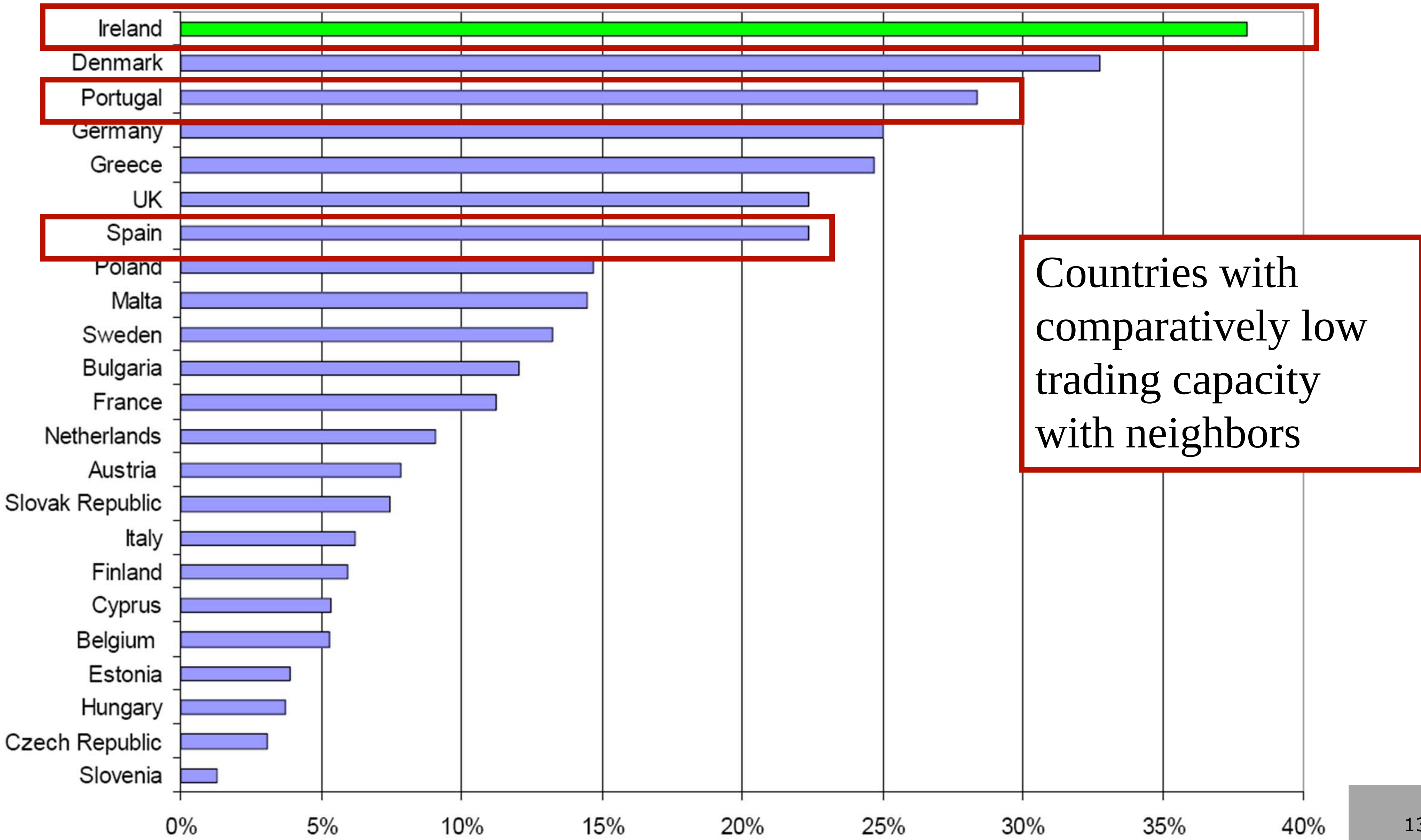
- **Wind power results in the same type of variations/ uncertainties (and solutions) as hydro power.**
- **But: Time perspective is much shorter!**



