Wind power. Barriers and opportunities

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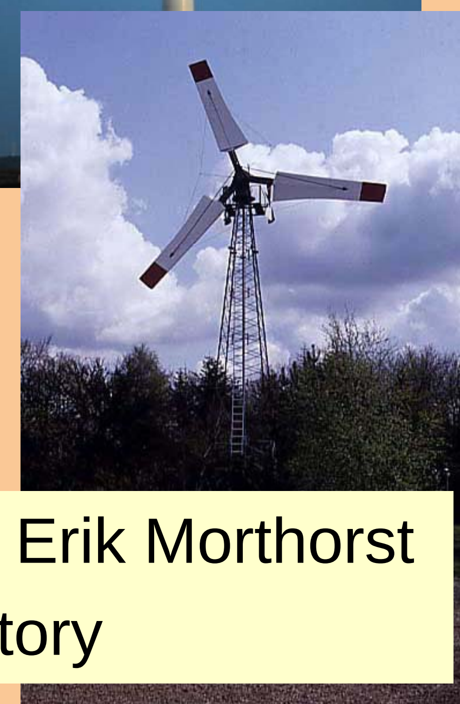
Wind Power
Barriers
and
Opportunities



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Risø National Laboratory

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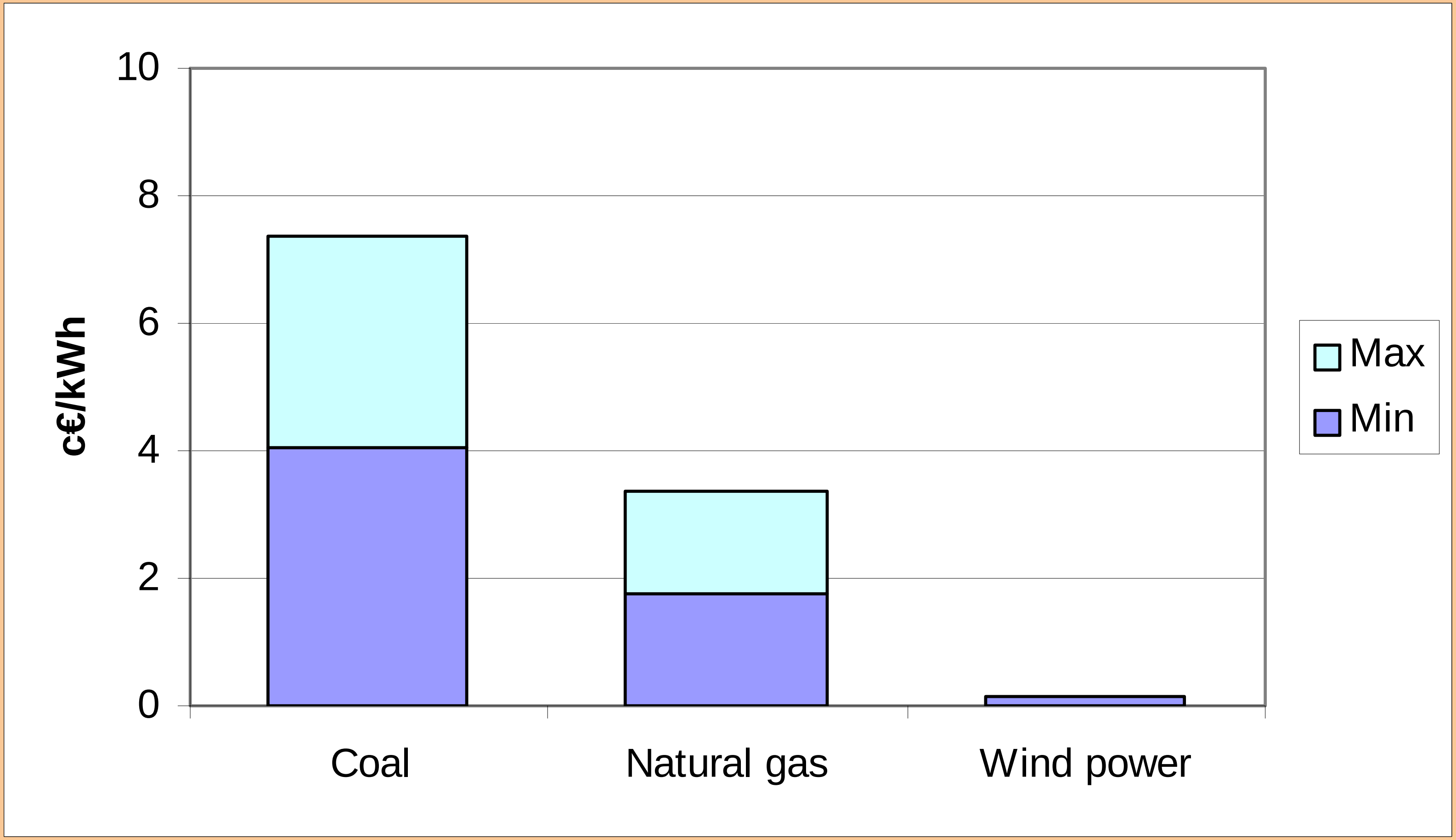
Disposition

- Why is Wind Power Interesting?
    - Driving Forces Behind the Development
- Barriers Towards Large Scale Integration of Wind Power
    - Wind and Intermittency
- The Economics of Wind Power
    - The Drive Towards Lower Costs
- New Emerging Markets and the Impacts on Wind Power
    - Emission Trading and Other Kyoto Markets

Monetised Externalities for Wind Power and Conventional Power Plants



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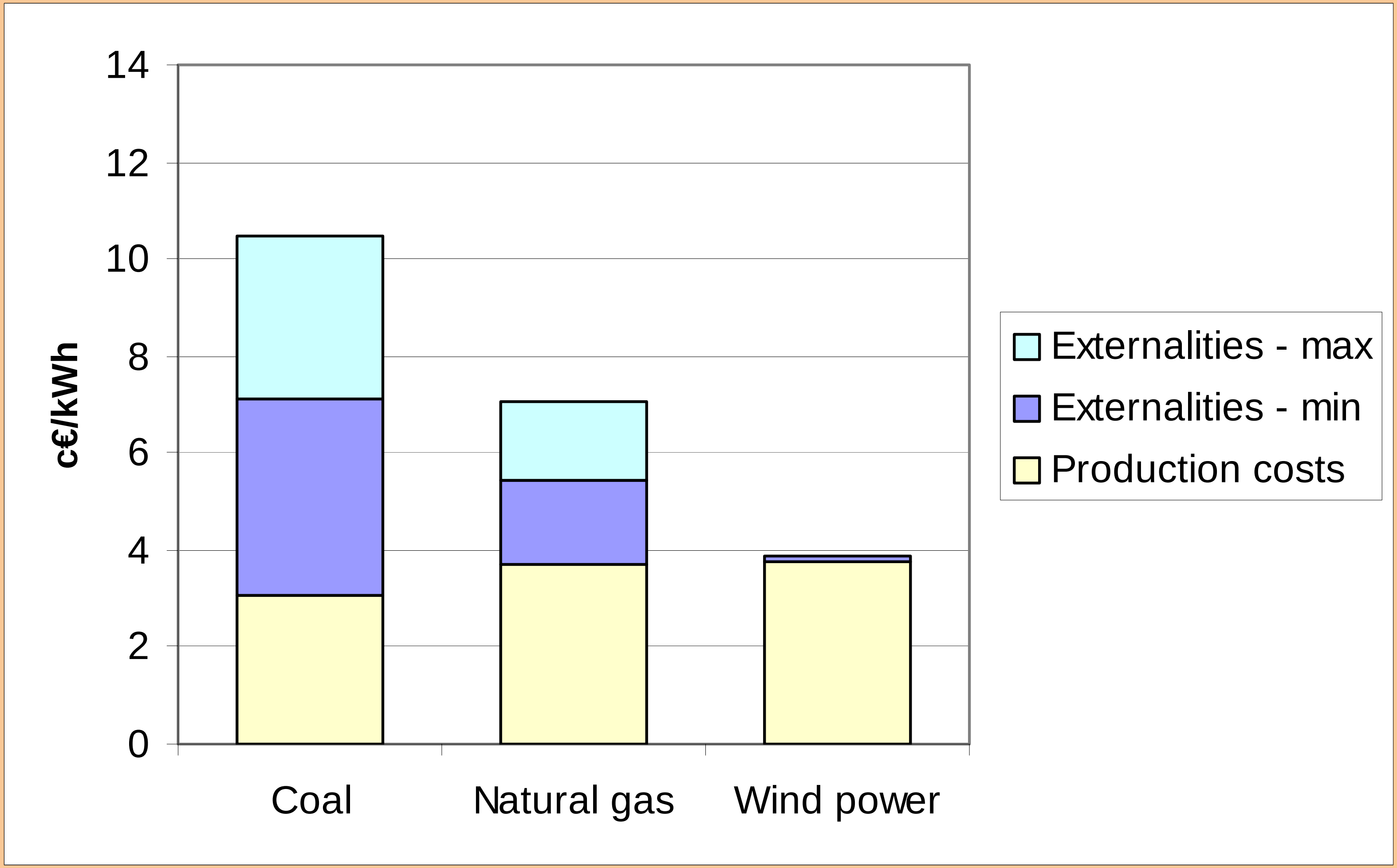
Externalities - what is that?

Impacts From the Energy Production that is not Included in the Price of Energy Today

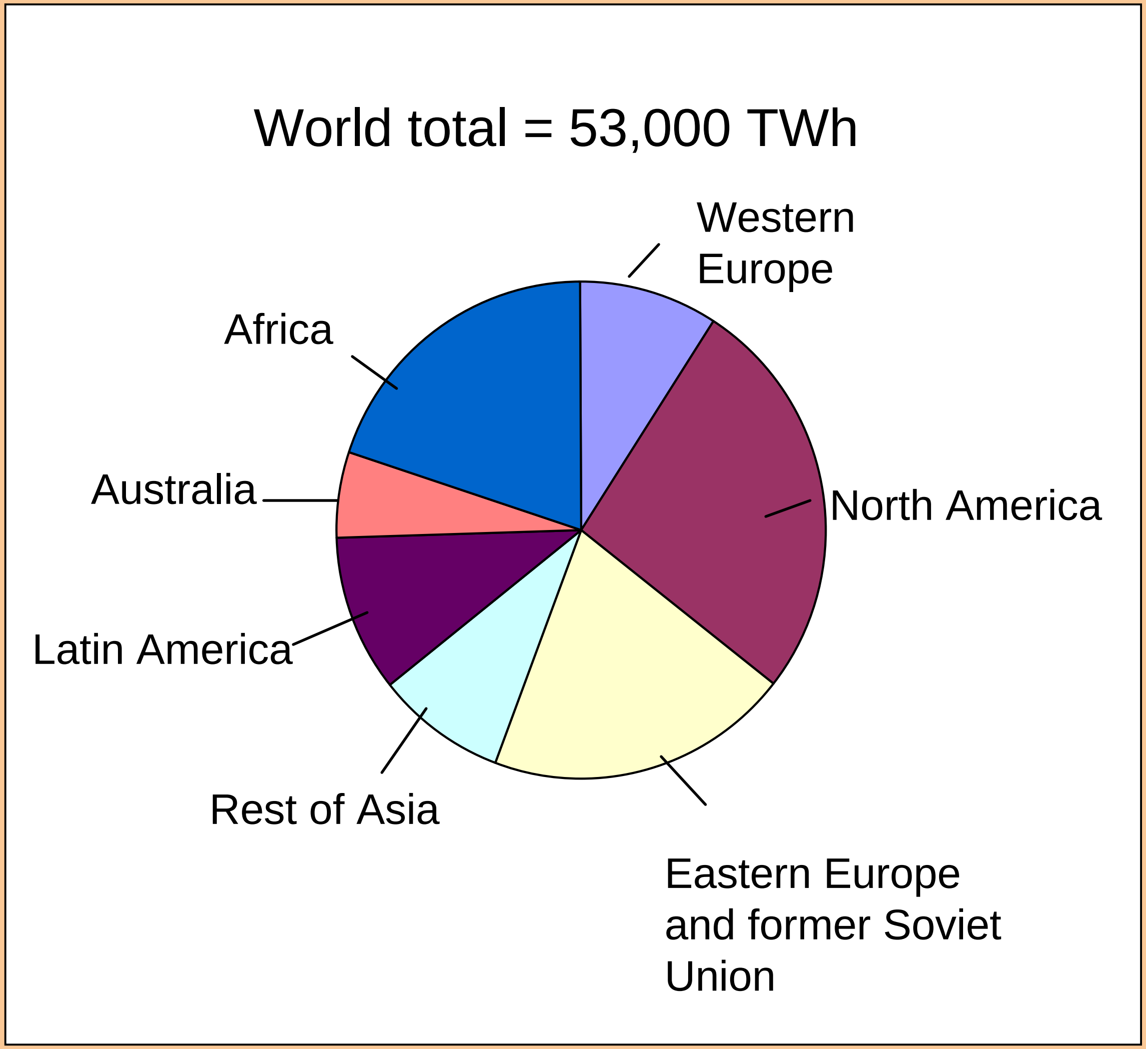
- Environmental emissions - CO_2, NO_x, SO_2
- Noise
- Visual impacts

- ExternE
  - Large EU-project
  - All the way from the impact to the damage is quantified - and monetised
  - Enormous uncertainties

