



# **eltra**

**Large-scale Wind Power**

**and**

**Energy Storage**

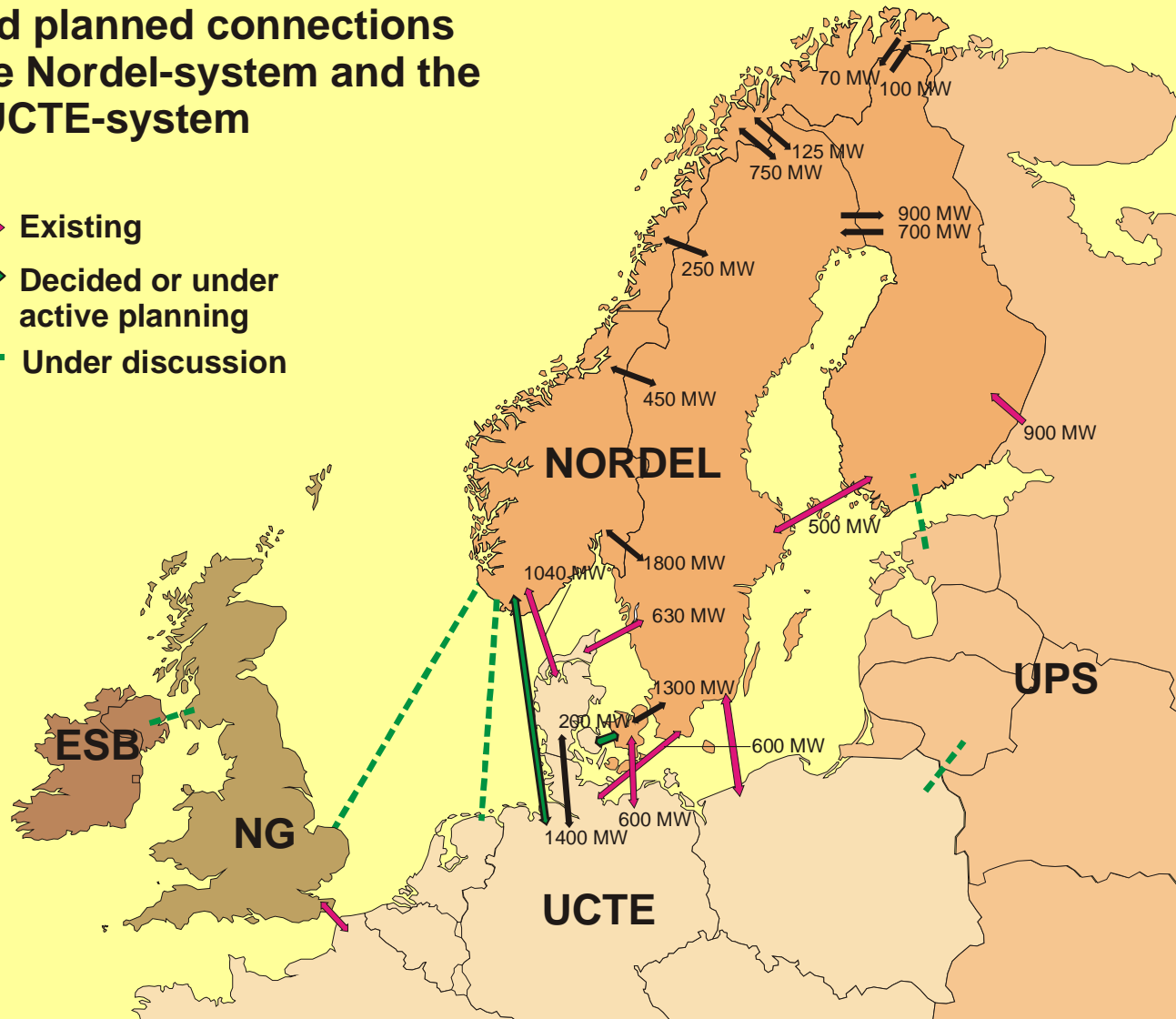
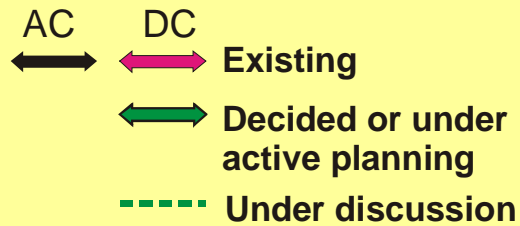
**by**

**Kent Søbrink**

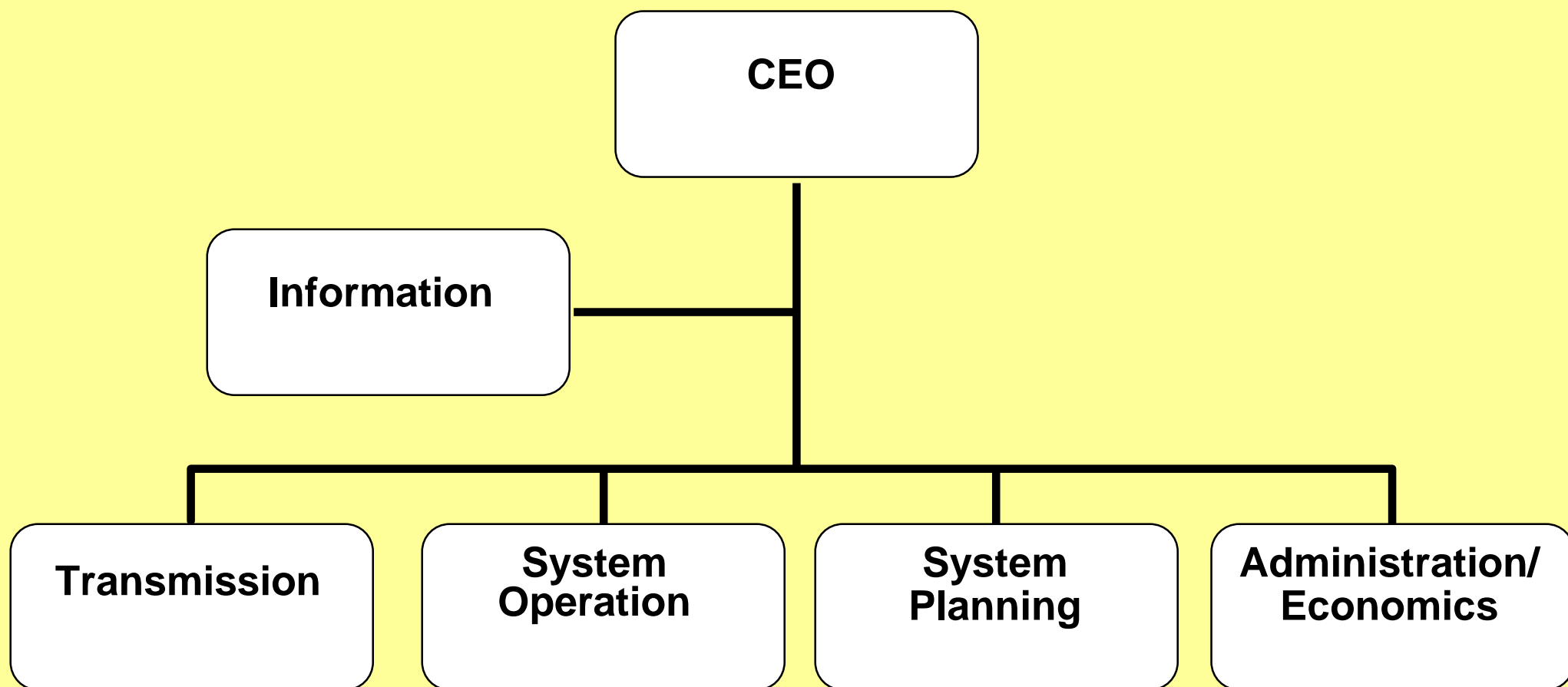
## Items to be covered.