Example from Denmark, when a storm front hit the country: -1800 MW in 6 hours



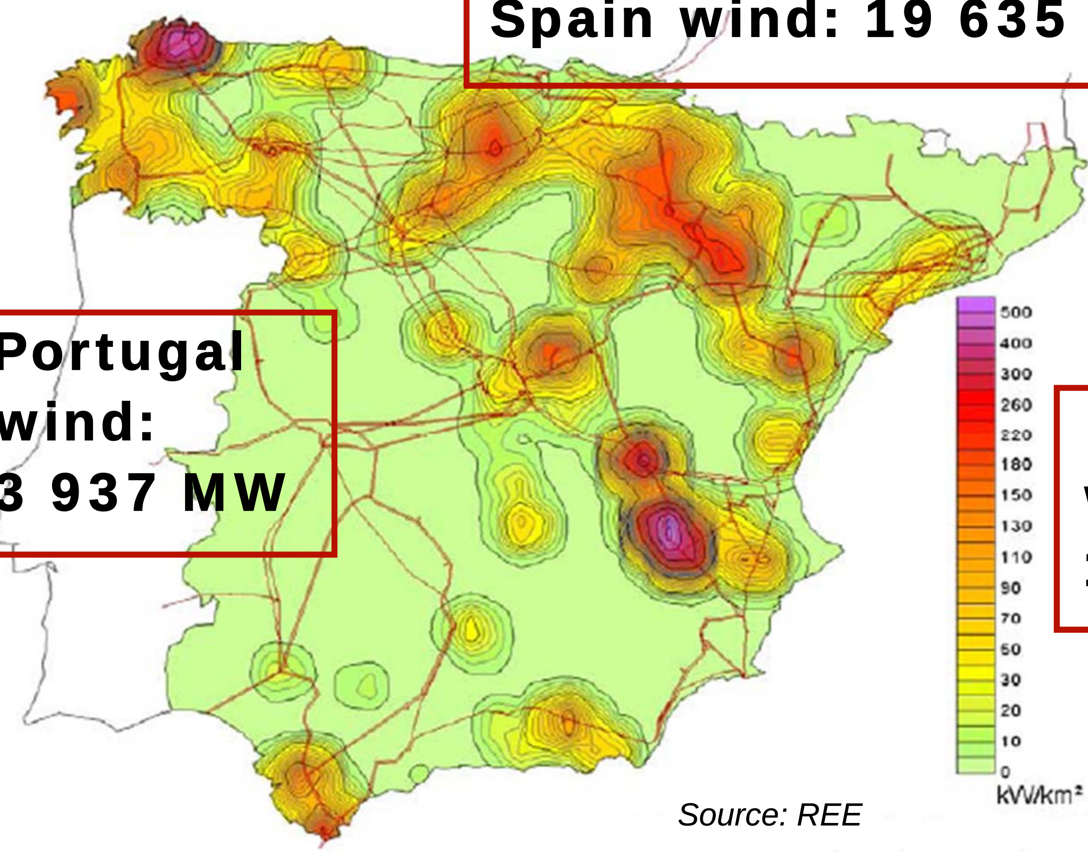
Wind as a Percentage of Total Electricity, 2020 target - Select EU Countries



Wind Power and Transmission capacities

Spain wind: 19 635 MW

Portugal wind: 3 937 MW



Ireland wind: 1539 MW

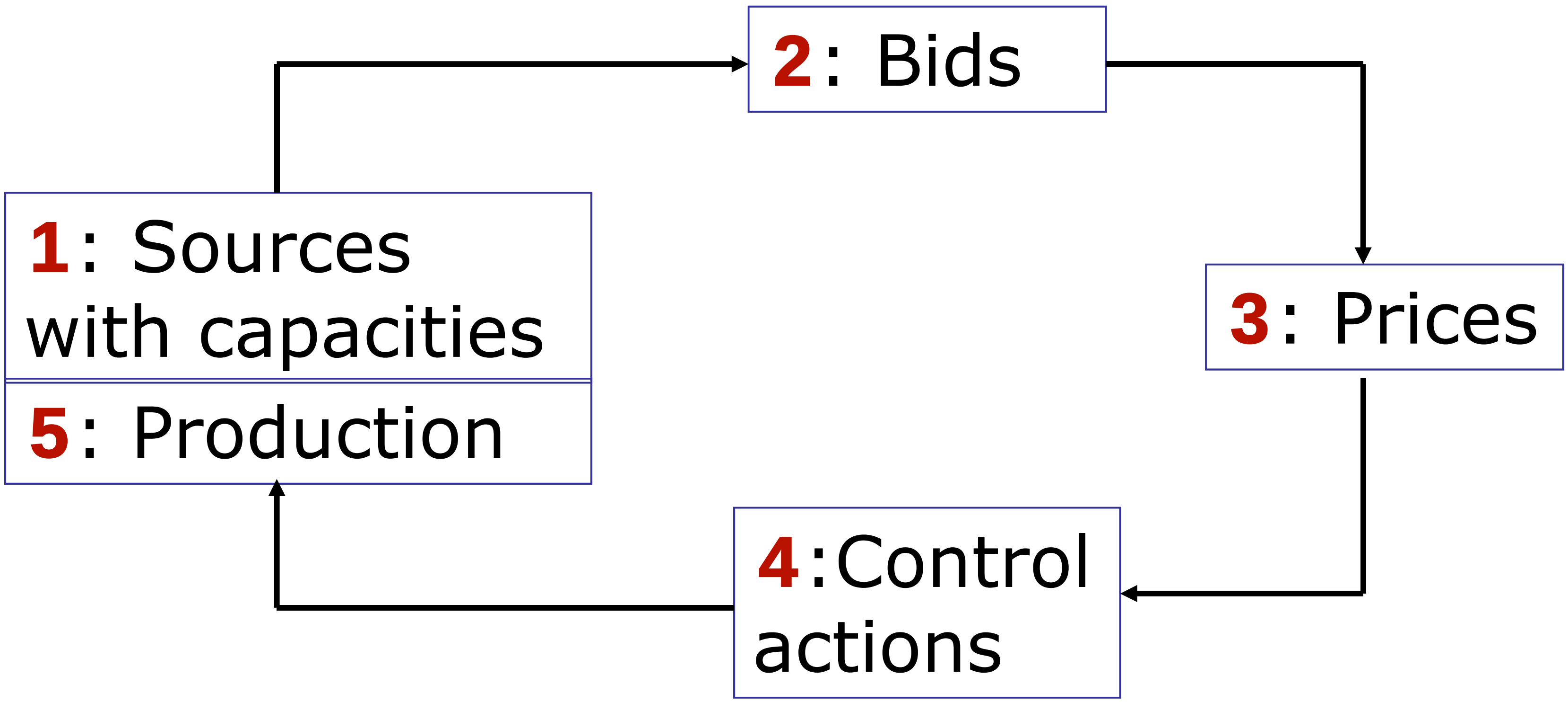
	Wind Energy 2010
Sp	16 %
Po	17 %
Ir	13 %