Production Costs plus Externalities



Wind Resource Potentials

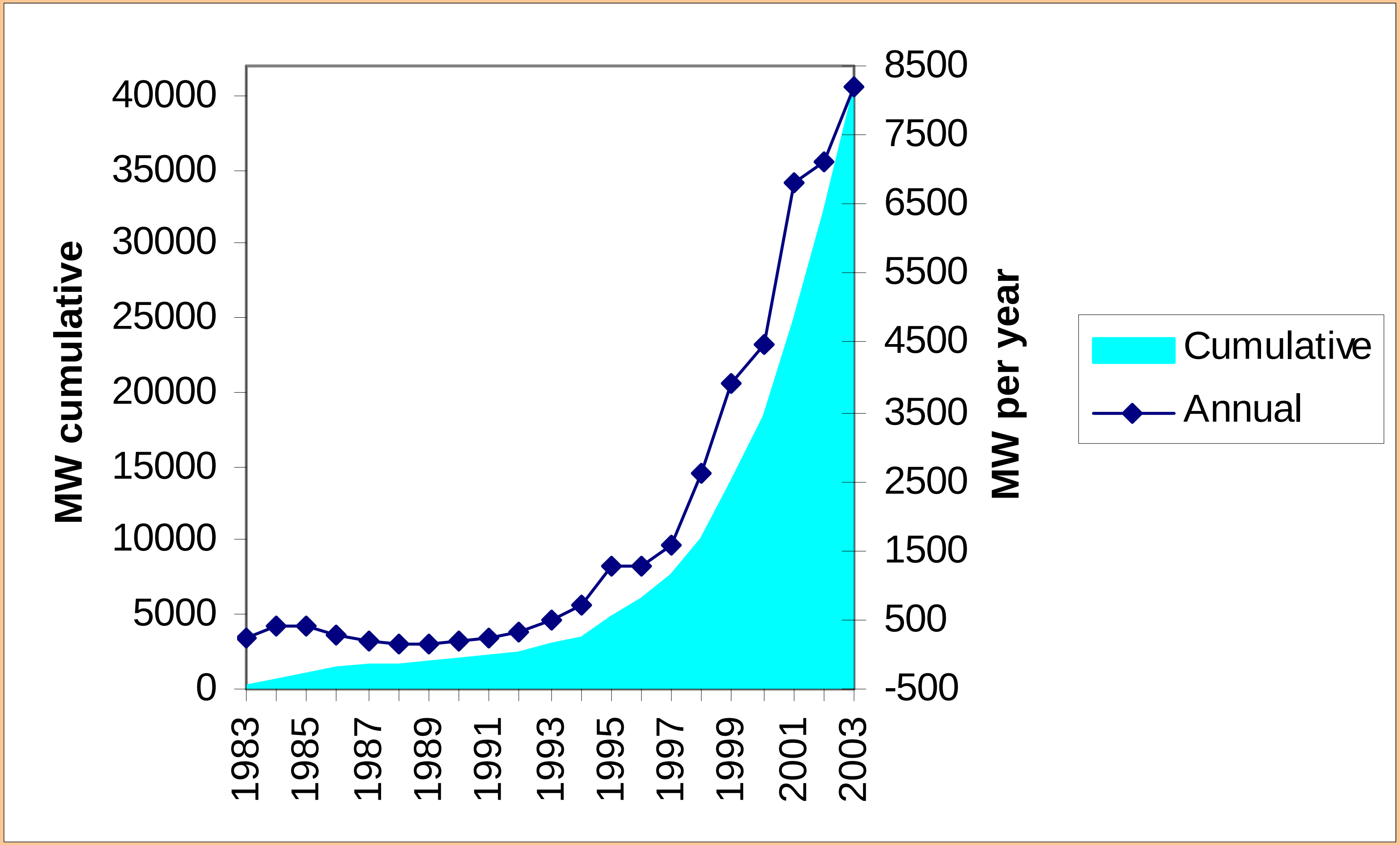


World Electricity Demand

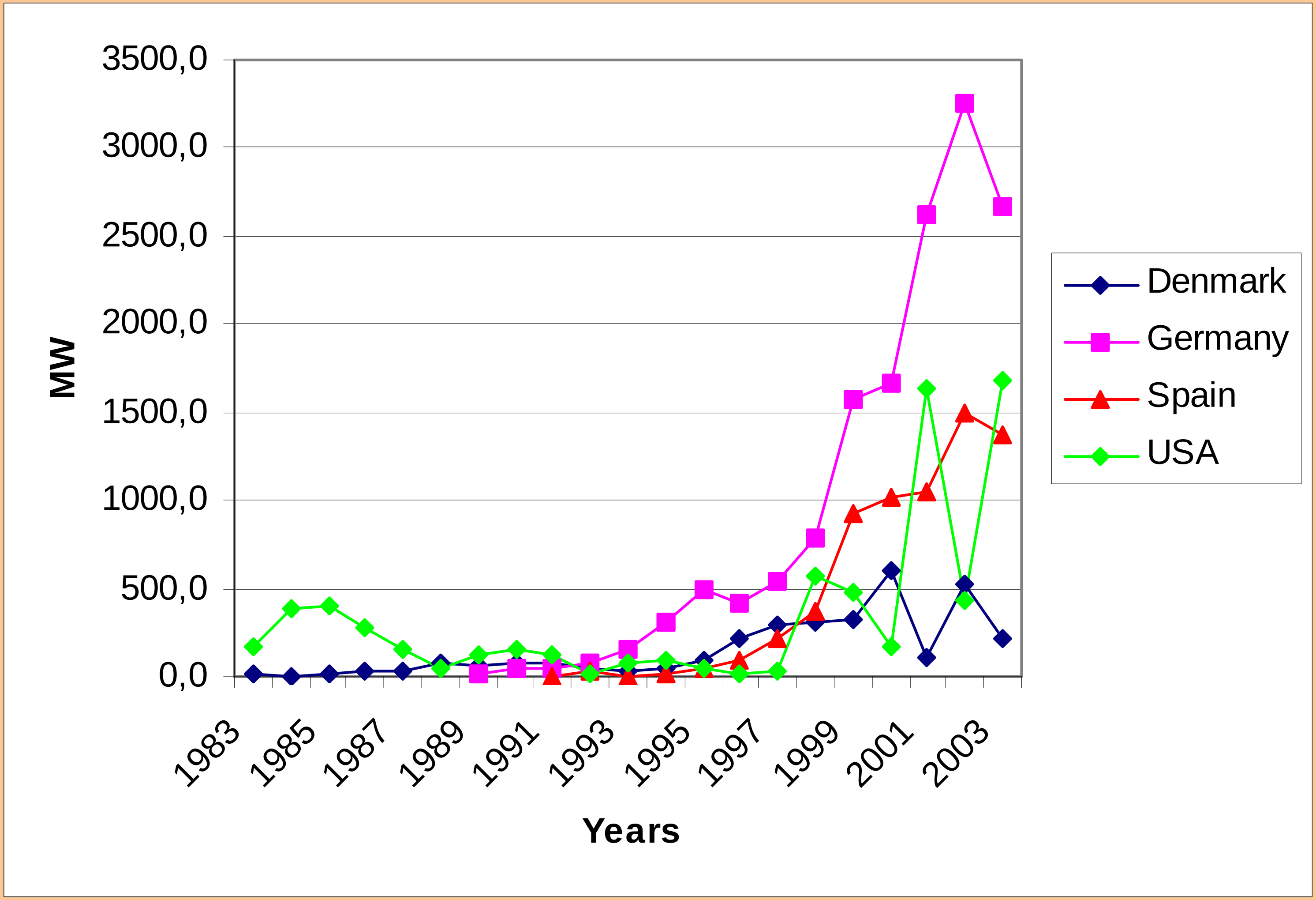
1998
14,000
TWh

2020
27,000
TWh

Global Development of Wind Power



Four Countries Dominating in the World



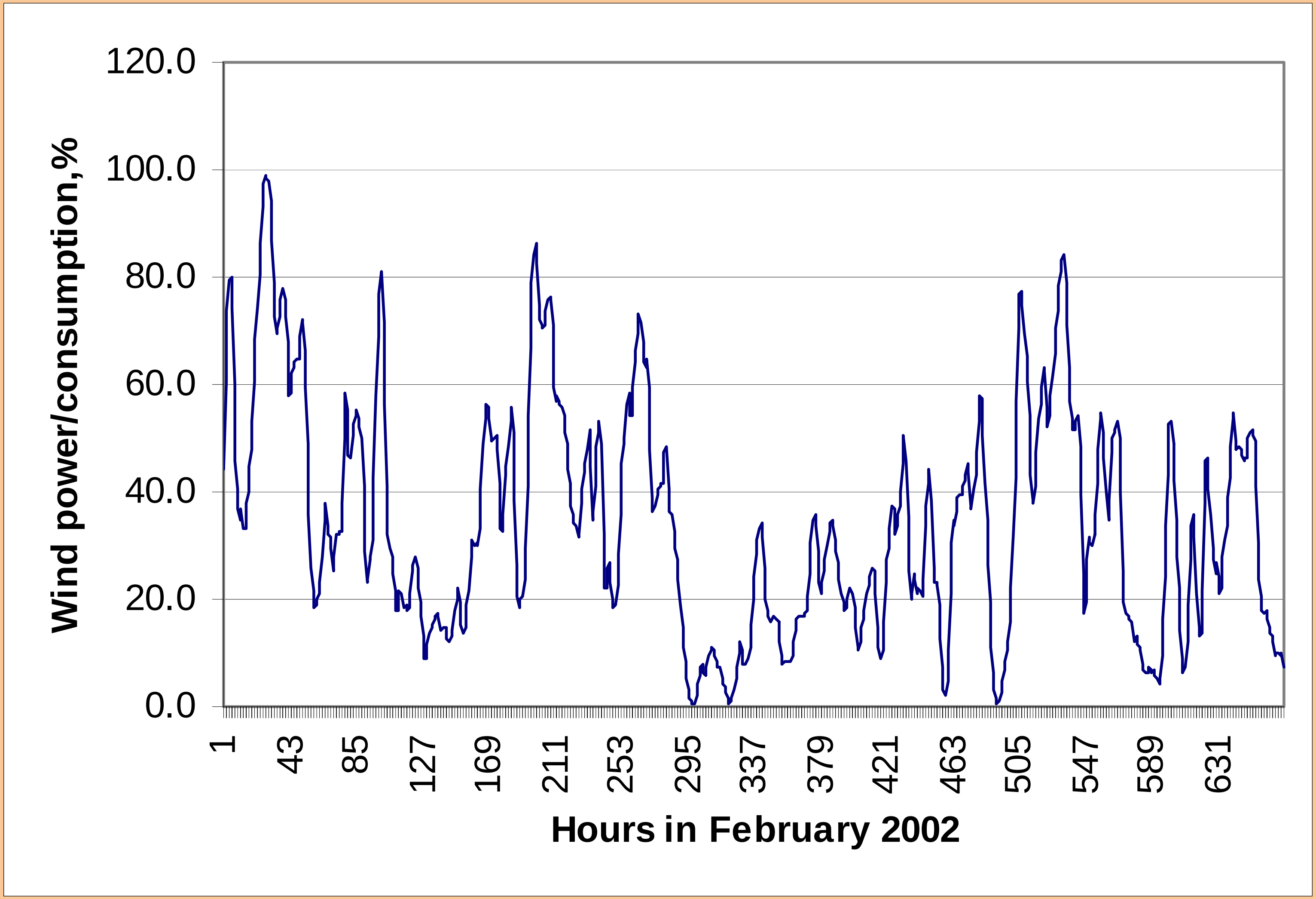
A Major Barrier for the Large Scale Development of Wind Power

Integration of Wind Power into the Power System - Intermittency

Two main issues to be resolved

- Wind turbines might not produce the power, when we need it
- Even though the turbines are producing, we can't know exactly how much they will produce

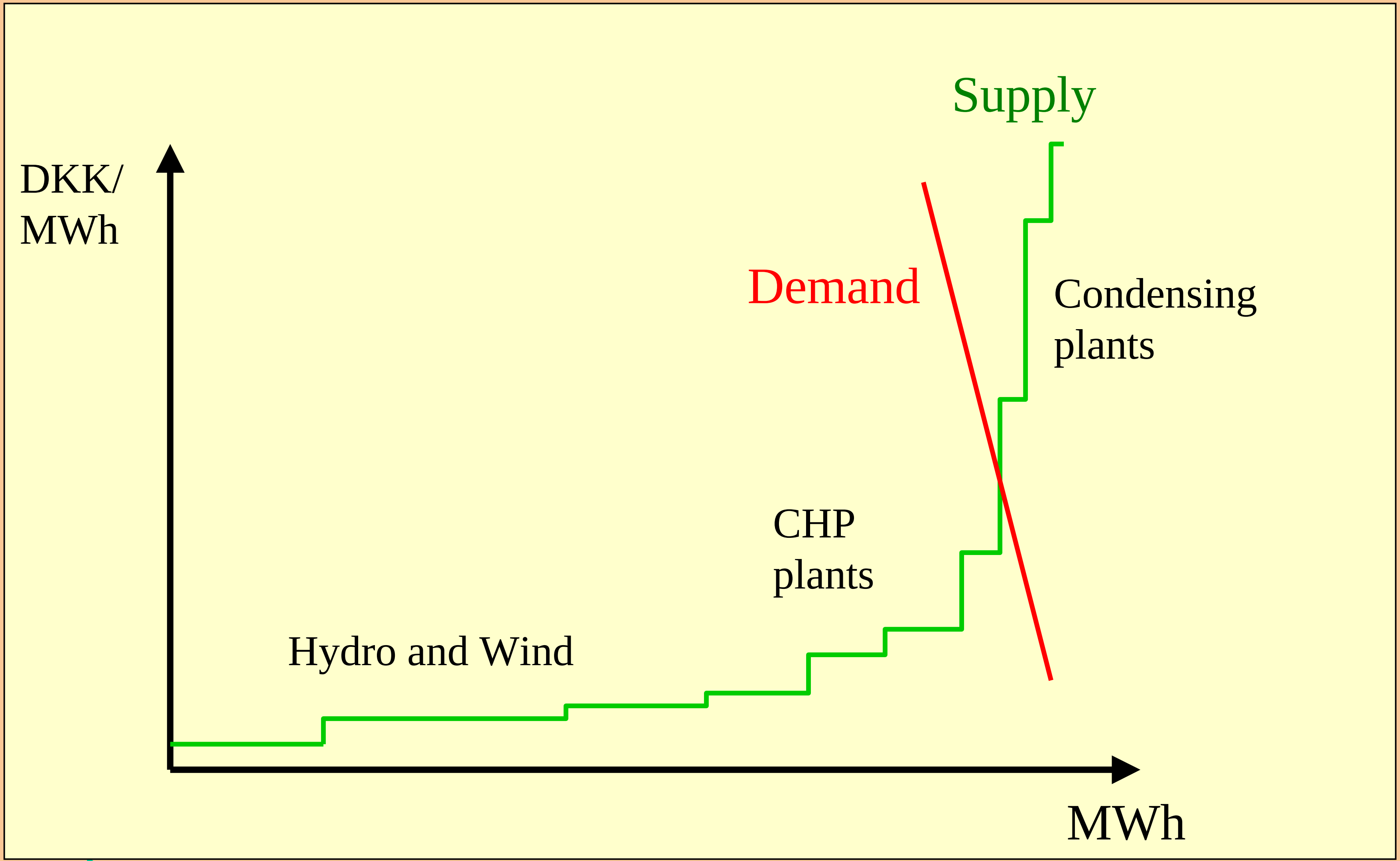
Wind Power in Percentage of Total Power Consumption in Western Denmark