- **About Eltra**
- The Danish action plan for renewable energy
- The Nordic electricity market
- Daily handling of wind power in the Eltra area
- Wind power integration using energy storage

## Existing and planned connections between the Nordel-system and the European UCTE-system



# Organisation



Approx. 210 employees

# Eltra

Since January 1, 1998

Independent System Operator in the Jutland/Funen area

## Tasks:

- **The transmission network**
- **System functioning**
- **Electricity market functioning**
- **Public Service Obligations**

## **Eltra's tasks (1)**

### **The transmission network**

- **Operation of transmission network (150 kV, 400 kV)**
- **Operation of HVDC-lines**
- **Settlement of transmission network**
- **Planning of transmission network**

## **Eltra's tasks (2)**

### **System functioning**

- **Overall responsibility for security of system**
- **Maintain overall balance in system**

## **Eltra's tasks (3)**

### **Electricity market functioning**

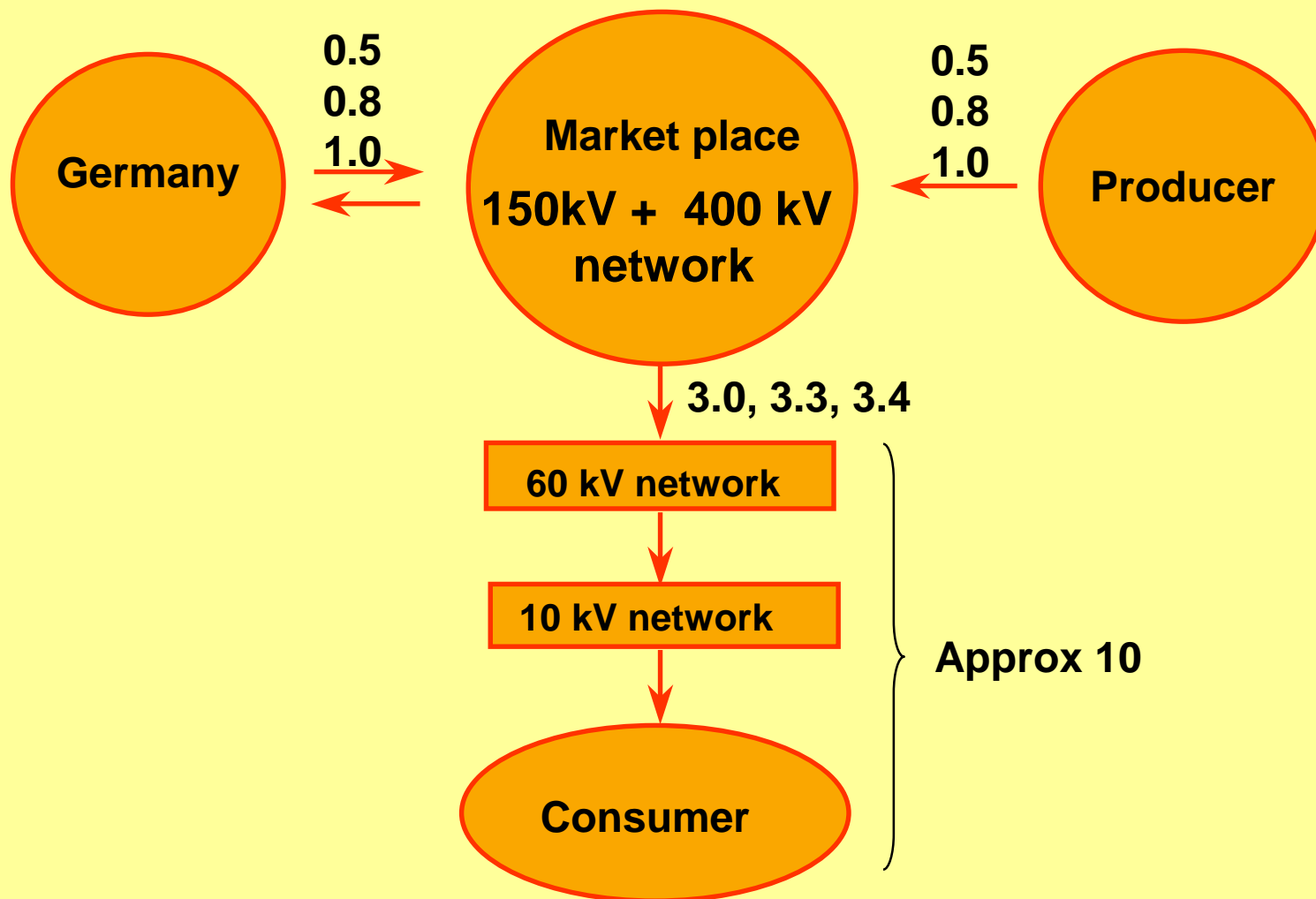
- **Balance exchange schedules from players**
- **Metering**
- **Settlement of balance**
- **Service messages for players**



## **Eltra's tasks (4)**

- **Operation and settlement of local CHP and wind turbines ("environmentally-friendly production")**
- **R&D "in environmentally-friendly production"**
- **Protection of consumers (equal terms)**
- **Decrees from the authorities**

# Net payments (øre/kWh)





## Items to be covered.

- About Eltra
- **The Danish action plan for renewable energy**
- The Nordic electricity market
- Daily handling of wind power in the Eltra area
- Offshore wind power integration using energy storage



## "Energy 21" - Action Plan of The Danish Government from 1996

### Overall aim for 2030:





-  To reduce CO<sub>2</sub> emissions by 50 %
-  To cover 35 % of Denmark's energy consumption by renewable energy

**Potential means: Substantial expansion of wind capacity**

### Goals for electricity consumption in Denmark:

-  20 % will be covered by renewable energy in 2003
-  50 % will be covered by renewable energy in 2030