	Wind max share
Sp	54 %
Po	81 %
Ir	52 %

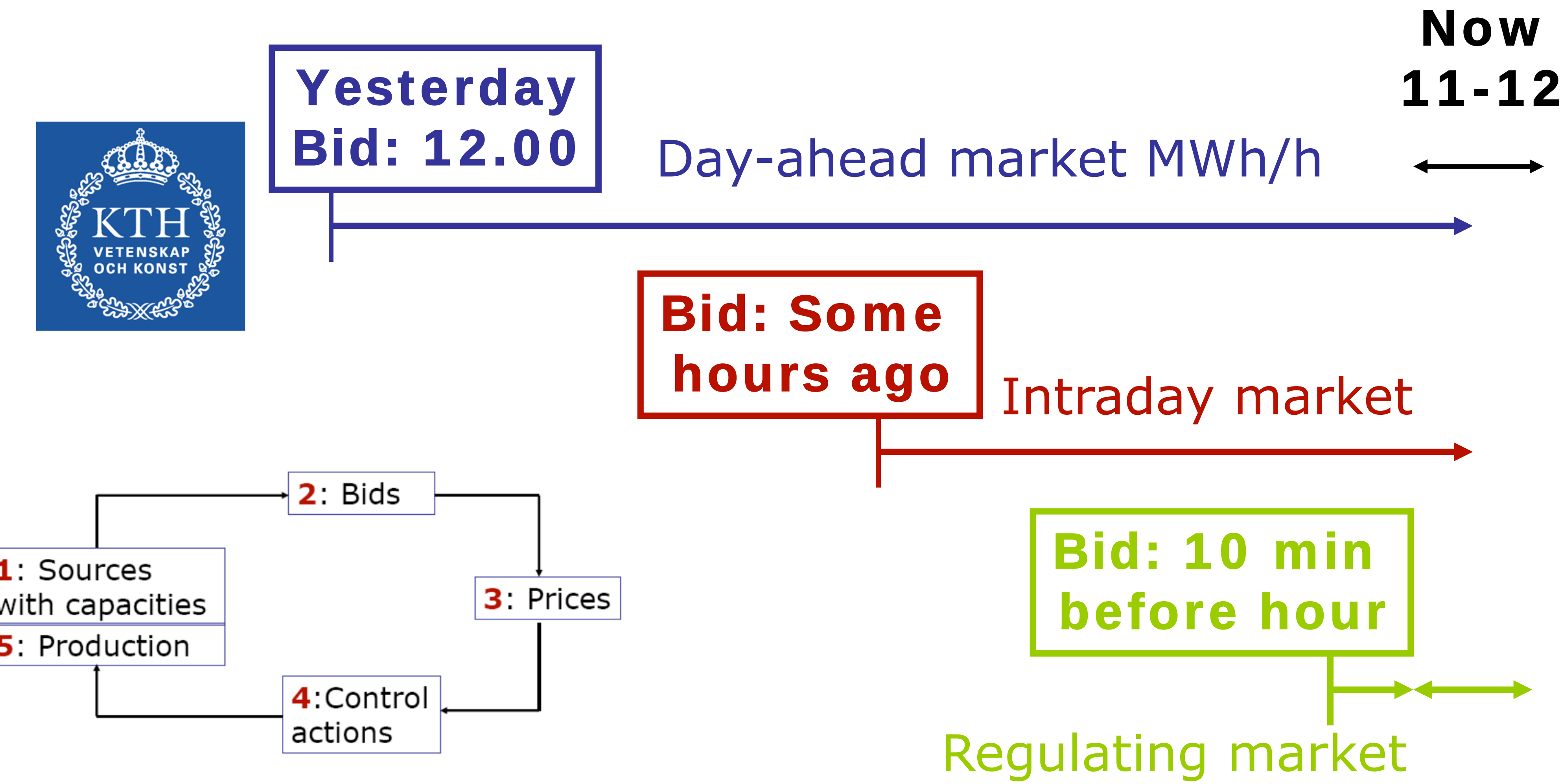
- Portugal –Spain: 1200 MW
- Spain – France: 1200 MW
- Spain – Morocco: 650 MW