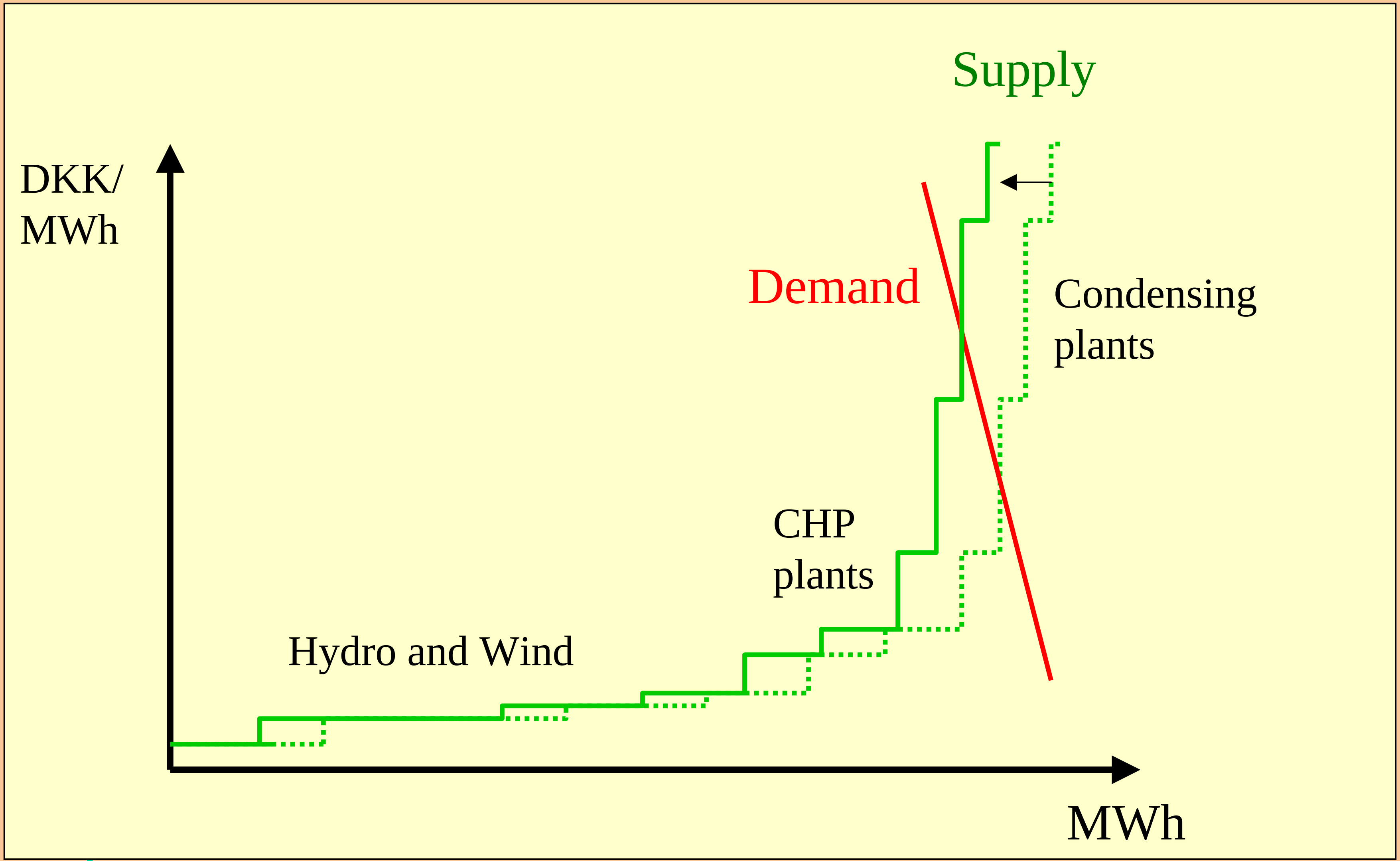
Conditions at the NordPool Market

- If we on before hand can predict how much power the wind turbines will produce, there is no direct penalty for not being available
  - If wind power is not producing the turbine owner's are of course losing revenues, but no additional costs are incurred
- If we cannot predict the amount of wind power produced there is a direct penalty
  - If other power producers have to step in this will imply additional costs for the turbine owner's

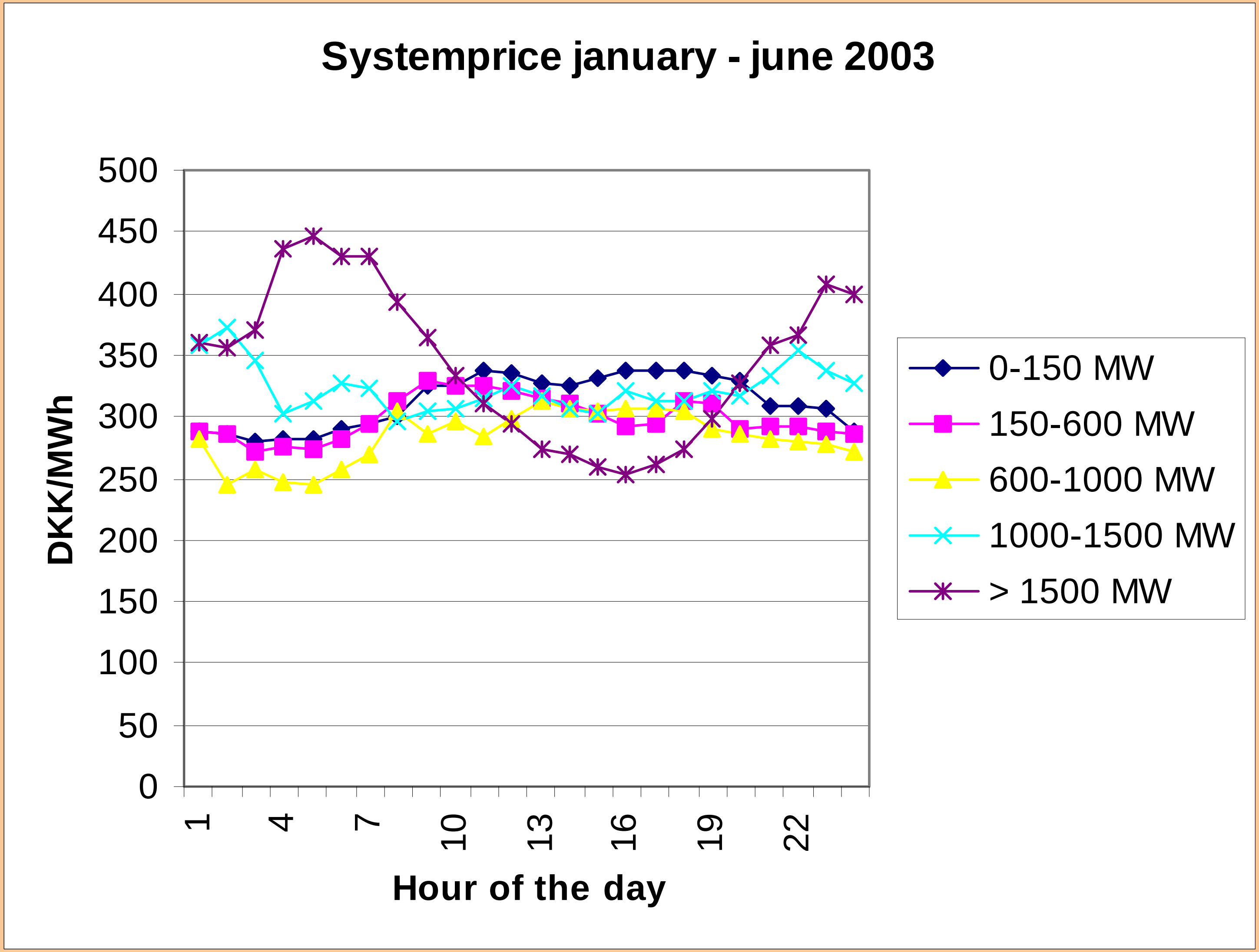
Determination of the Power Price



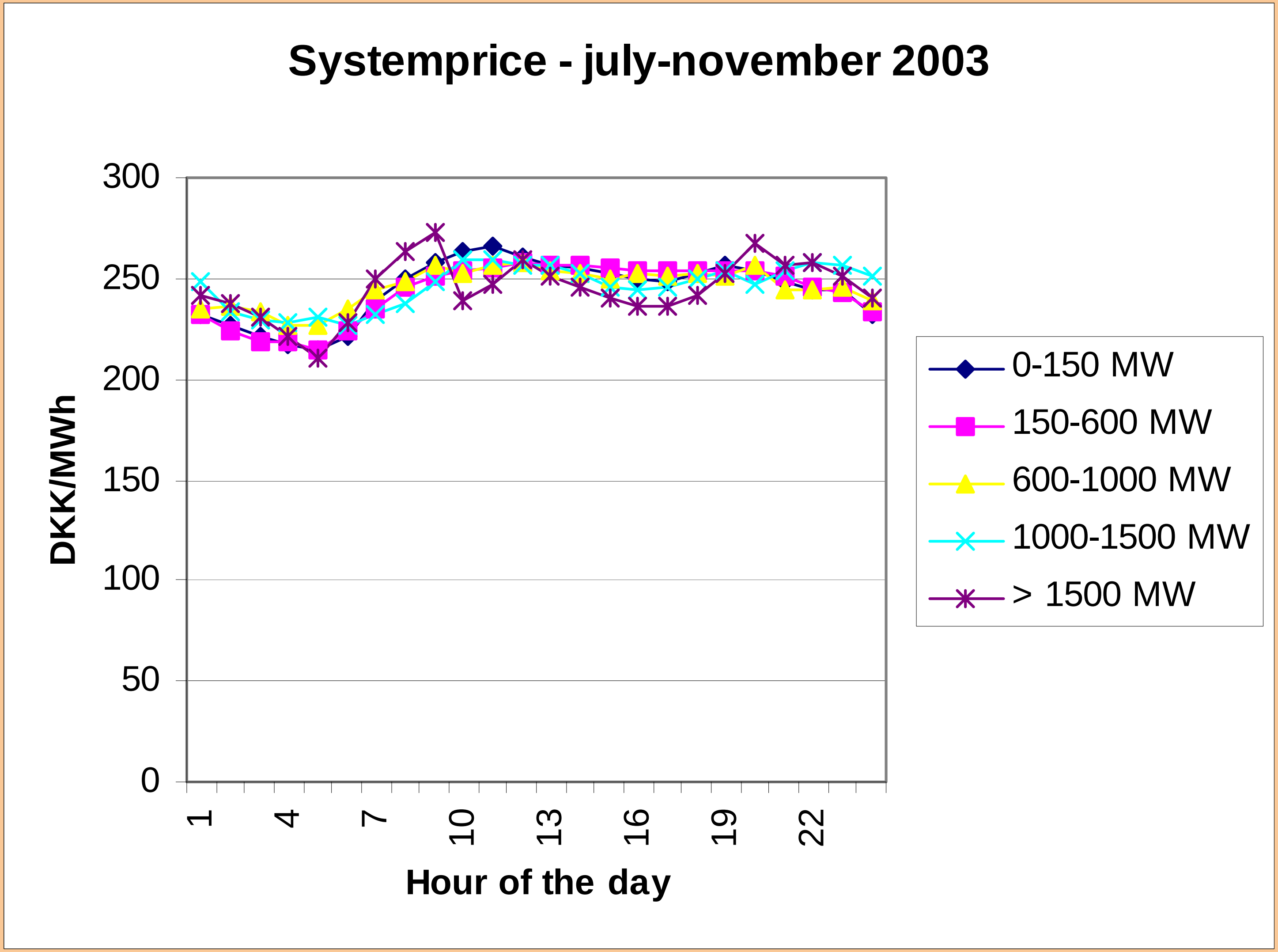
Determination of the Power Price, when the wind is low



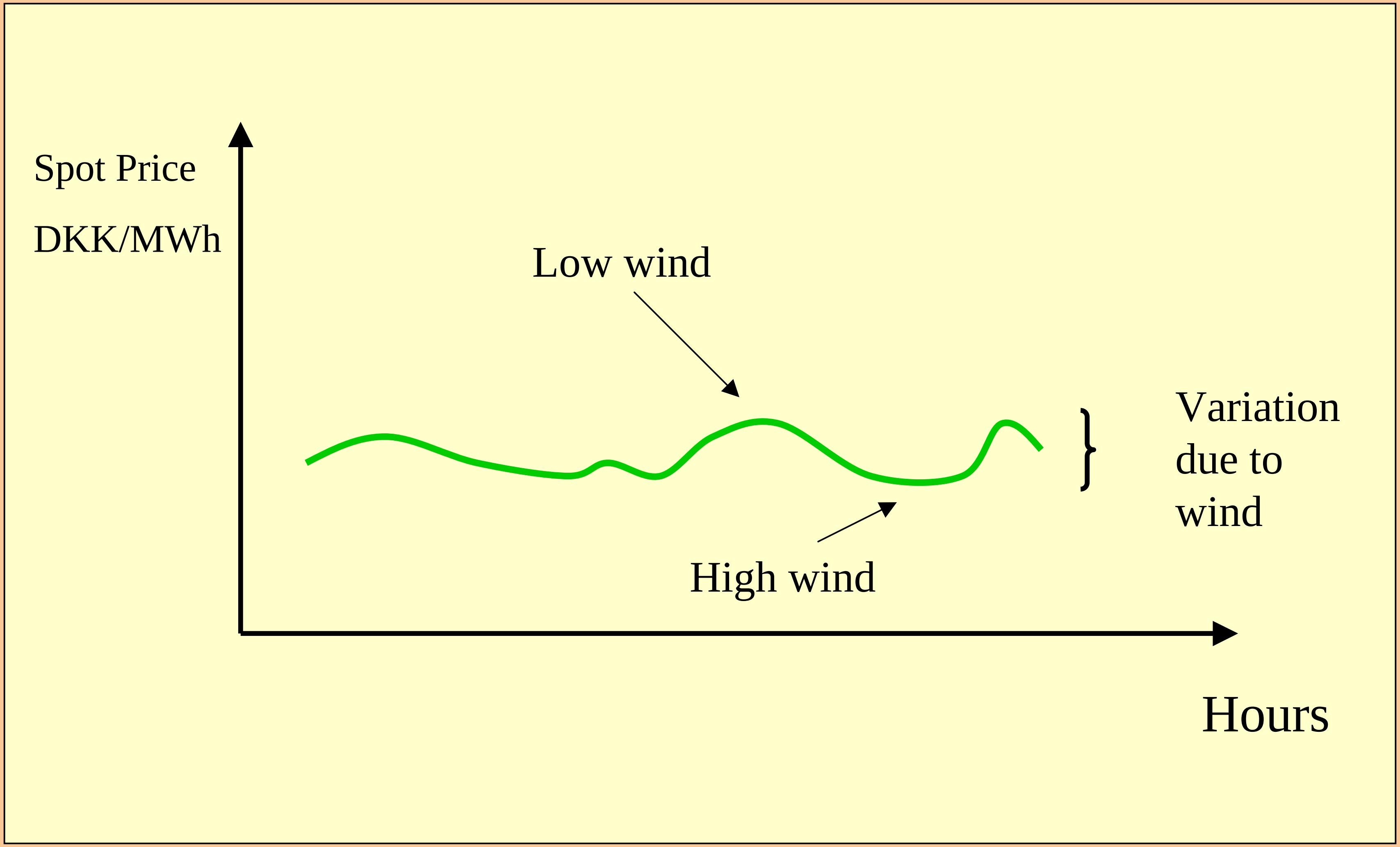
The Influence of Wind Power on the System Price at the NordPool market