## **Action Plan for Offshore Wind Farms in Danish Waters June 1997**

-  **Five sites for offshore wind farms evaluated**
-  **The economy will be comparable to that of onshore wind turbines**
-  **A demonstration project is recommended on each site**
-  **Each project should be based on 60-80 wind turbines of an expected unit capacity of 1.5-2.0 MW**

## Action Plan for Offshore Wind Turbines

### Key Figures for Offshore Wind Farms

	Gedser 1	Rødsand 1	Omø 1	Læsø 1	Horns Rev 1	
<b>Installed capacity</b>	<b>144</b>	<b>144</b>	<b>144</b>	<b>117</b>	<b>120</b>	<b>MW</b>
<b>Utilisation time (full-load hours)</b>	<b>3287</b>	<b>3330</b>	<b>3014</b>	<b>3380</b>	<b>3530</b>	<b>Hours/year</b>
<b>Investment per kW</b>	<b>1668</b>	<b>1547</b>	<b>1480</b>	<b>1574</b>	<b>1574</b>	<b>EUR</b>
<b>Capital costs per kWh</b>	<b>0.040</b>	<b>0.038</b>	<b>0.039</b>	<b>0.038</b>	<b>0.036</b>	<b>EUR</b>
<b>Operation and maintenance</b>	<b>0.010</b>	<b>0.010</b>	<b>0.010</b>	<b>0.010</b>	<b>0.010</b>	<b>EUR</b>
<b>Total costs per kWh</b>	<b>0.050</b>	<b>0.048</b>	<b>0.049</b>	<b>0.048</b>	<b>0.046</b>	<b>EUR</b>

## Plan for Expansion of Wind Power in Energy 21

Year	Onshore		Offshore	
1997	800 MW	(1100 MW realised)	0 MW	
2000	1000 MW	(2200 MW realised)	0 MW	(40 MW realised)
2005	1300 MW	(2500 MW expected)	200 MW	(640 MW expected)
2030	1500 MW		4000 MW	