- Ireland - Scottland: 450 MW
- Planned: +850 MW

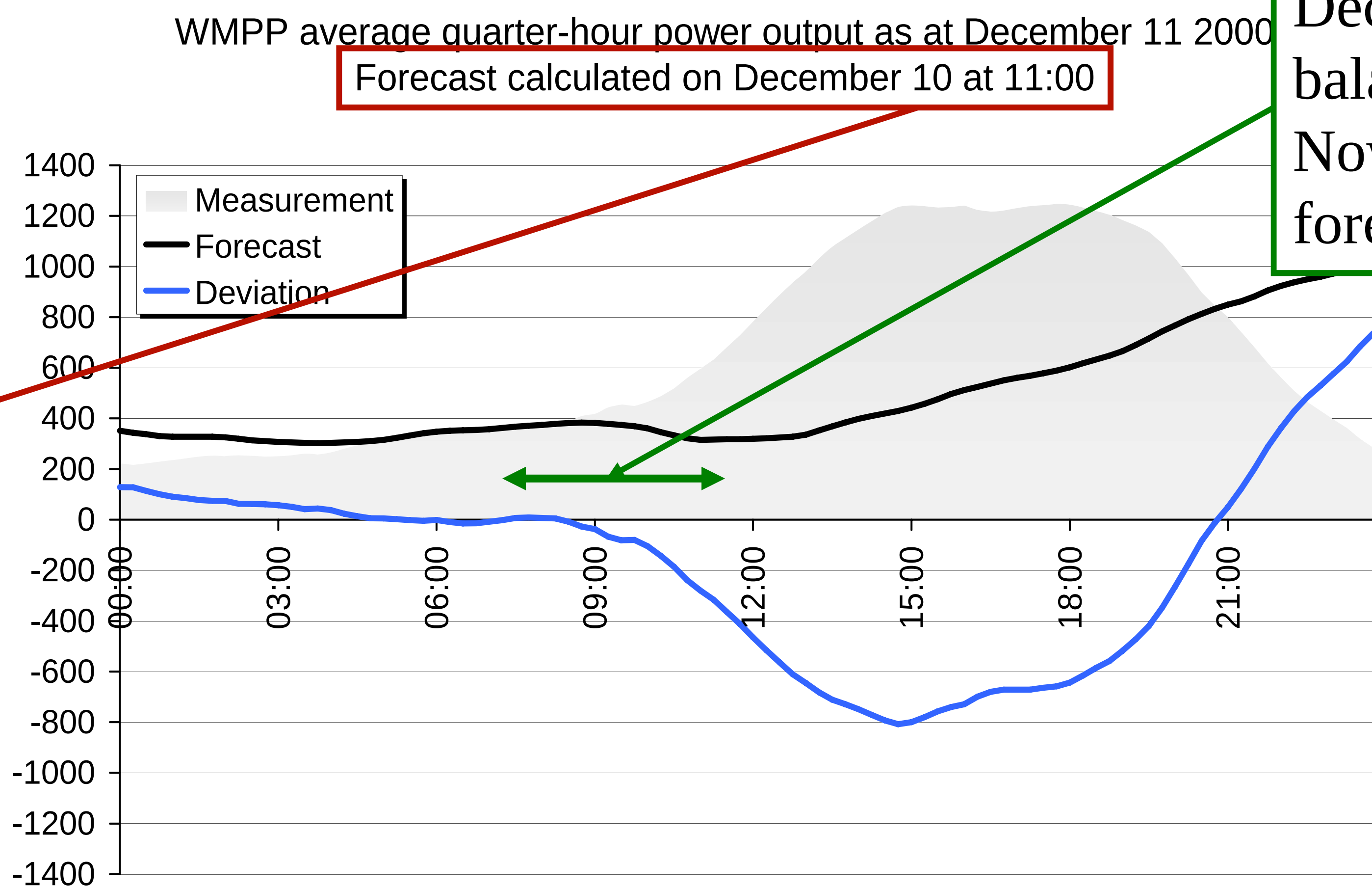
Pricing in power markets - 1



Pricing in power systems - 2



On up-dated forecasts



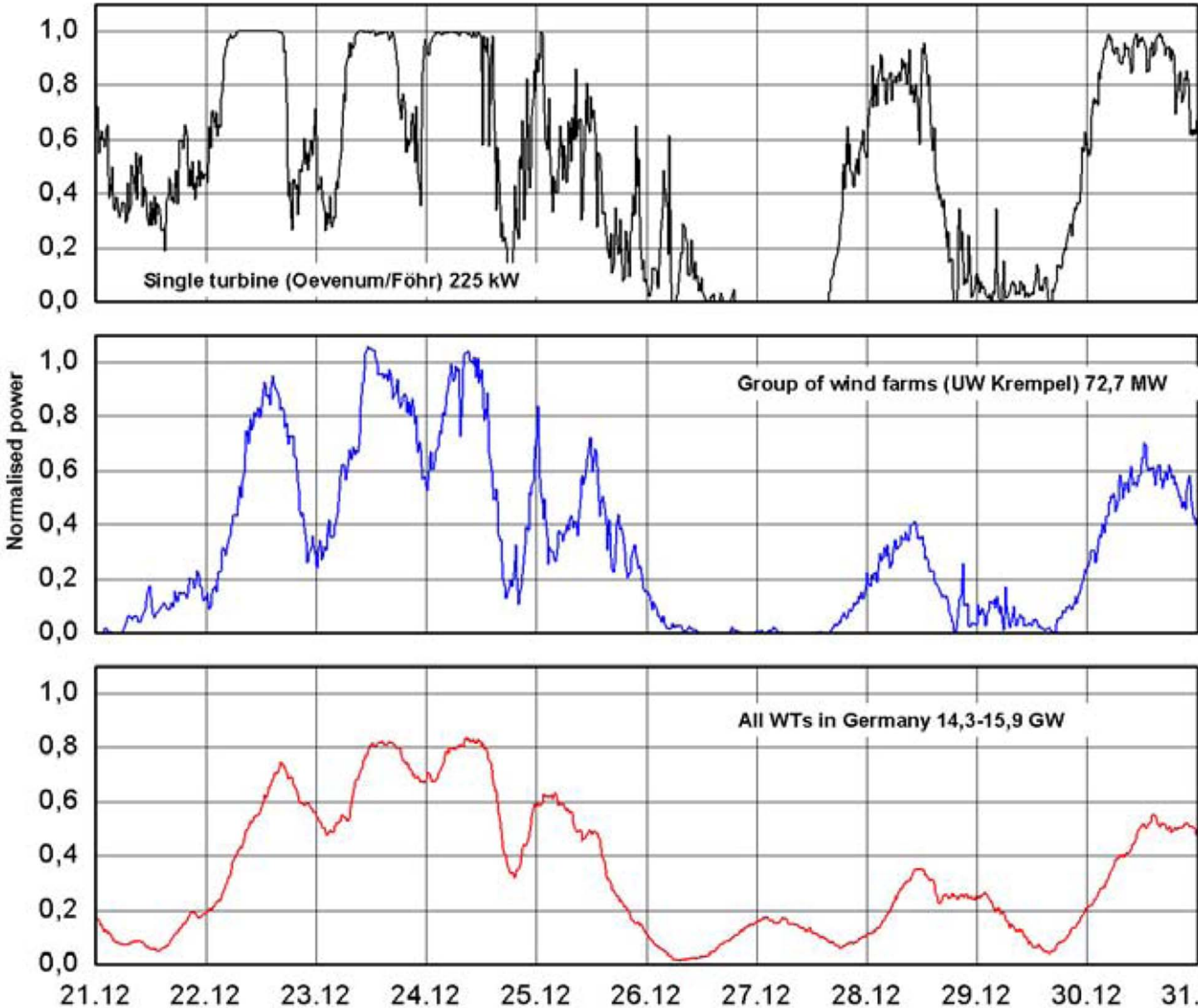
Decision for balancing: Now improved forecast!

German example

1 turbine

a farm

all German wind power



2004