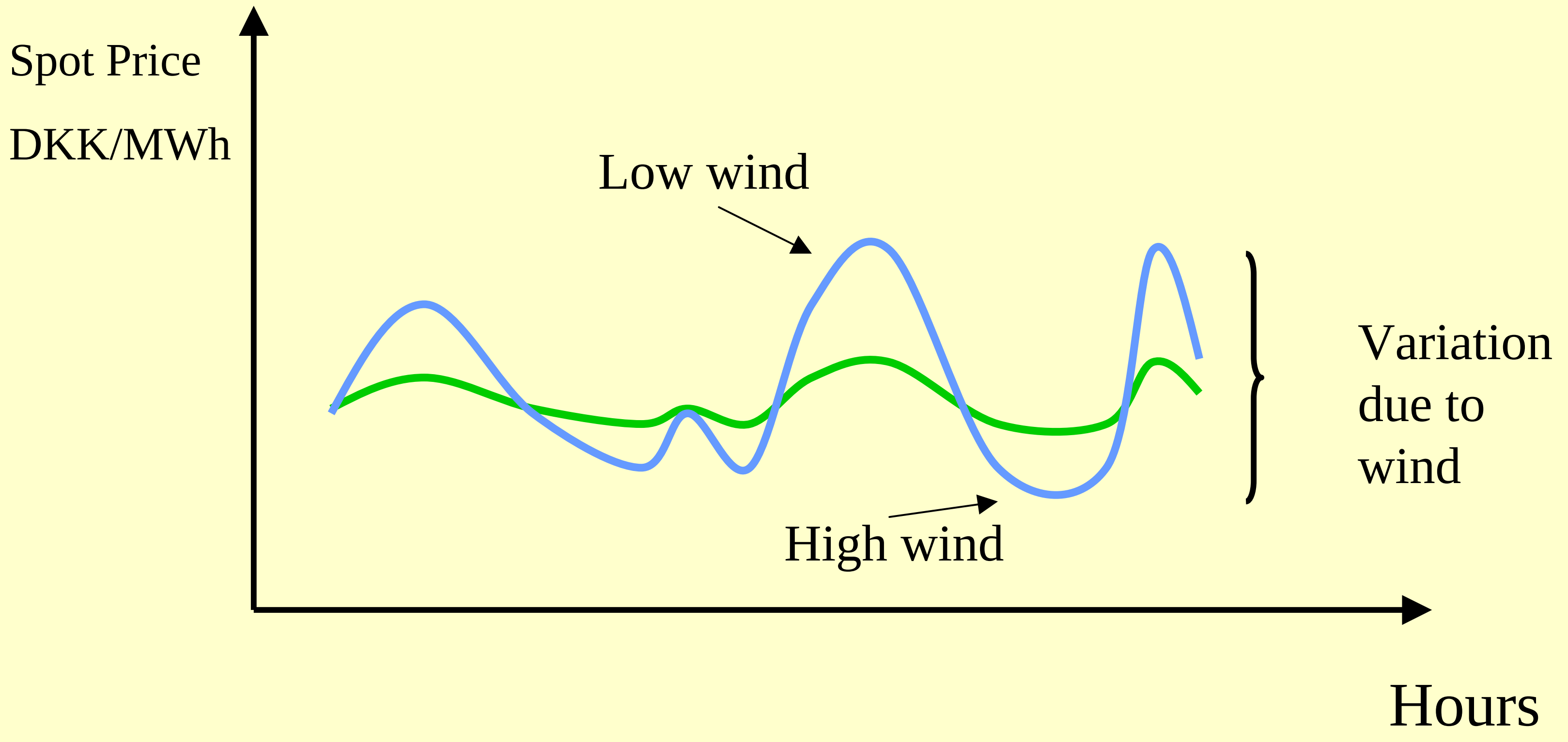
The Influence of Wind Power on the System Price



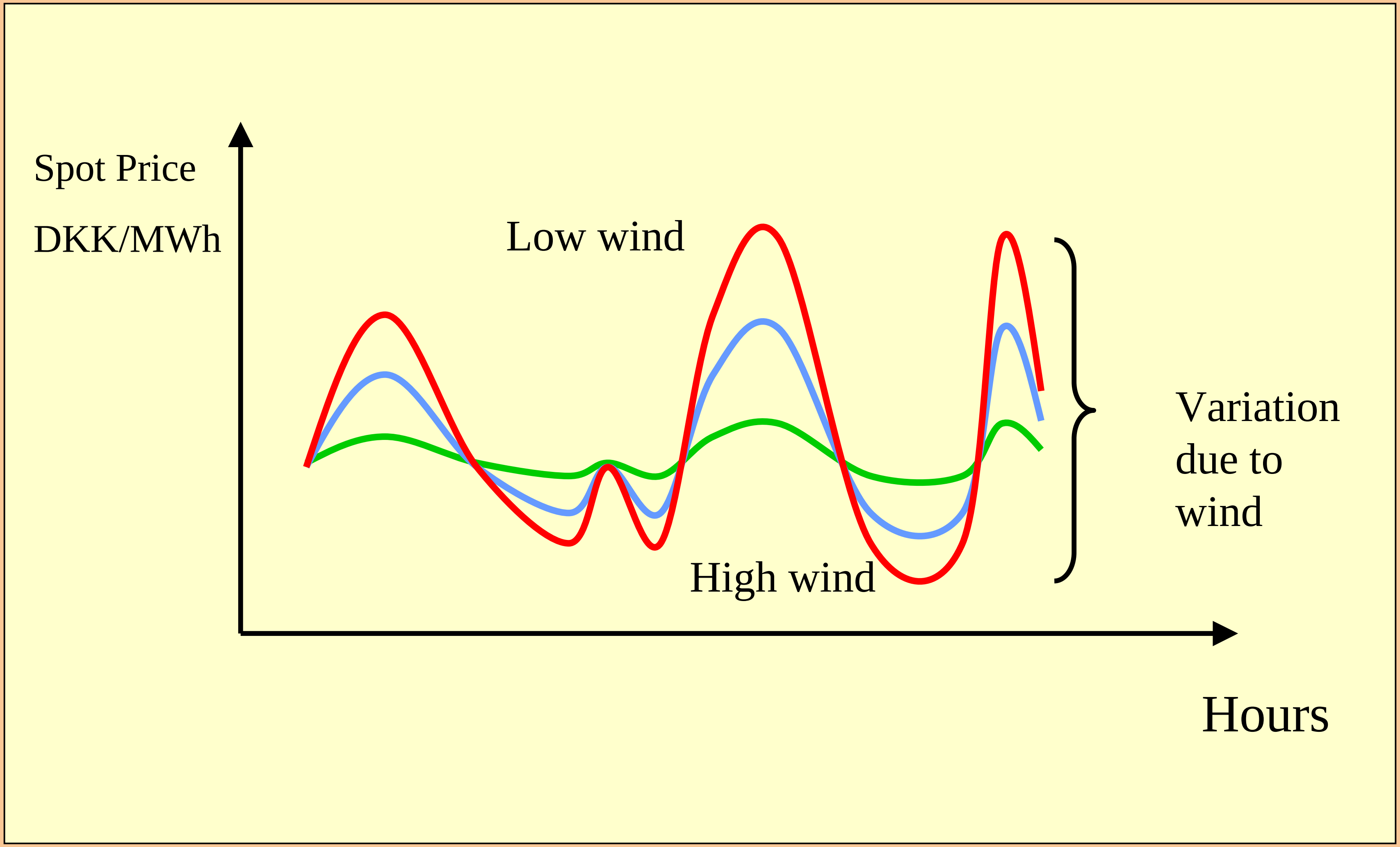
Wind Power and Spot Prices – at present



Wind Power and Spot Prices – high penetration of wind power



Wind Power and Spot Prices – very high penetration of wind power



A Market Problem?

Will the market initiate the necessary investments in new capacity?

Depending on the number of hours the shortage arise!

- More transmission capacity to other countries
- New domestic capacity, preferably fast reacting natural gas combined cycle plants or gas turbines
- Medium term storage facilities (batteries, hydrogen etc.)
- Medium term possibilities for switching off power consumption at selected locations

Intermittency - The Importance of Wind Power Delivering the Power as Expected

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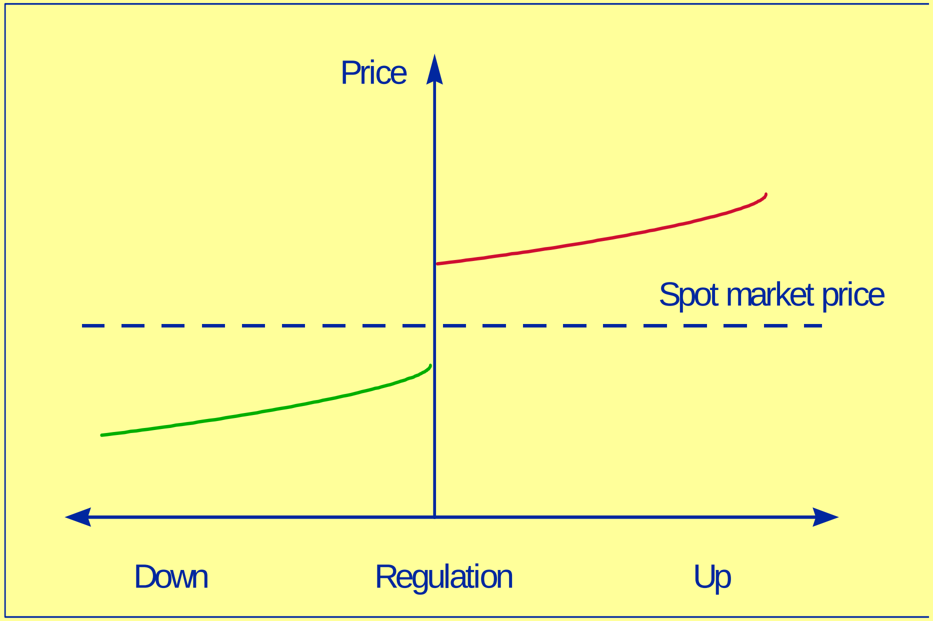
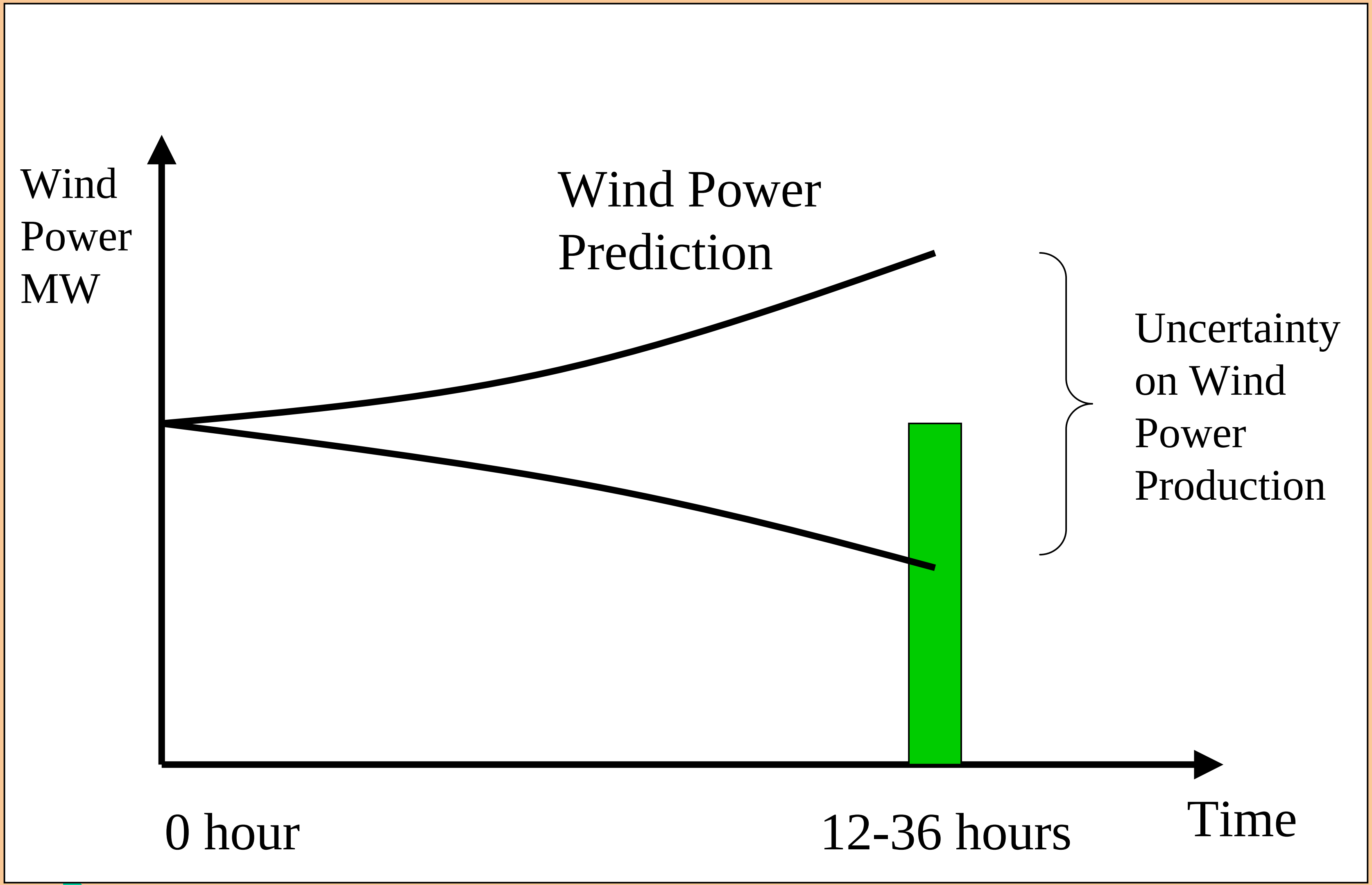
- If wind power produces less than predicted other power producers have to deliver more power
- If wind power produces more than predicted other power producers have to switch some of their plants off
- In both cases there is an additional cost to be born by wind turbine owners