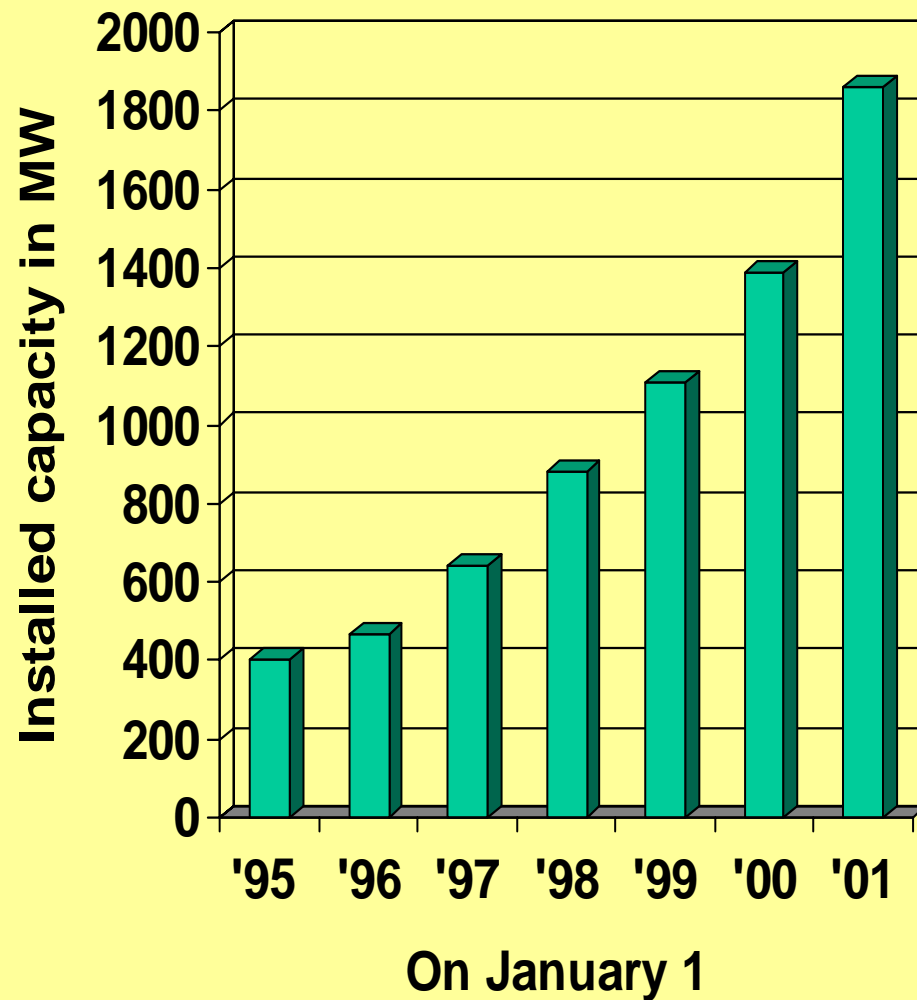
## Development in Installed Wind Power

**As at 2000-03-01:**

Installed capacity: 1882 MW

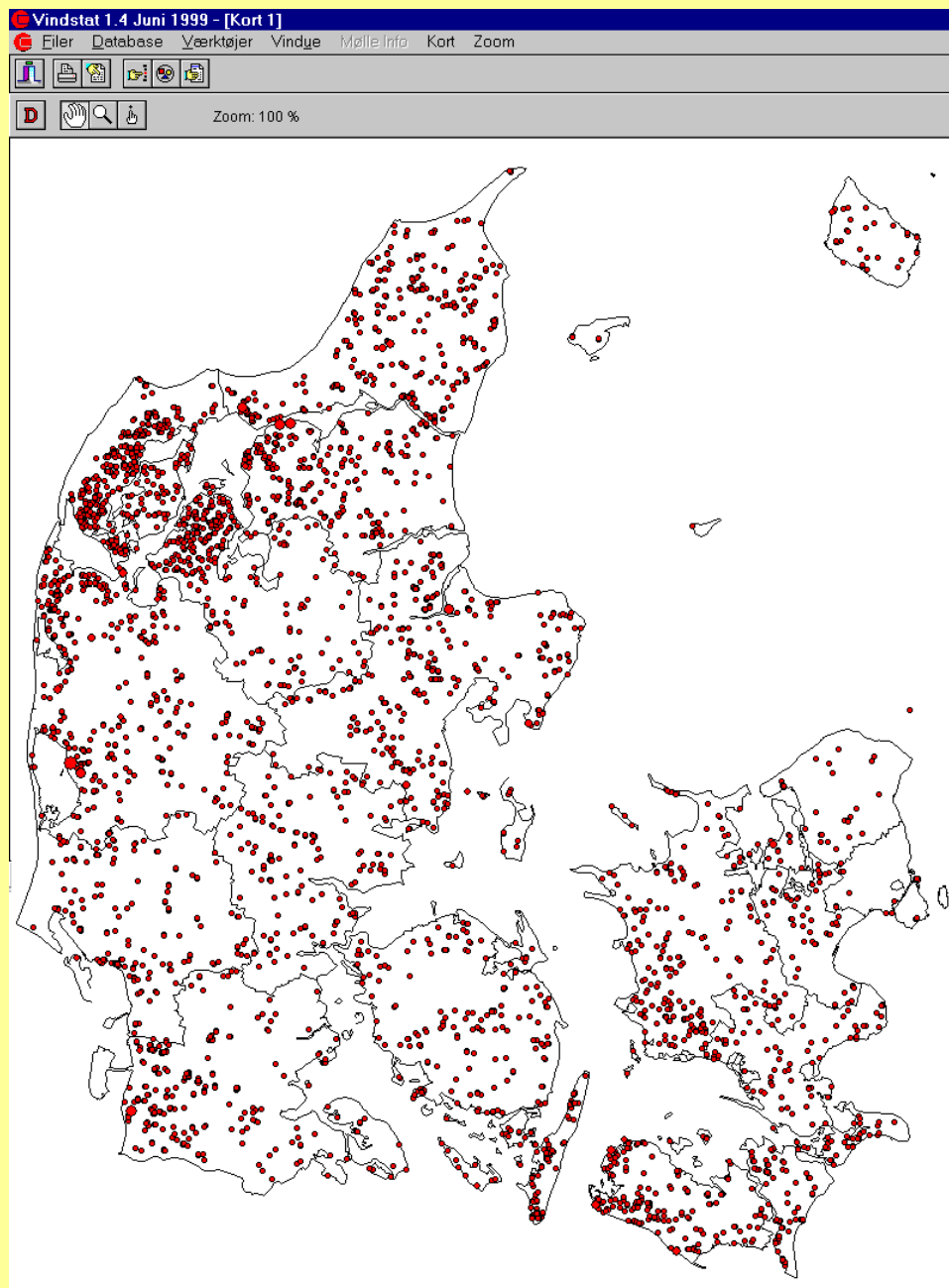
**Equal to approximately:**

- 160 % of min. load
- 50 % of max. load



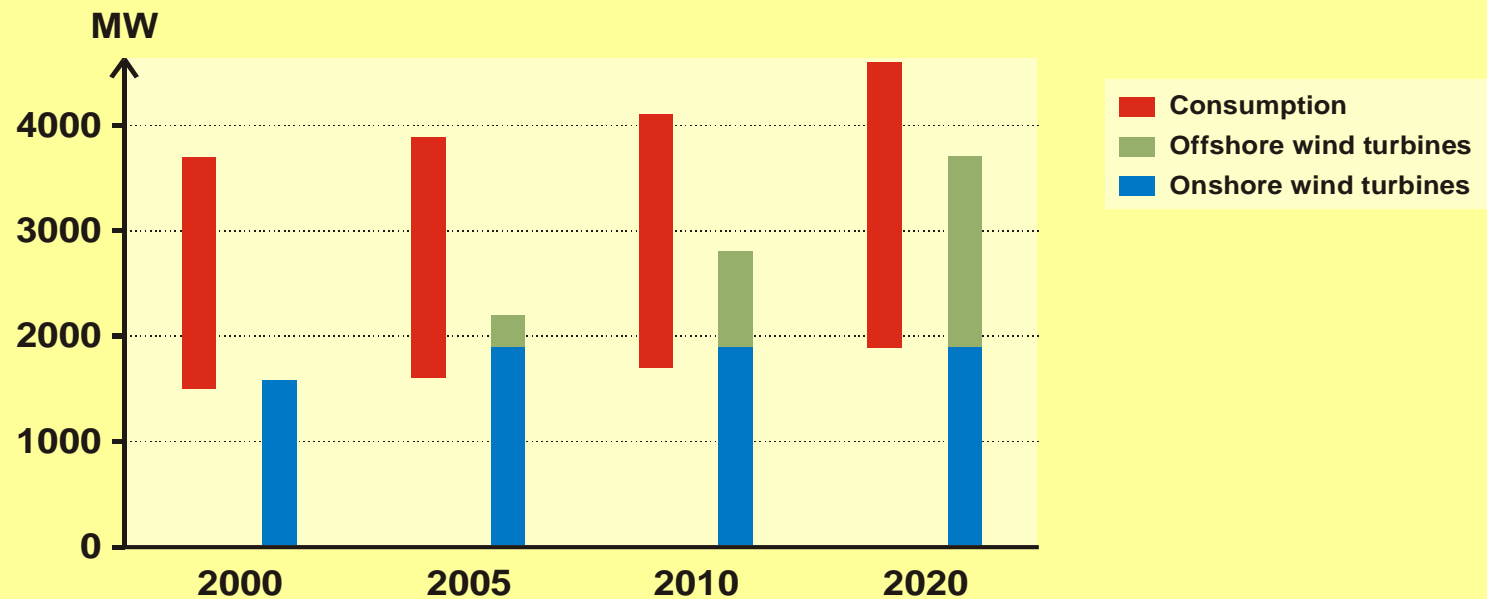


# Wind Turbines in Denmark

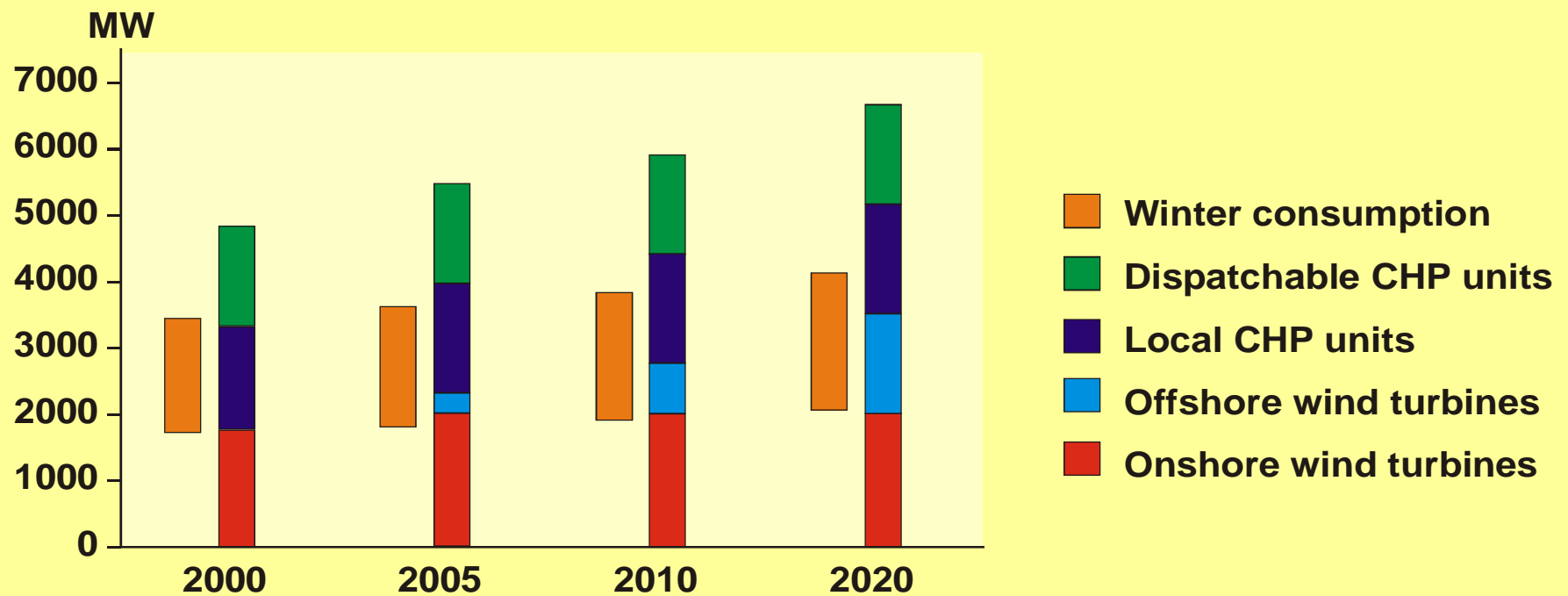


Ref. [www.emd.dk](http://www.emd.dk)

## Variation in Electricity Consumption Compared with the Installed Capacity of Wind Turbines



## Consumption (MW) Compared with the Capacity of the Bound Production in Eltra's Area



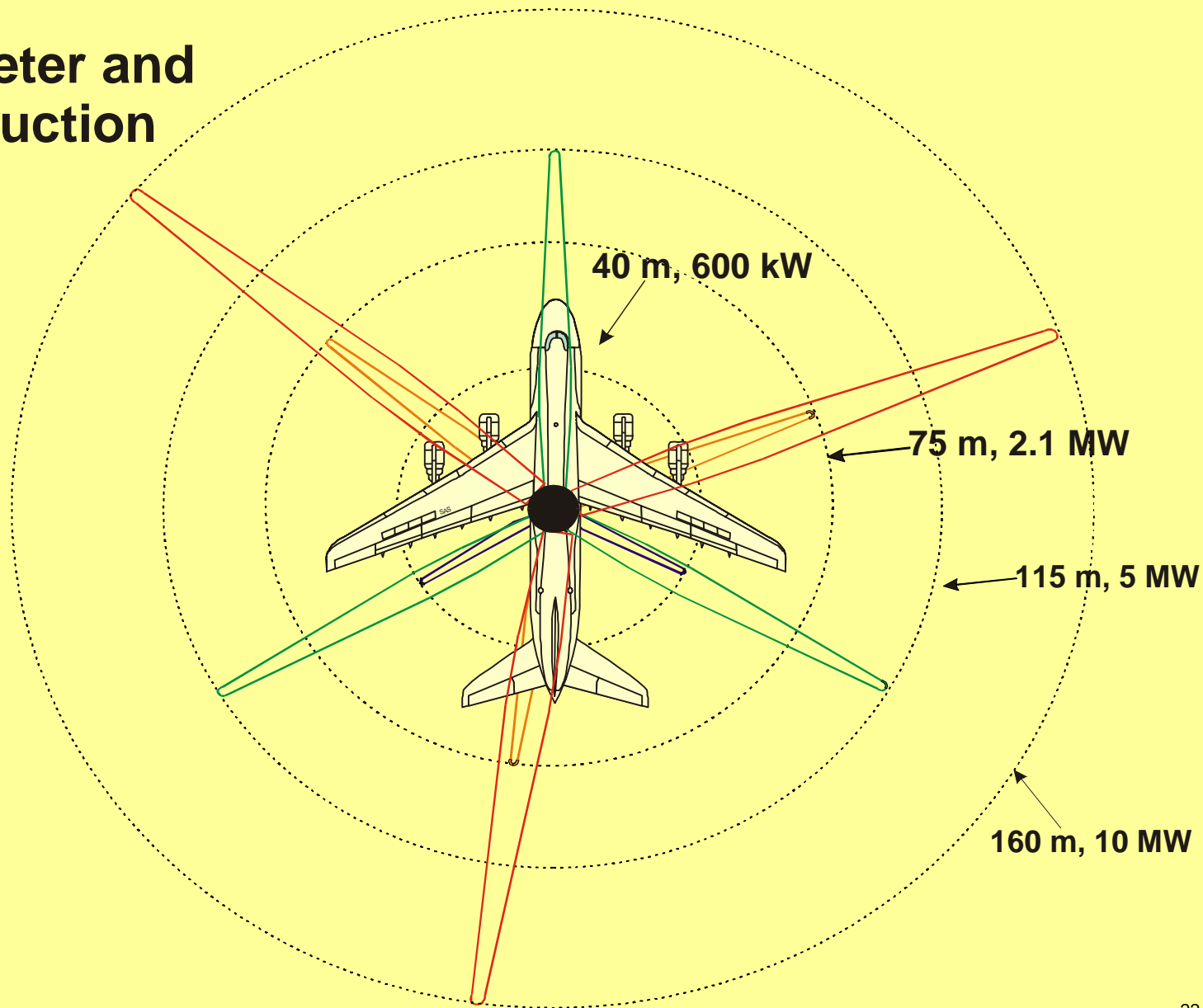
## Production Capacity in Eltra's Area

- |                                         |                |
|-----------------------------------------|----------------|
| • <b>Central units approximately:</b>   | <b>3330 MW</b> |
| • <b>Local CHP plants:</b>              | <b>1461 MW</b> |
| • <b>Prioritised wind turbines:</b>     | <b>1747 MW</b> |
| • <b>Non- prioritised turbines:</b>     | <b>135 MW</b>  |
| • <b>Total installed wind turbines:</b> | <b>1882 MW</b> |
| • <b>Total installed capacity:</b>      | <b>6673 MW</b> |