Pricing in power systems - 3

Challenges:

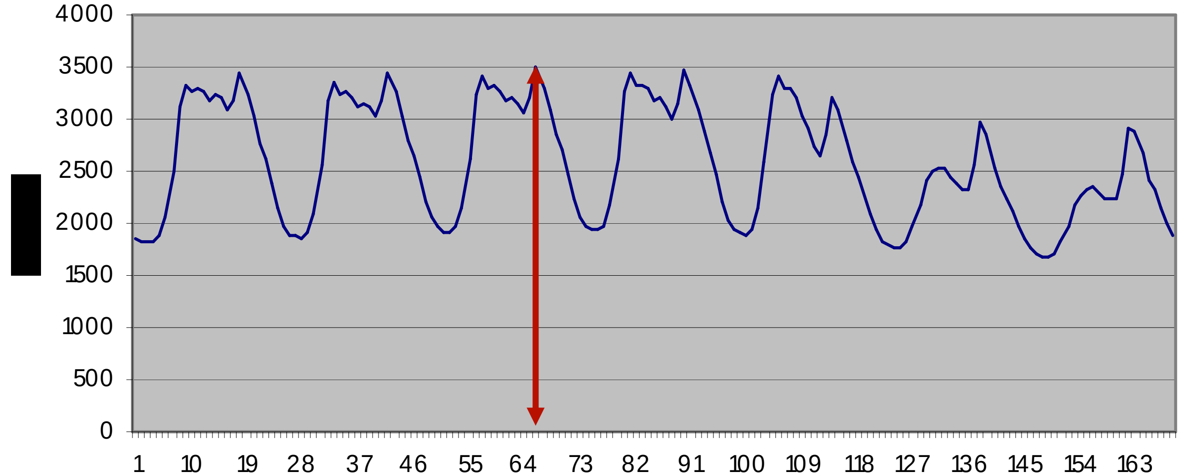
- **Bid planning** considering opportunities and uncertainties
- **Production planning** and operation considering opportunities and uncertainties
- **Estimation of** future **prices** in different systems
- **Stochastic optimization** approach needed
- **Intra hour modelling**