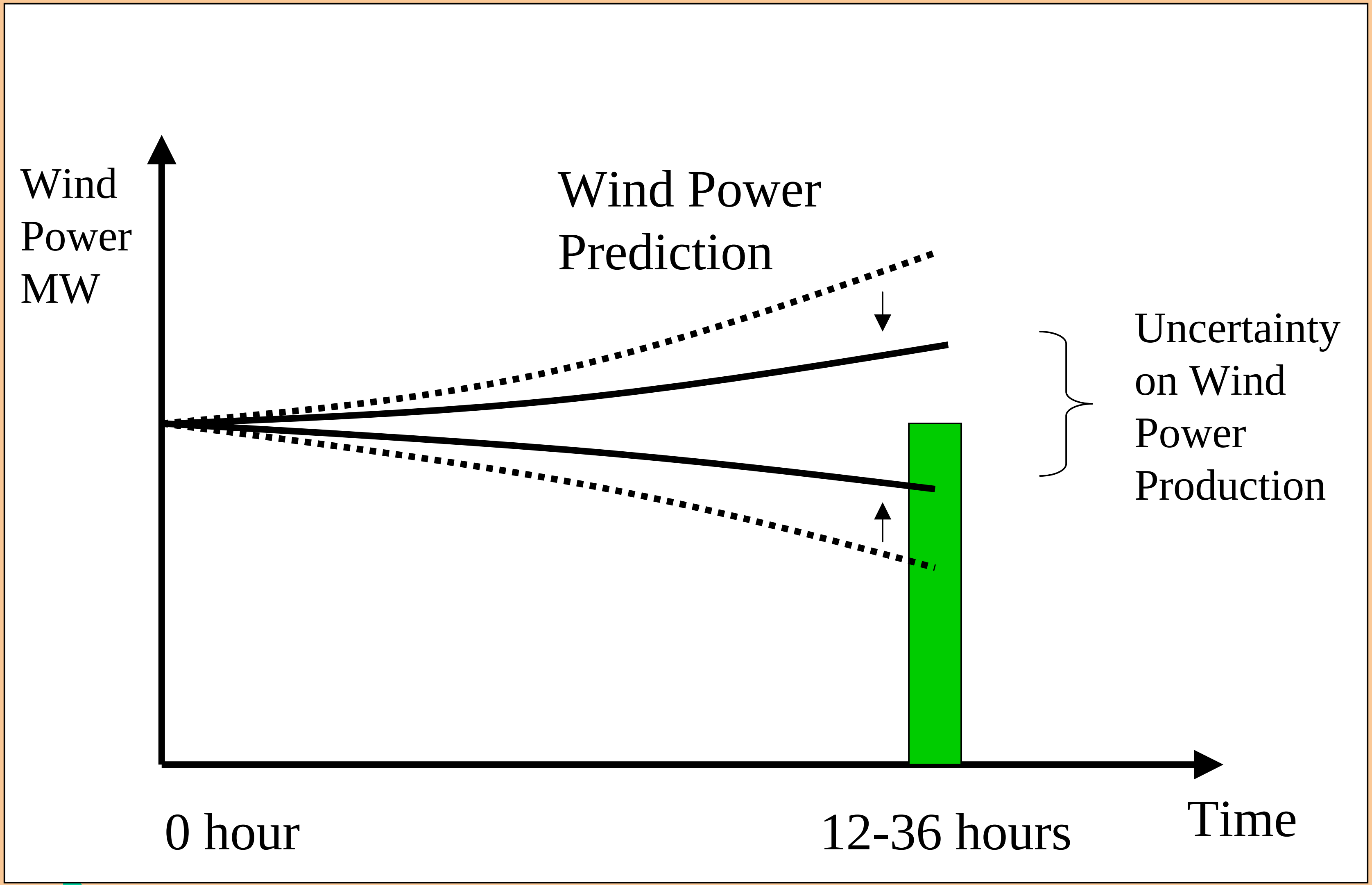
The Regulatory Market



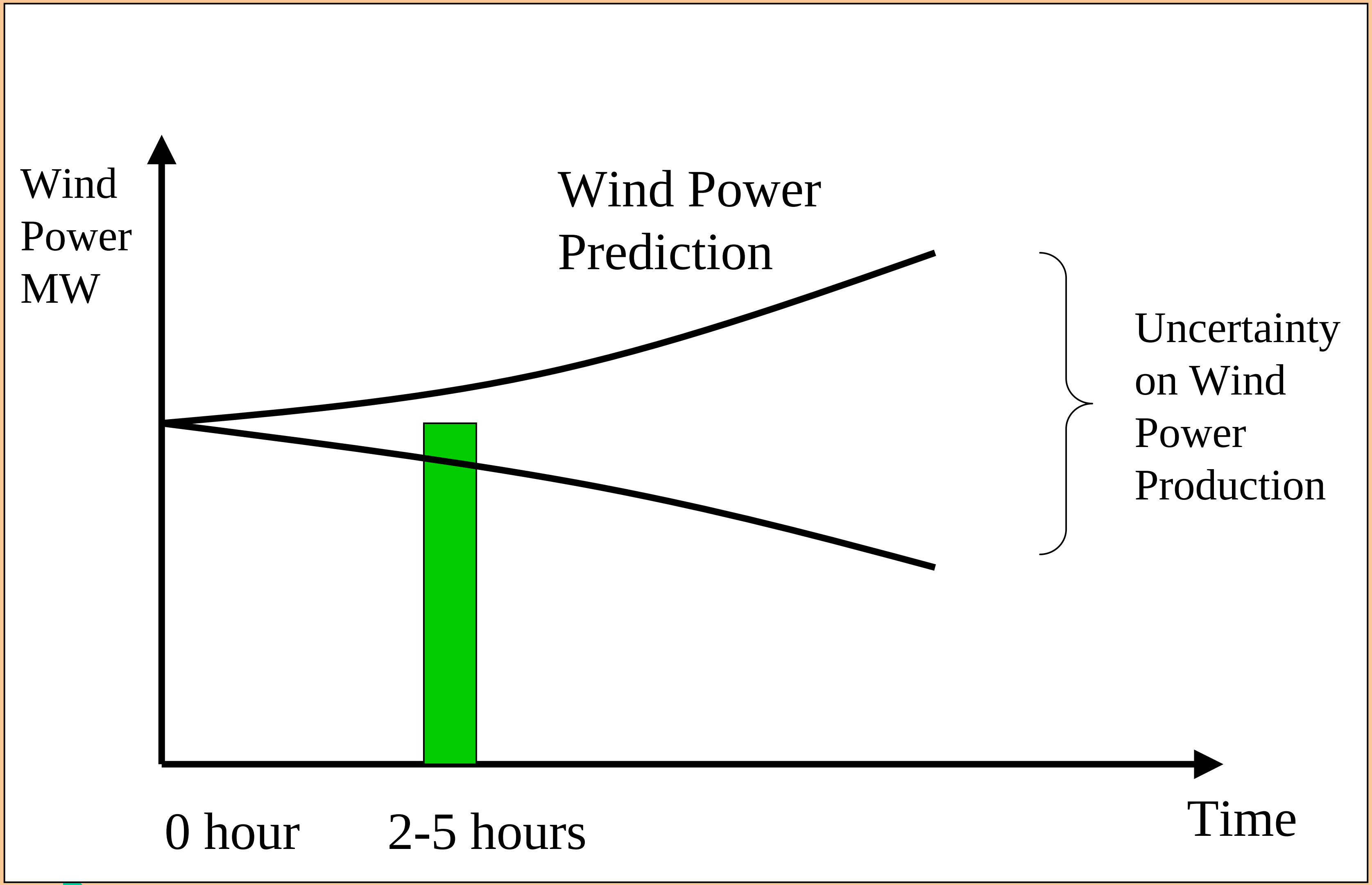
The Importance of Wind Power Fulfilling its Bid



Better Predictions



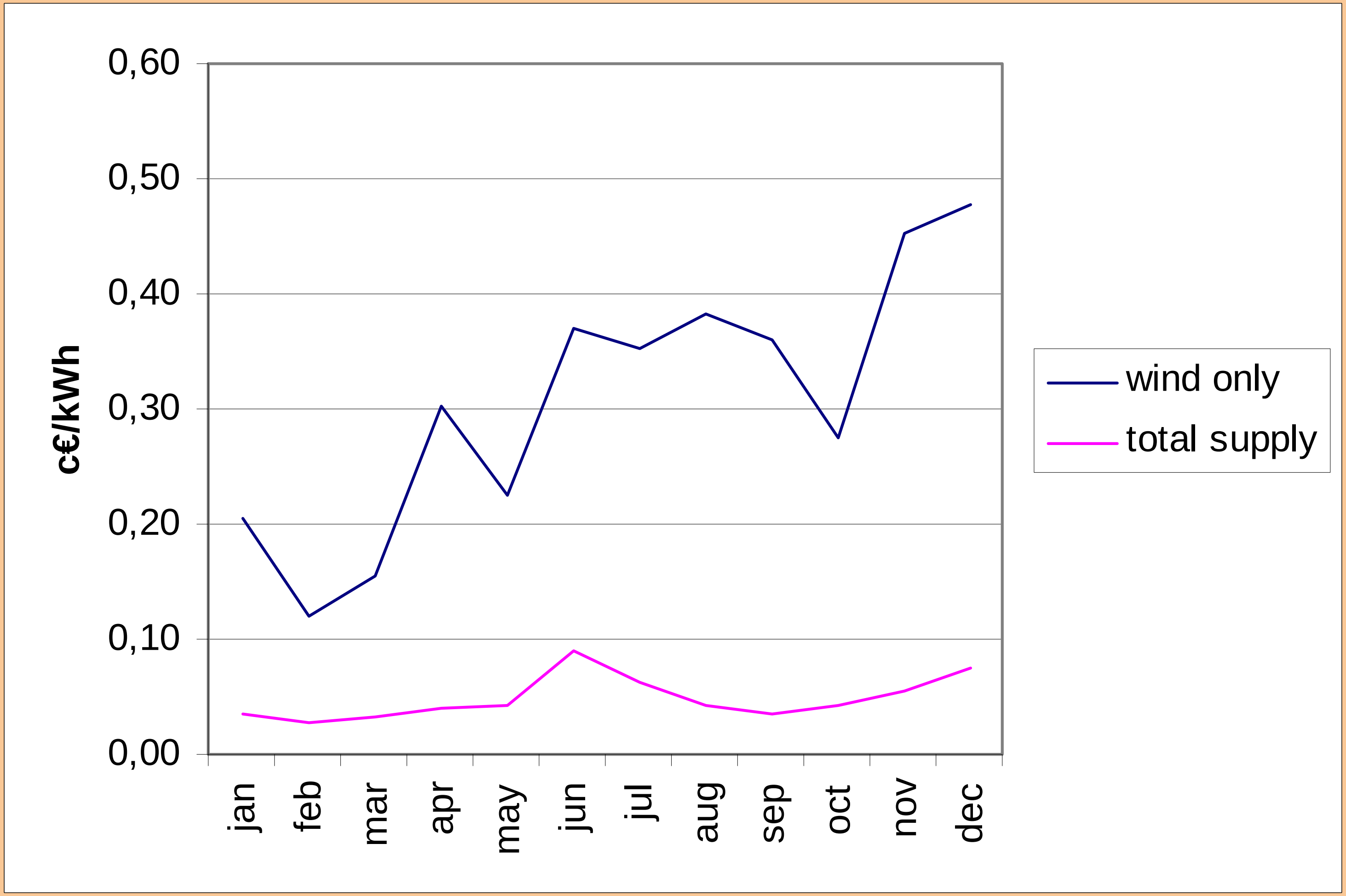
Shorter bidding periods



How can we Minimise the Cost of Regulation?

- Lower regulation costs
  - New regulation technologies, to press the conventional regulation technologies (hydro) down in price
  - Power storage equipment should be further investigated
- Closer integration with demand
  - Priceflexibility in consumer’s power demand
  - Specific industrial processes may be regulated with short notice at low or (almost) no costs

Regulation Costs in 2002 – Monthly Average



Advantages of Wind Power in the future?

- Increased regulatory capabilities of turbines
  - Fast ramp up and down
  - Participating in the regulatory market
- Fault-ride-through
  - The wind turbines don’t stop in case a conventional power plant drops off the grid
  - Keeps the grid up and running
- Independent power cells
  - In case of grid failure specific areas are supplied by wind power independently of the rest of the system

The Economics of Wind Power

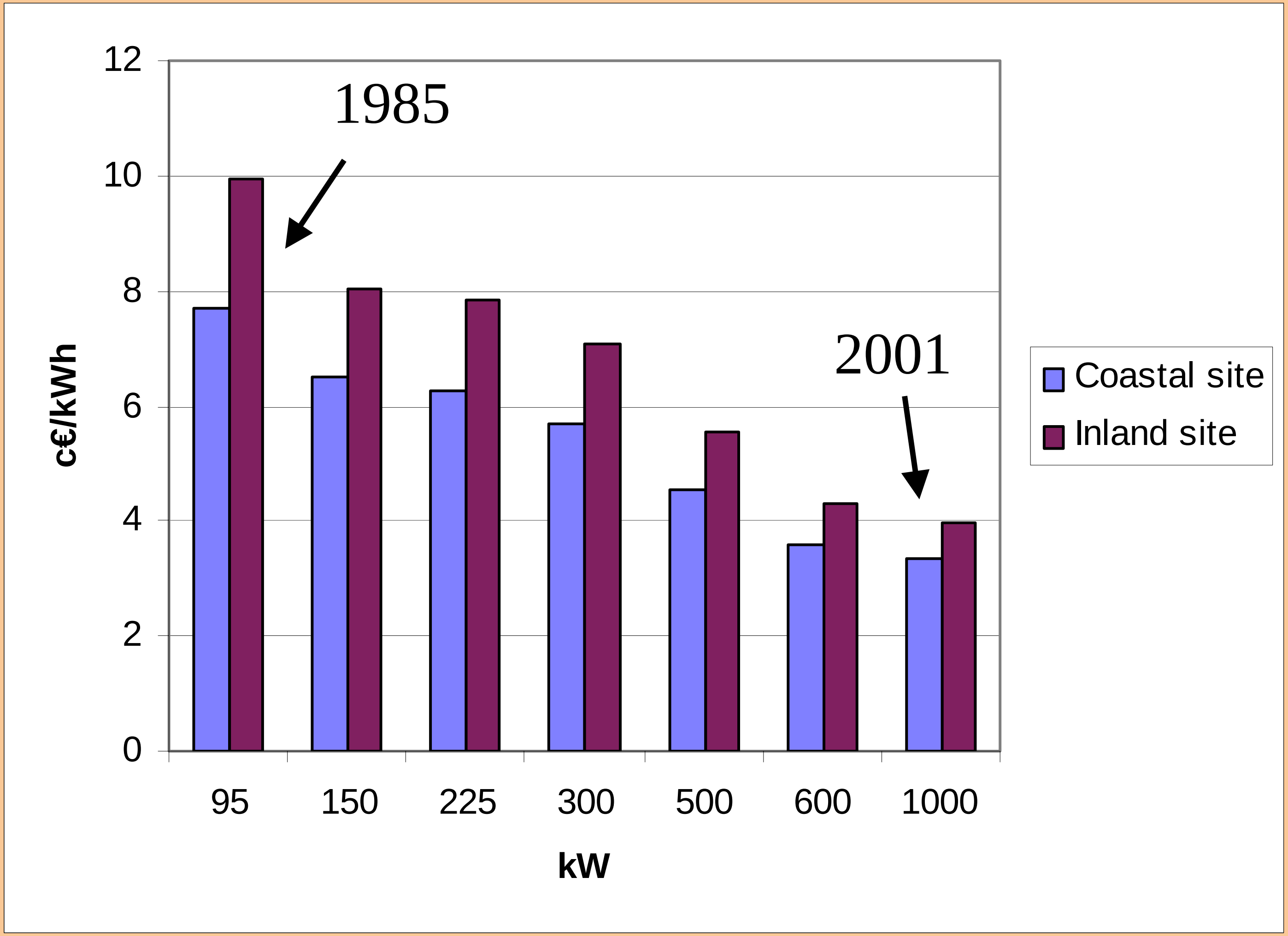
The main parameters governing wind power economics include the following:

- Investment costs, including auxiliary costs for foundation, grid-connection, and so on.
- Operation and maintenance costs
- Electricity production / average wind speed
- Turbine lifetime
- Discount rate