# Offshore Demonstrations projects in Denmark



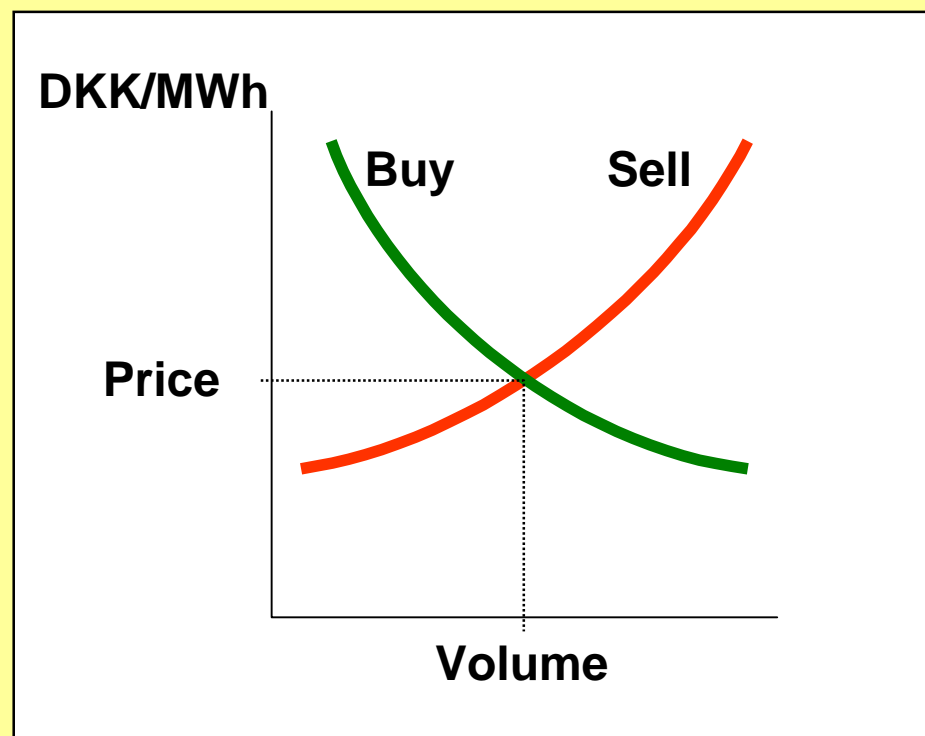
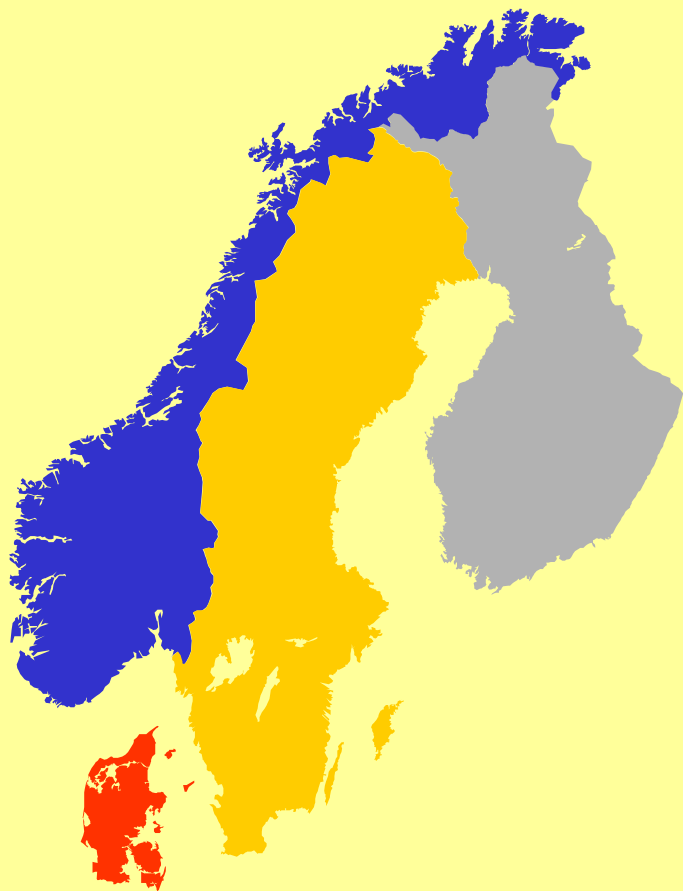
# Rotor Diameter and Power Production



## Items to be covered.

- About Eltra
- The Danish action plan for renewable energy
- **The Nordic electricity market**
- Daily handling of wind power in the Eltra area
- Wind power integration using energy storage

# Nord Pool





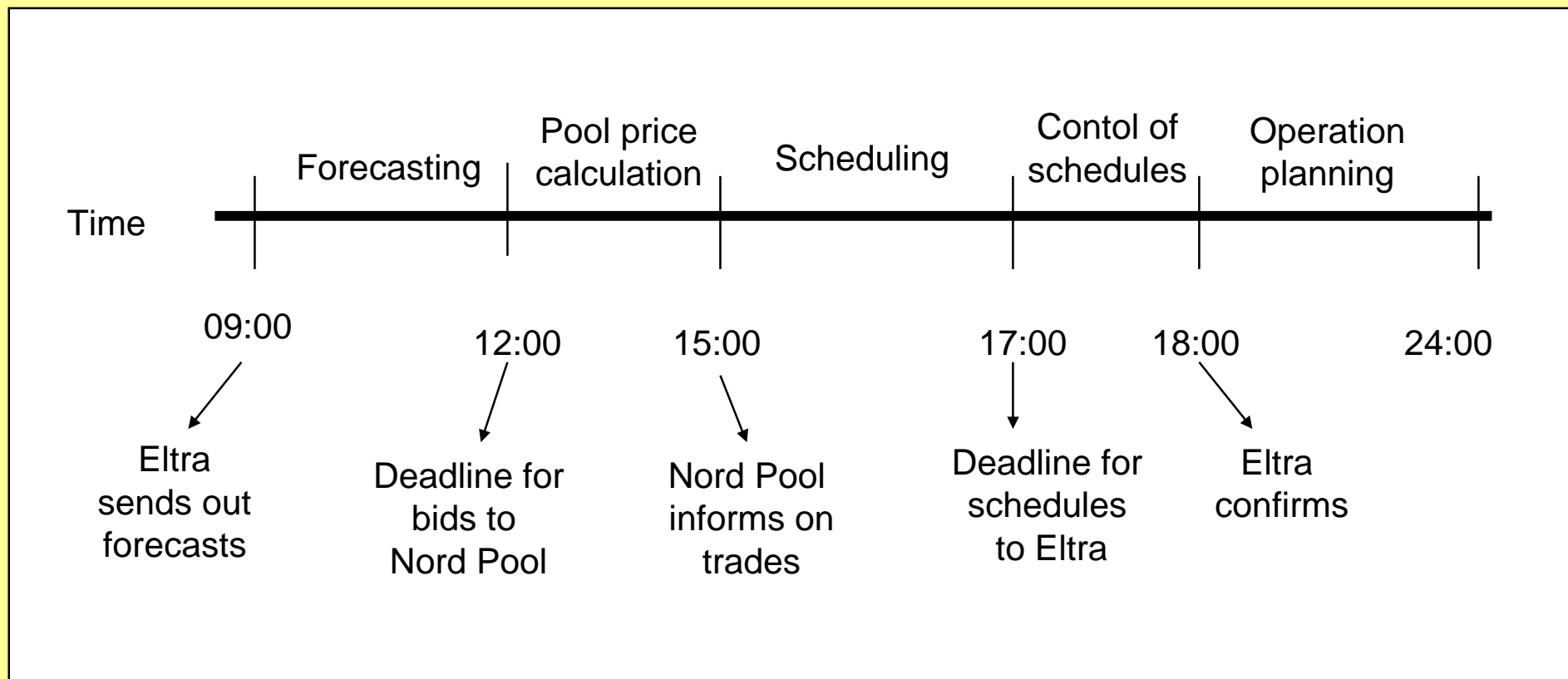
# The Electricity Market

- **A spot market**
- **A financial market**
- **A bilateral market**
- **A balance market**
  - Balance power
  - Regulating power