Pricing in power systems - 4

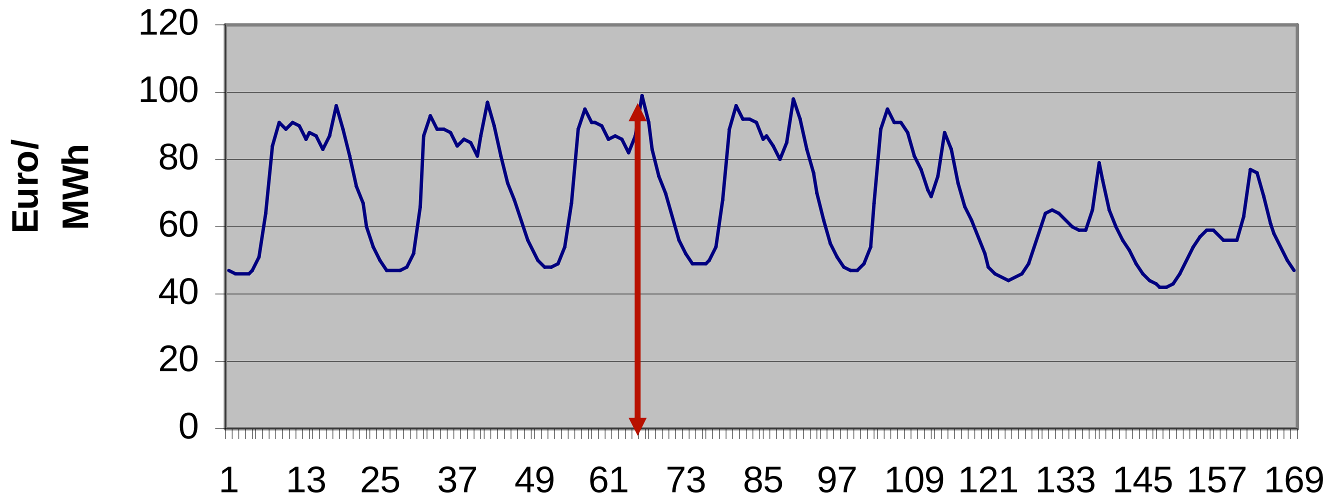
With an assumption of perfect competition:

- Prices are based on production marginal costs
- Low costs units are used first
- Higher load ➔ higher prices:

Weekly demand



pricing



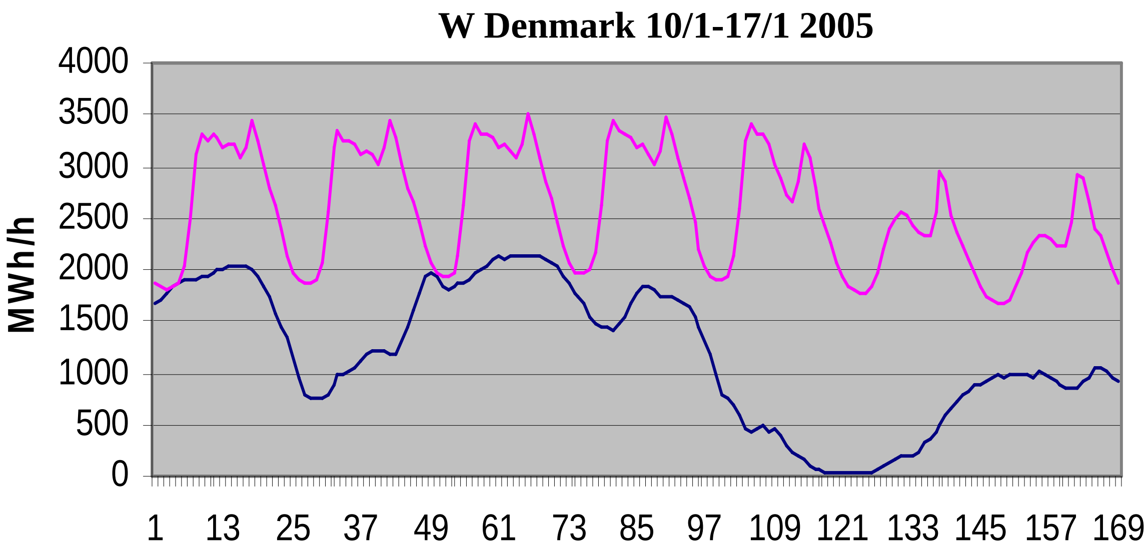
Pricing in presence of variable sources (e.g. wind)

Wind power has a marginal cost ≈ zero

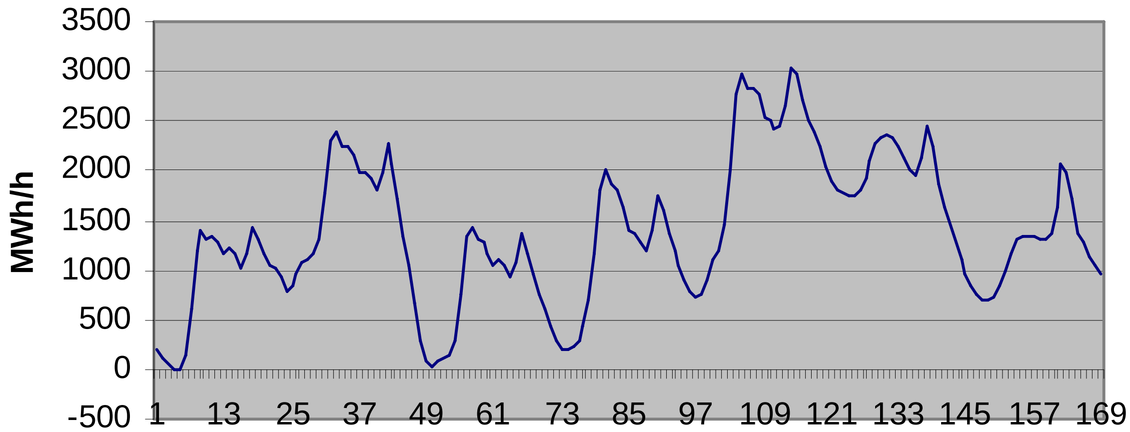
The production level is depending on wind speed