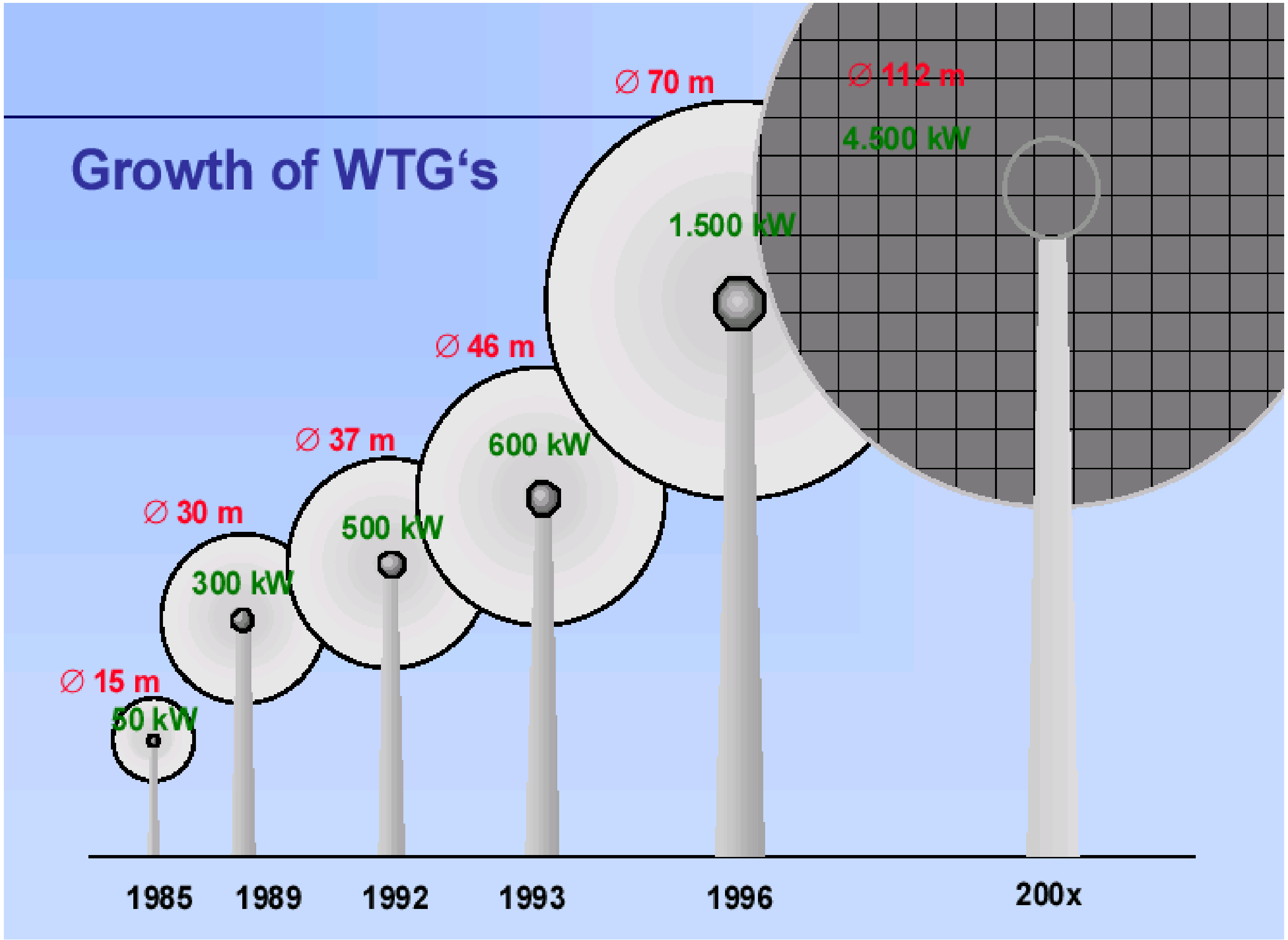
Investments in a 1 MW Turbine

	Investment (1000 €)	Share (%)
Turbine (ex works)	748	81.9
Foundation	44	4.8
Electric installation	10	1.1
Grid-connection	60	6.6
Control systems	2	0.2
Consultancy	8	0.9
Land	27	2.9
Financial costs	8	0.9
Road	7	0.7
Total	914	100.0

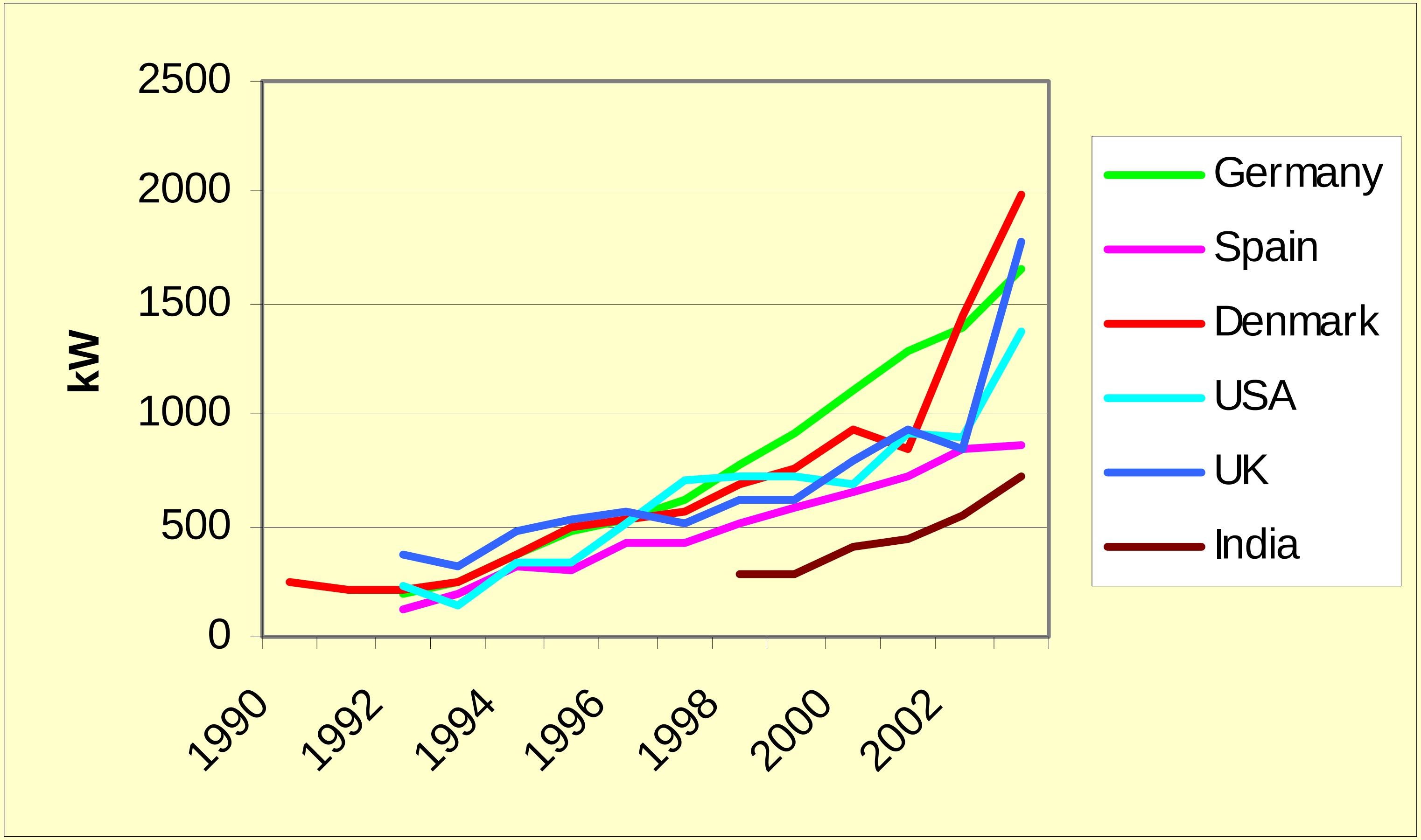
The Development of the Cost of Wind Power



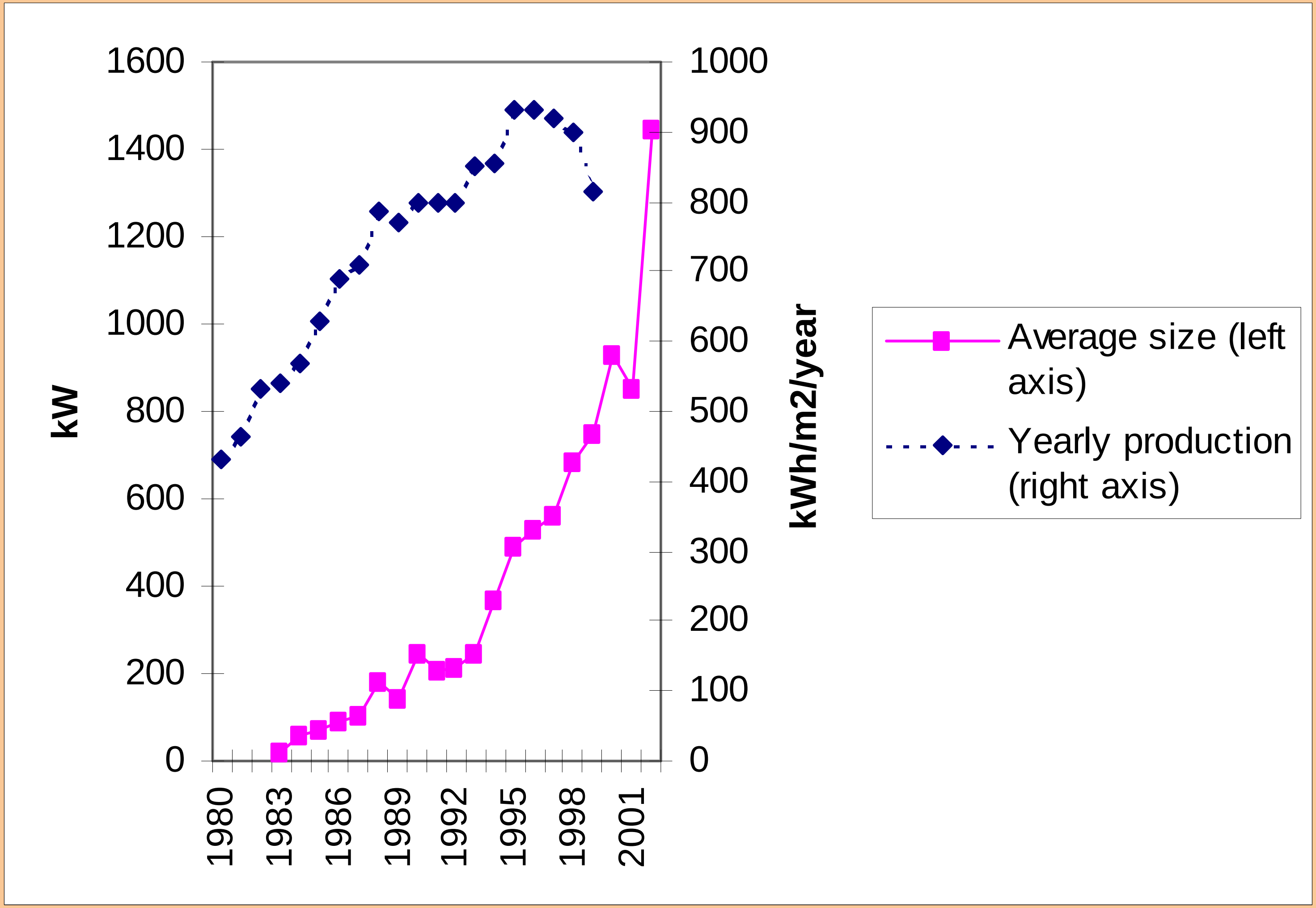
Turbine size



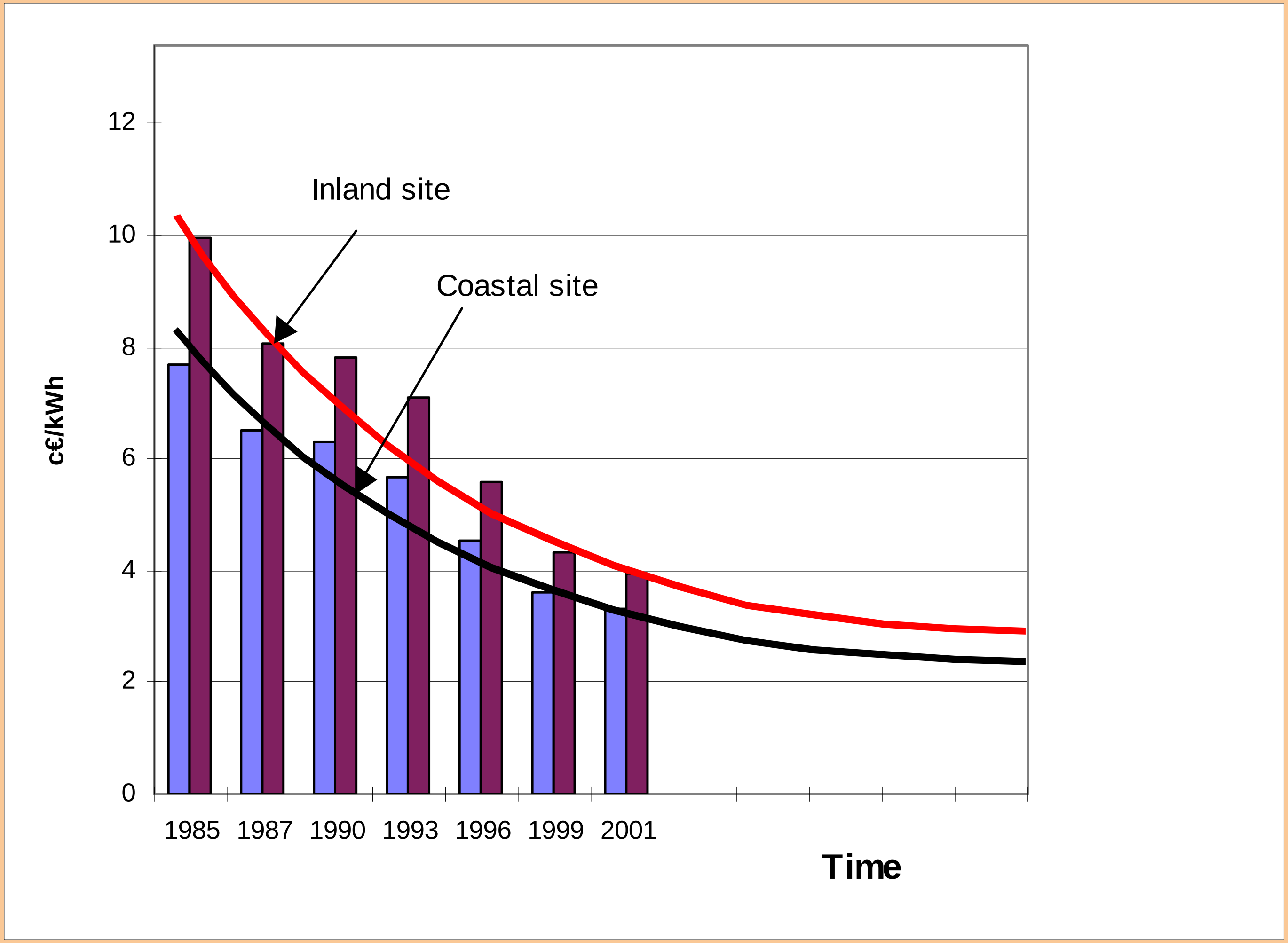
Development of Average Installed Turbine Size in Different Countries



Size and Efficiency



Cost within the Next 10 Years



Will Up-scaling of Turbines Continue?