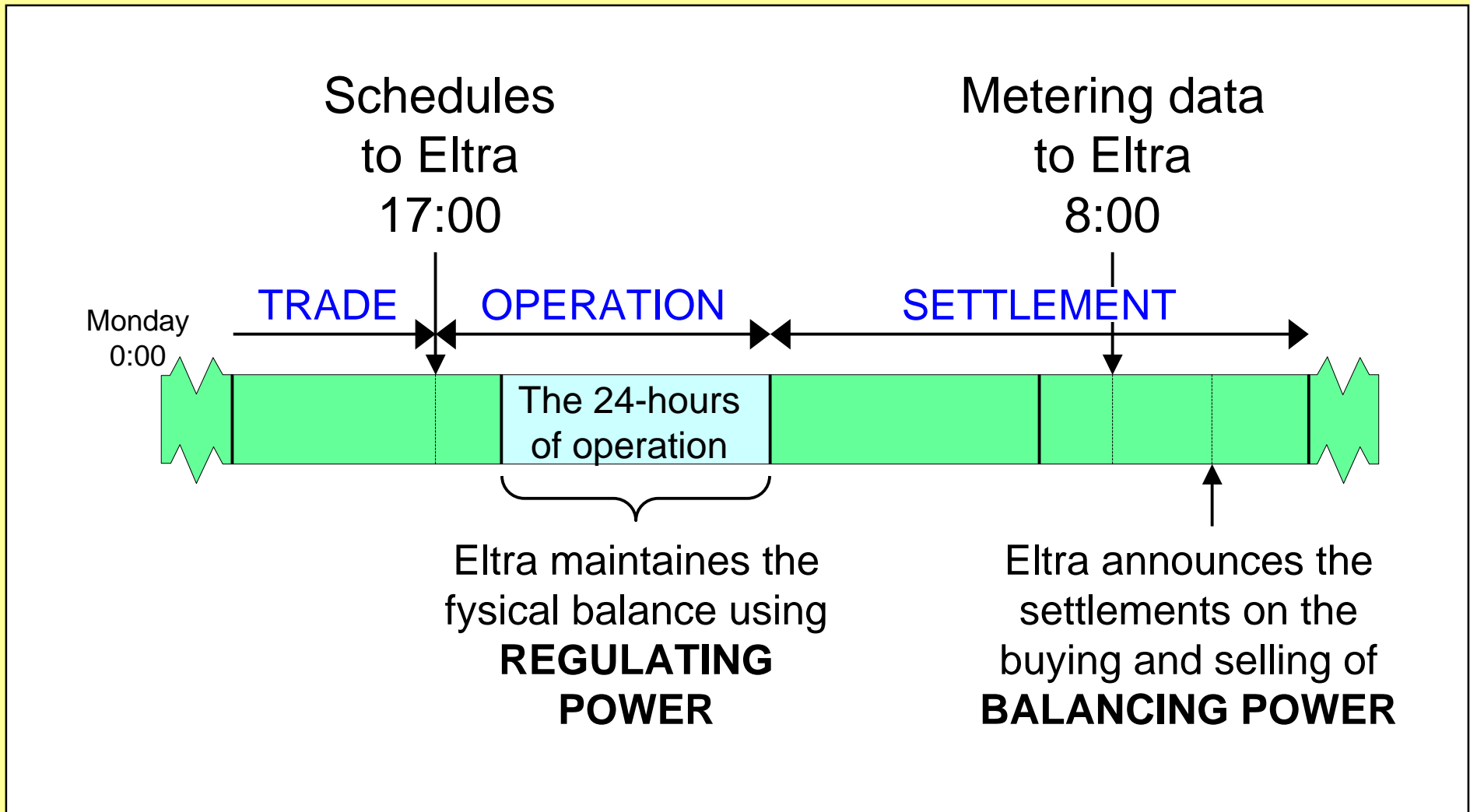
## Players on the Danish Electricity Market

- **Producers**
- **Transmission system operator**
  - East Denmark : Elkraft system and West -: Eltra
- **Locale grid companies**
- **Trading companies**
- **Supply-committed companies**
- **Other Players**
  - brokers
  - traders
  - Oil companies (Shell, Statoil)