It is not easy to make good long term (hours) forecasts

Other units have to cover the net load = demand - wind



Weekly deman[d] + wind



Weekly net deman[d]

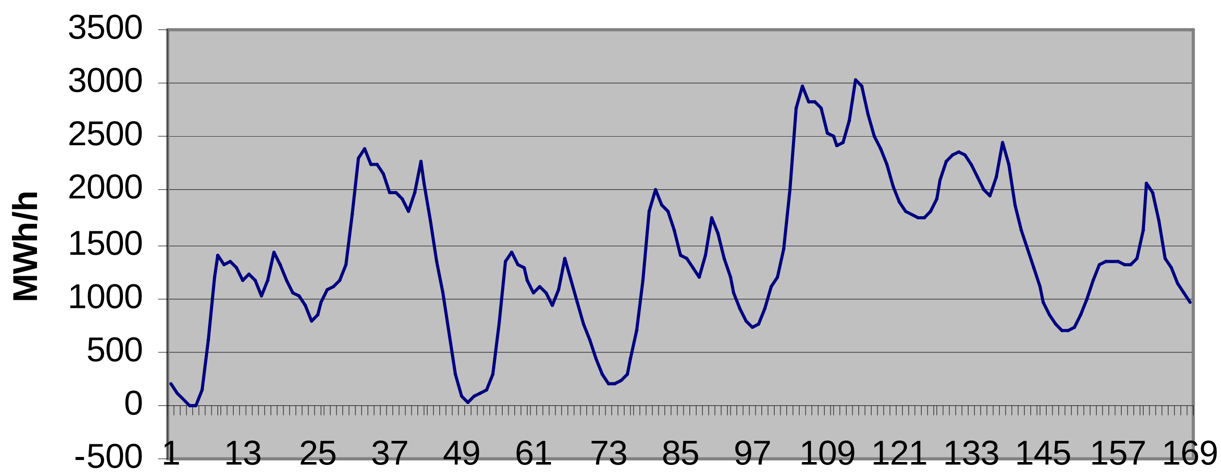
Pricing in presence of variable sources

Other units have to cover the net load = demand – wind

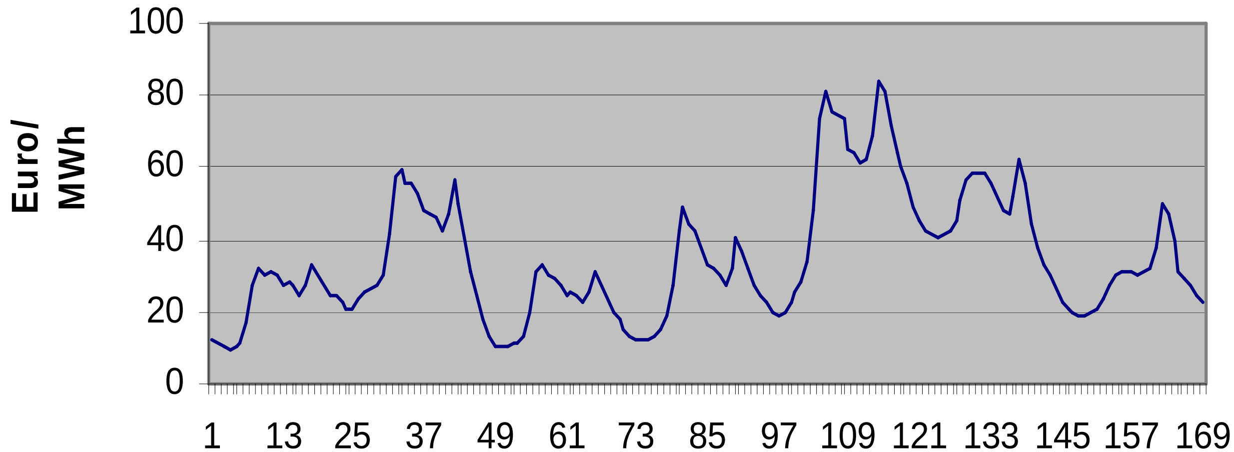
The other units production is controlled by price!