- The 5 MW machine is just about there
  - Rotor diameter of 110-120 m
- Weight is an important issue
  - The weight of nacelle and blades are relatively reduced
- New materials are used in blade production
  - carbon fibres - hybrid constructions

Significant Cost Reductions Achieved Through Continued Up-scaling

- Aerodynamic experts say no physical barriers before we are above 20 MW

- Up-scaling will continue for the next 20 years
  - 10 MW in 2010 - rotor diameter of 160 m
  - 20 MW in 2020 - rotor diameter of 220 m

- Perhaps we will see 30-40 MW machines
  - continued technological development
  - infrastructure might be the constraining factor

Siting of Large Turbines

- Increased offshore siting
  - 15% offshore expected within the next 10 years
  - A huge potential in European waters - 7000-8000 MW just in Danish waters
- Large turbines even for on-land use
  - In Germany the use of 2 MW turbines today is quite usual
  - For small communities one or a few turbines can replace a decentralised power plant

Visual impact

- Larger on-land turbines may be visually more acceptable
  - one 3 MW machine has much lower visual impact than fifty 55 kW machines
  - lower rotation speed (same tip speed)

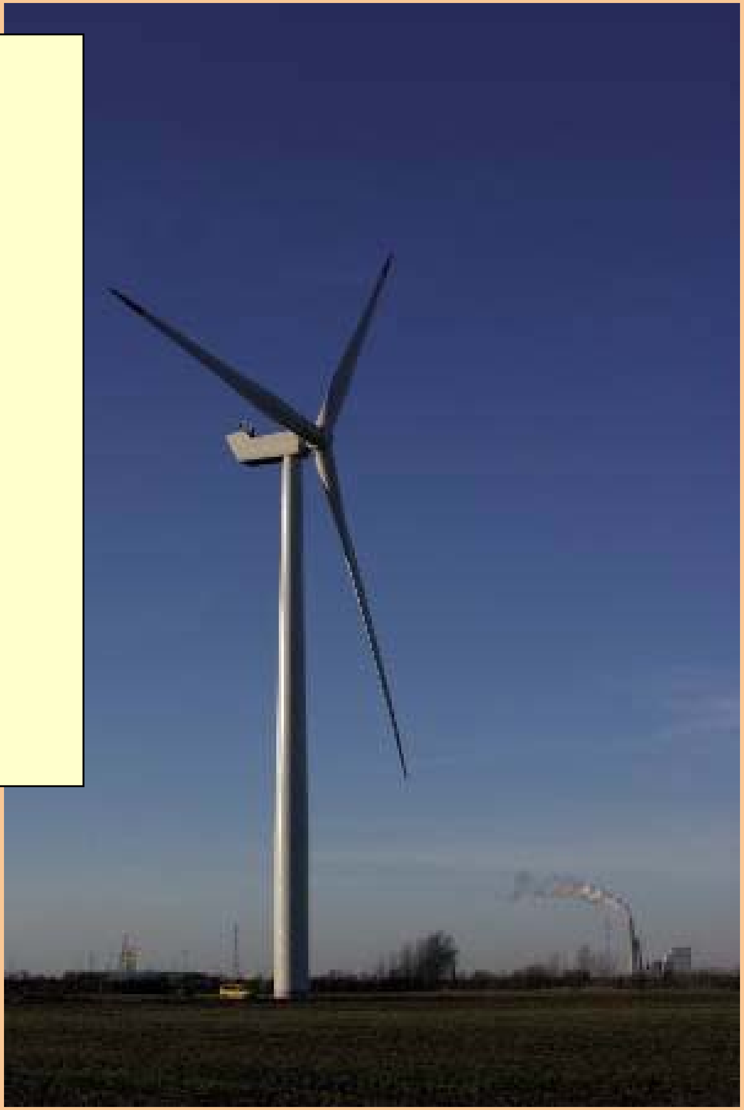
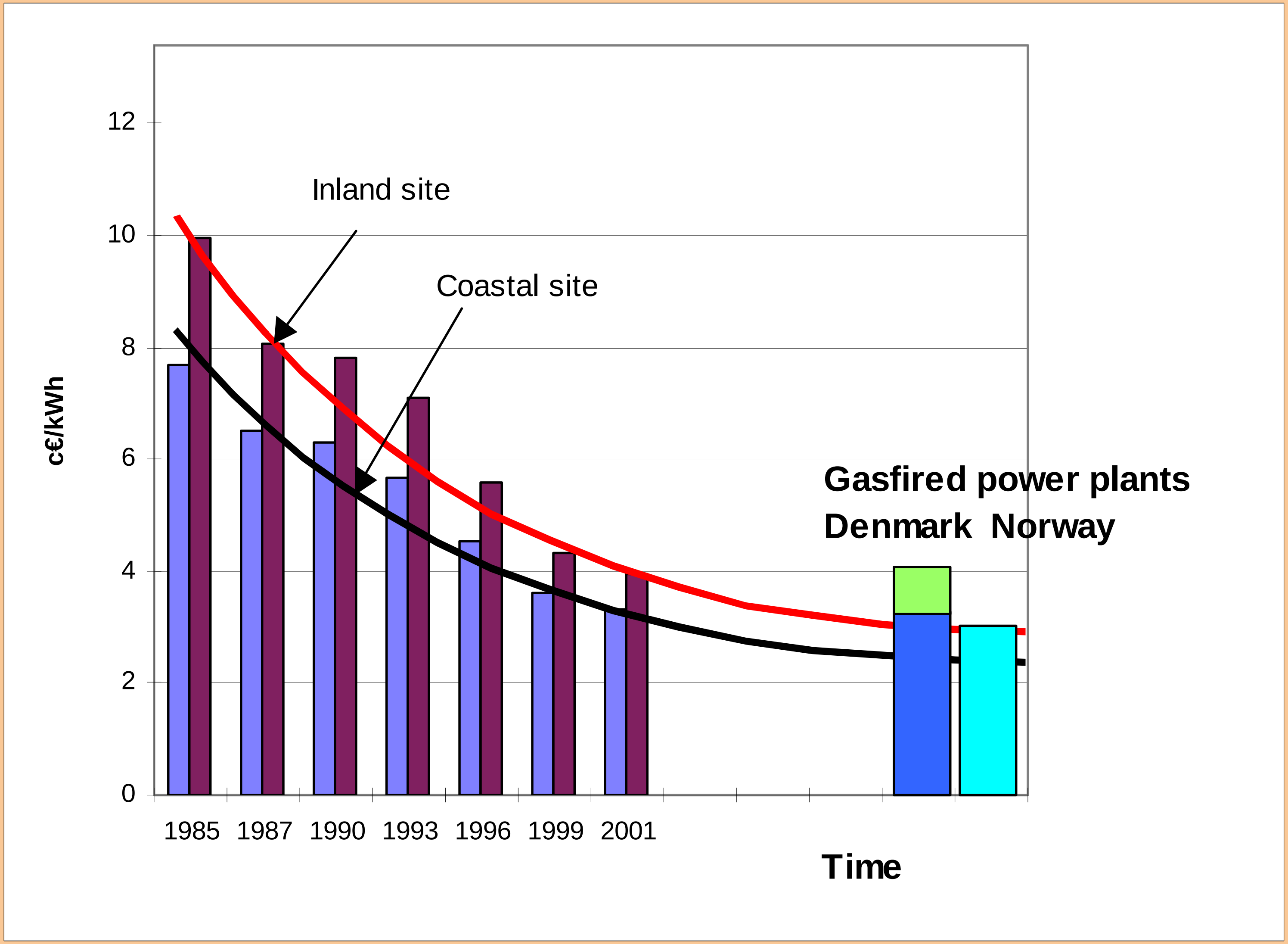


Photo:NEG-Micon

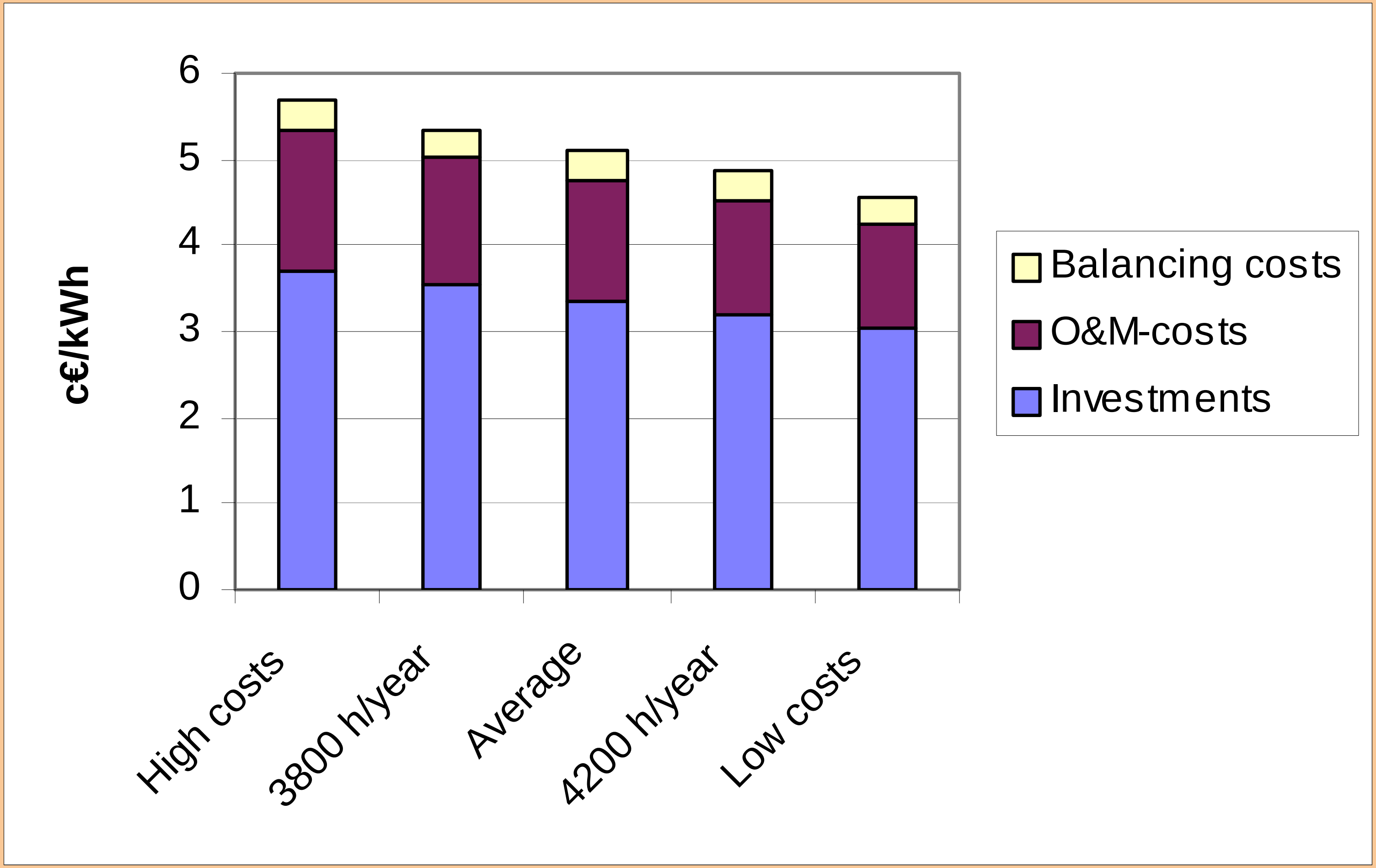
Future cost - compared to conventional power production



Offshore sites in Denmark

- Vindeby
- Tunø Knob
- Middelgrunden
- Horns Reef
- Samsoe
- Roenland
- Frederikshavn
- Nysted-Roedsand
- Grenå

Economics of Offshore Turbines – excluding transmission costs



Expected Production Costs of Horns Reef, Including Transmission

- Horns Reef
  - 80 2MW turbines, in total 160 MW
  - Investment 230 million €
  - Transmission 40 million €
  - Production: Measured 4689 h/y in 2000 – adjusted for losses: 4190 h/y

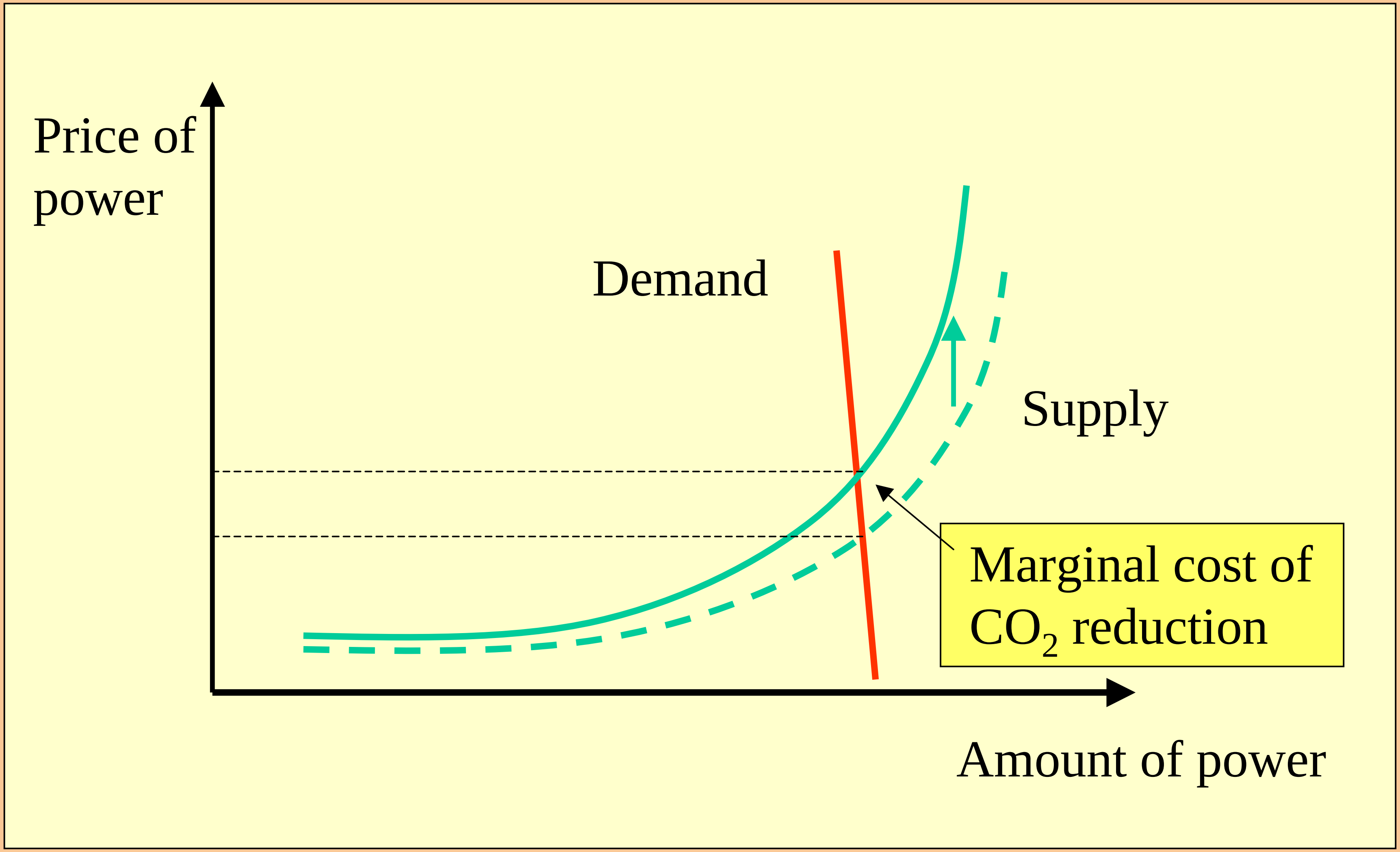
- Social Economic costs
  - In total 5.3 c€/kWh over 20 years, including regulation costs of 0.3 c€ /kWh
  - Of this Operation and Maintenance cost is approximately 1.6 c€/kWh

Emission trading scheme

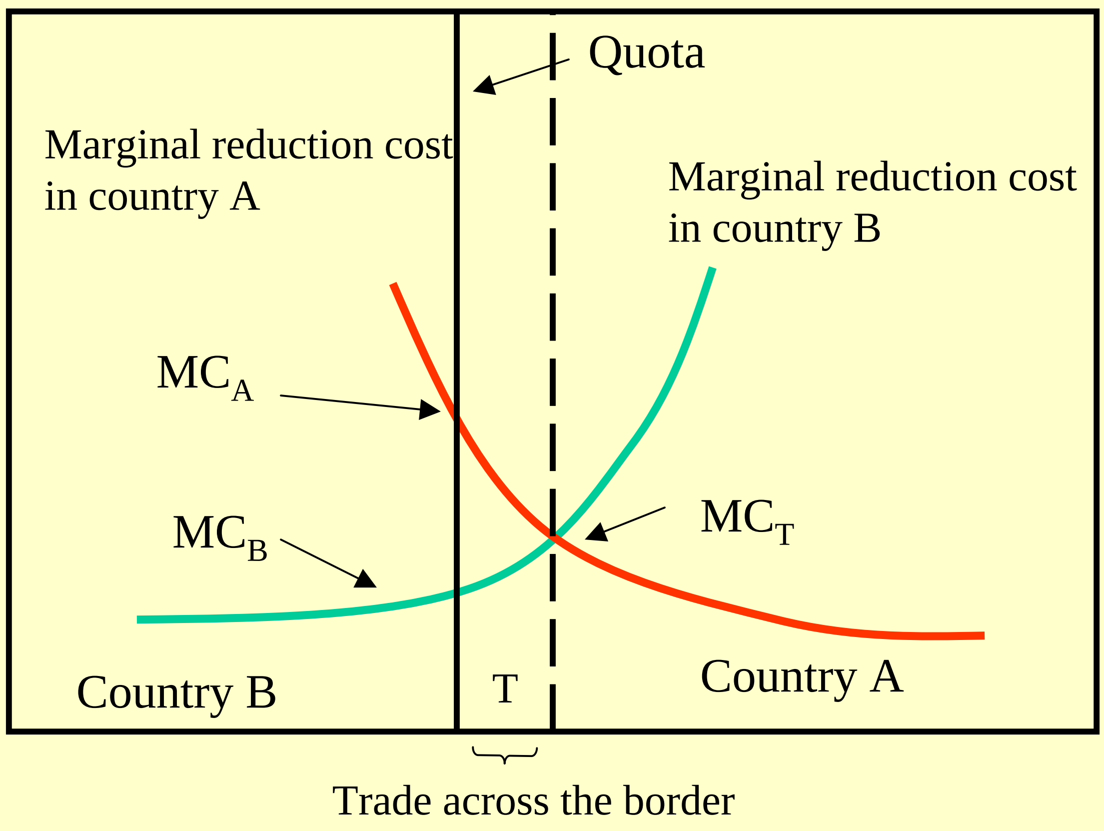
The idea is to achieve reductions in CO_2-emissions from the power industry and other energy-intensive industries by establishing a set of national quotas (allowances)

- Allows the industry to emit a certain volume of CO_2
  - Quotas determined by national authorities in agreement with EU - A penalty is paid for not complying to the quota
- National and international trade in permits is possible
  - Emission reductions are undertaken where they are least costly

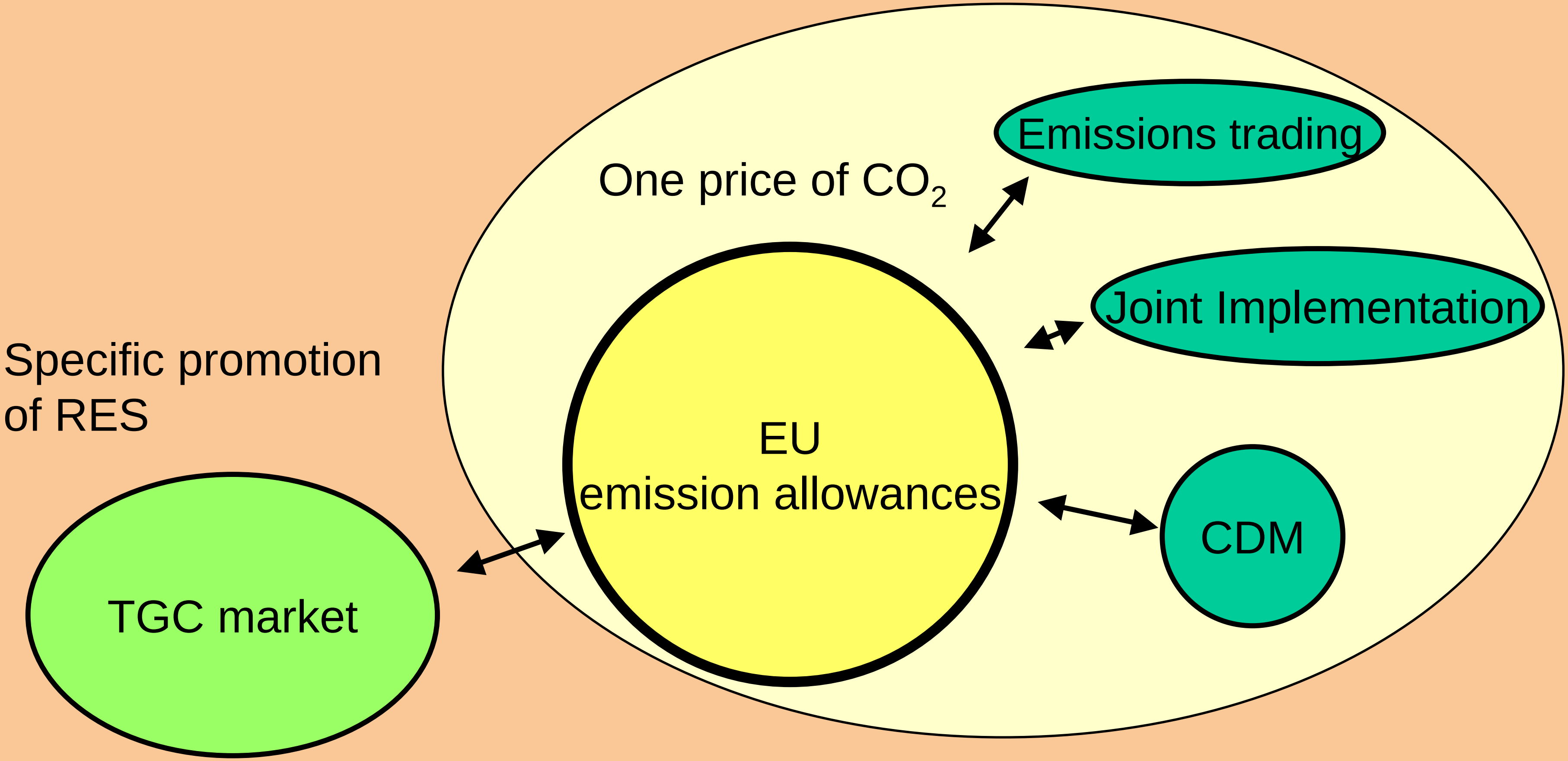
The spot market - impact of emission trading scheme



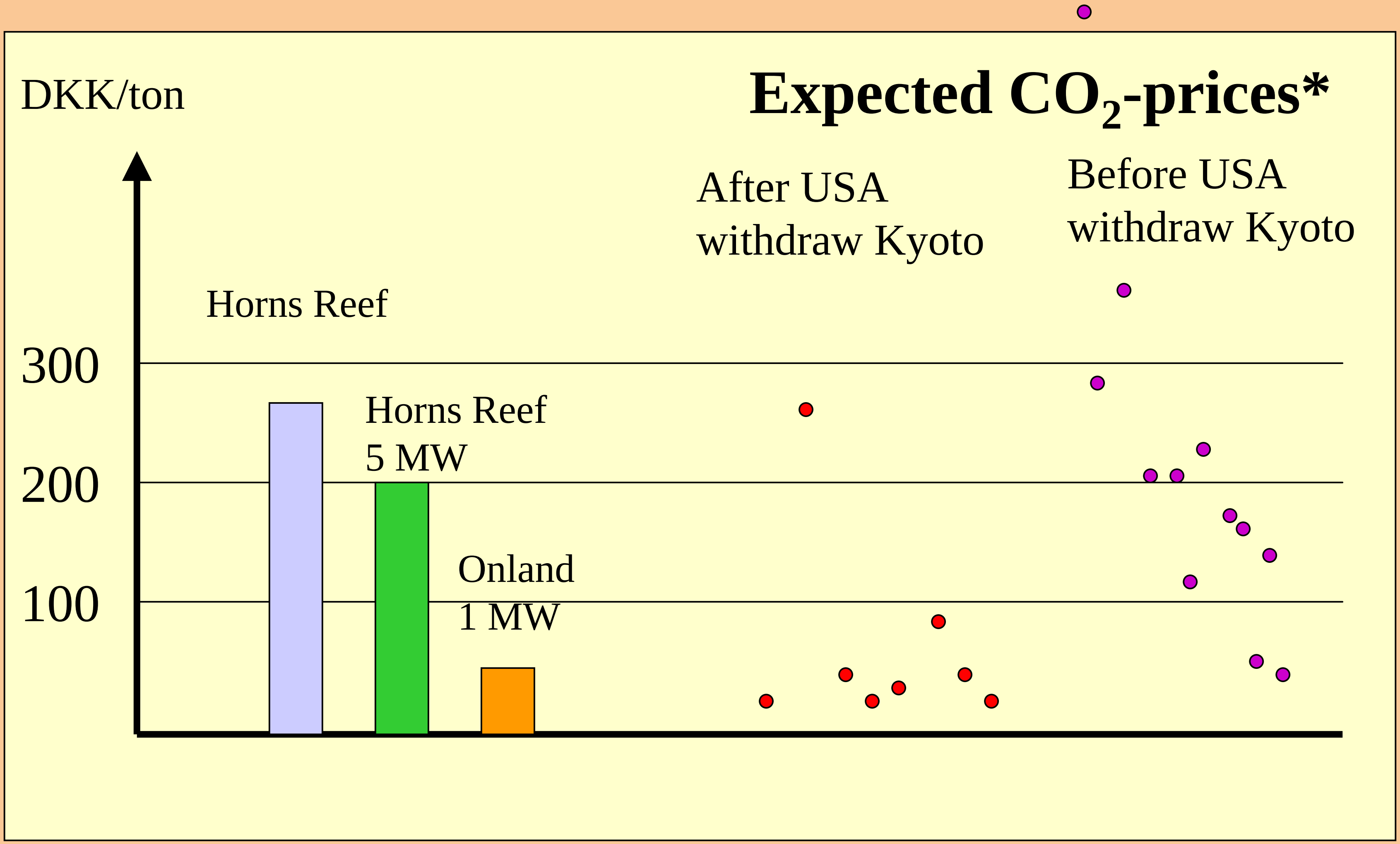
Efficiency = trade across the borders



Interacting Markets

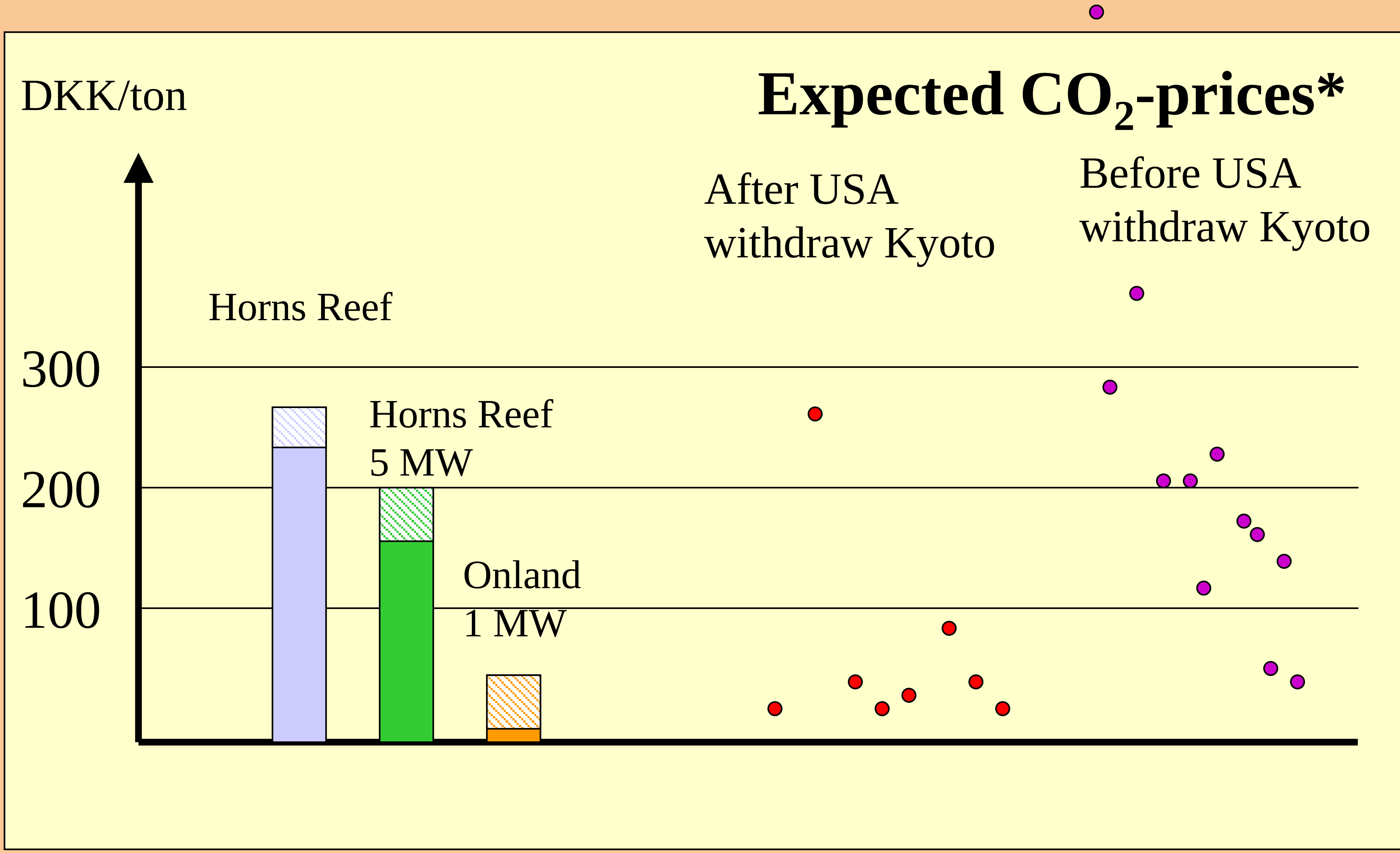


CO_2-reduction costs
Litterature comparison



* Source: The Danish Energy Authority

CO_2-reduction costs, if a Danish Natural Gas Plant is Marginal at the Spot Market



* Source: The Danish Energy Authority

Conclusions

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- Intermittency is seen as a major barrier for large scale wind power development
  - Systems solutions with shorter bidding periods should be thoroughly investigated
  - More accurate prediction tools are on the way
  - New regulation and storage technologies are important
- Wind power has come to stay
  - Within 7-10 years wind power is expected to be fully economic competitive compared to conventional power plants
  - Up-scaling will continue the next 20 years and make wind power even more competitive
  - More optimisation of medium sized onland turbines has the potential of further lowering the costs
- Emission trading will make wind power closer to competitiveness
  - In the short run specific support schemes are still needed