➔ more volatile price

Note: This is independent of ”fixed price” etc



Weekly net demand

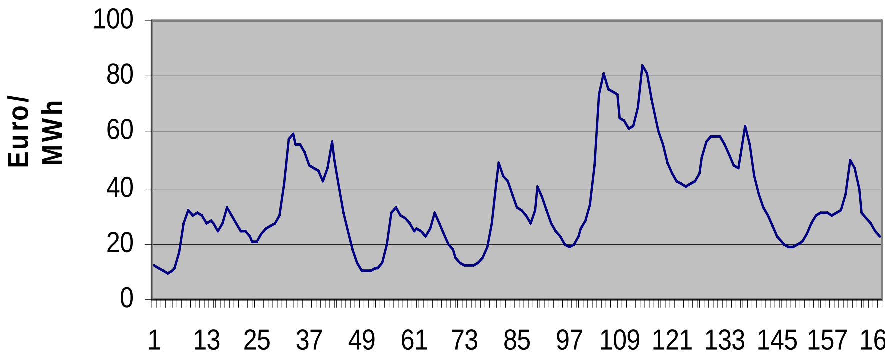


”Thermal pricing”

Solutions and competition

Assume a system with large price variation:

- ➔ Three types of ”business opportunities”



More trading with neighbors

Demand side management

Flexible plants

- There is a competition between these methods.
- Much transmission reduces price changes ➔ less interest in DSM

Impact on operation, inter-area trading and investments

Operation:

- Larger variation and larger uncertainties ➔ prices on day-ahead markets do not reflect marginal costs

Interarea trading:

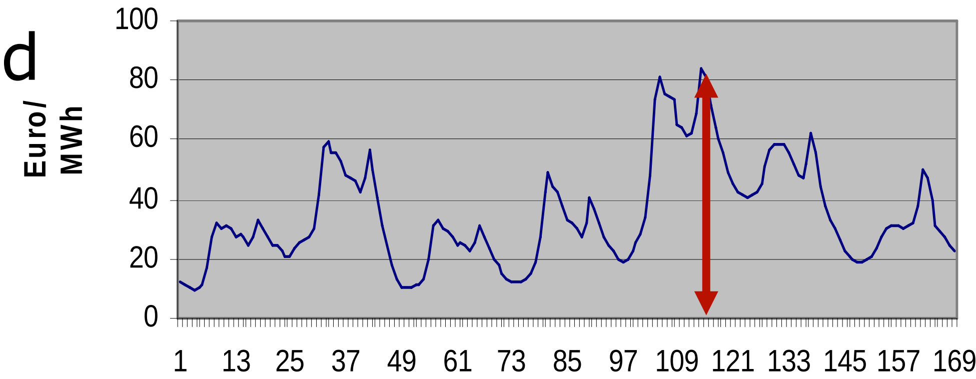
- Large amounts of wind power in one area ➔ large interest to buy this in neighboring systems since marginal cost is low.

Investments:

- Also so-called ”base-plants” will have an economic value to be more flexible, since the power price can be below their marginal operation cost.

Capacity challenge

- Who want to invest in rarely used units? With wind power the utilization time decreases
- If not we get ”capacity deficit”

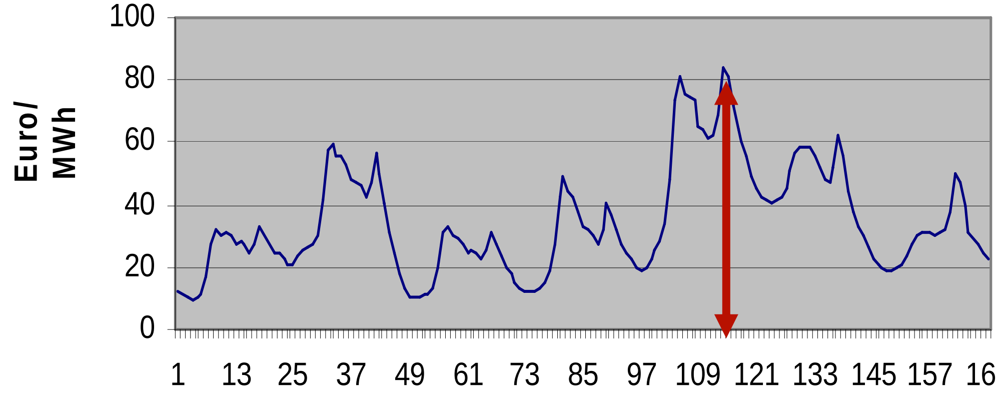


Deregulation

- **Before deregulation:** most system operators kept ”enough” reserves and ”extra” reserves with trading possibilities with other systems
- **”Good” deregulation:** open competition also cross border ➔ no double margins any longer ➔ increased LOLP

Capacity challenge

- Three important system parameters / variables



Maximum price

- Extreme prices for few hours can finance peak plants

System reliability

- Requirement of max LOLP

Subsidized plants

- MW of power plants not paid with market price

- One of these three can be calculated from the other two.
- **Comment**: Wind power capacity credit reduces the utilization time of the peak unit.

Summary

Possibilities:

- Huge! 100% possible!

Challenges:

- More varible power ➔ higher price volatility
- The higher price volatility is needed since other power plants have to vary their production more
- This is independent of ”fixed price”, ”certificates” etc
- There is a true competition between transmission, DSM and flexible production.
- The capacity challenge increases with deregulation and with wind power capacity credit.