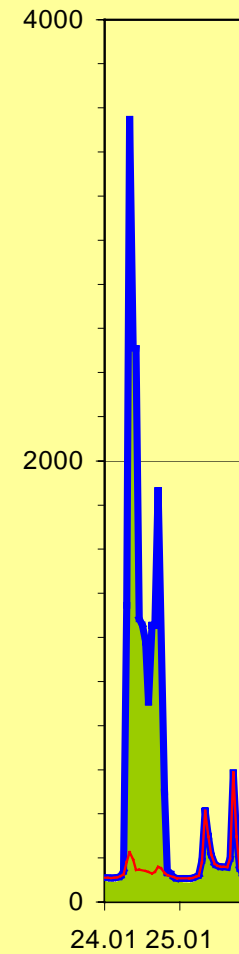
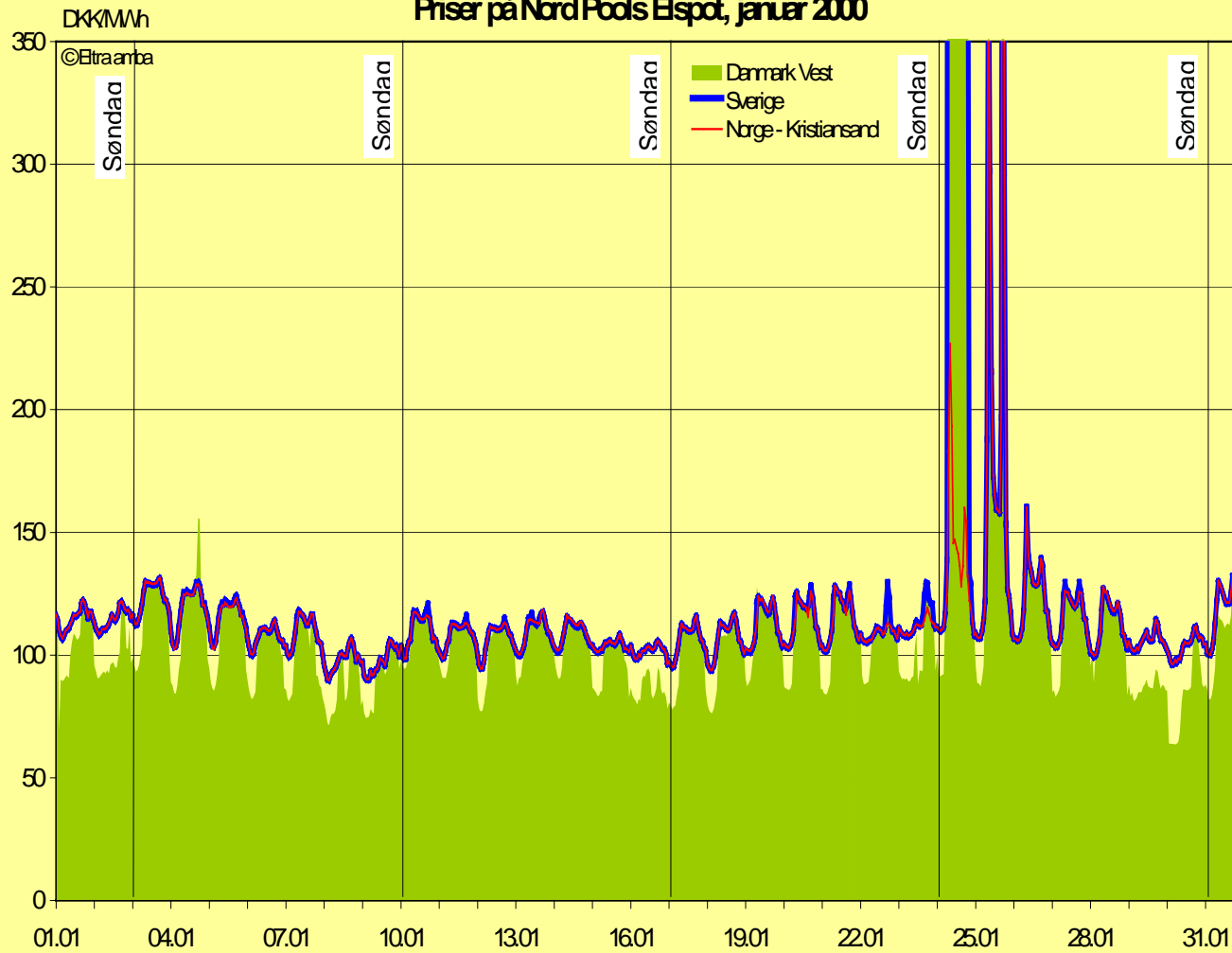
## Time schedule



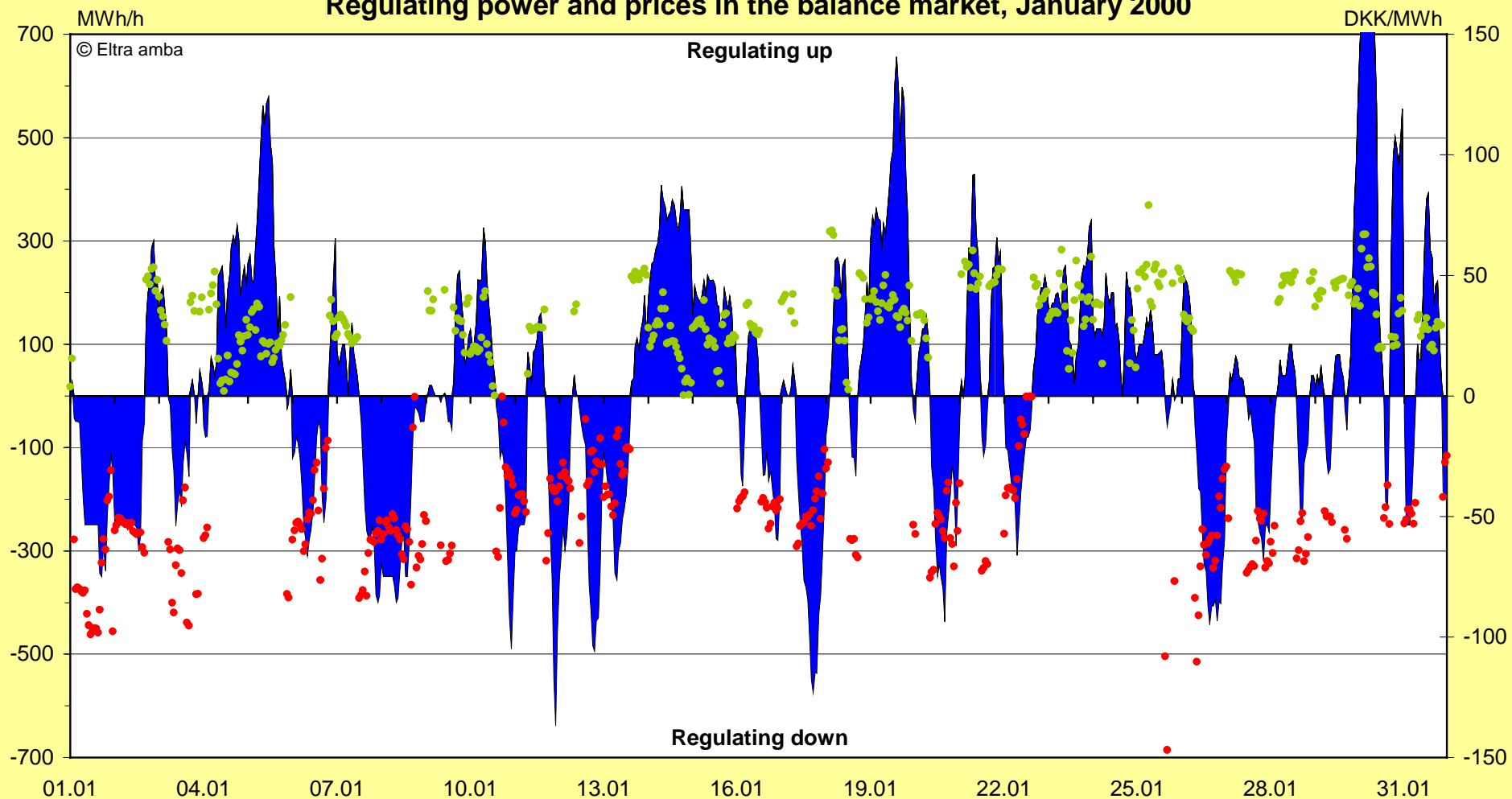
# Real time market



### Priser på Nord Pools Elspot, januar 2000



### Regulating power and prices in the balance market, January 2000



## Transmission System Operator in Jutland/Funen

- **Responsible for:**
  - Safe running and maintenance of the primary grid.
  - Physical balance in the system and create equal conditions for all balance responsible market players.
  - Co-operation between neighbouring System Operators.
  - Handling of priority production - including prioritised **wind turbines**.
  - Making up and settling of market players.

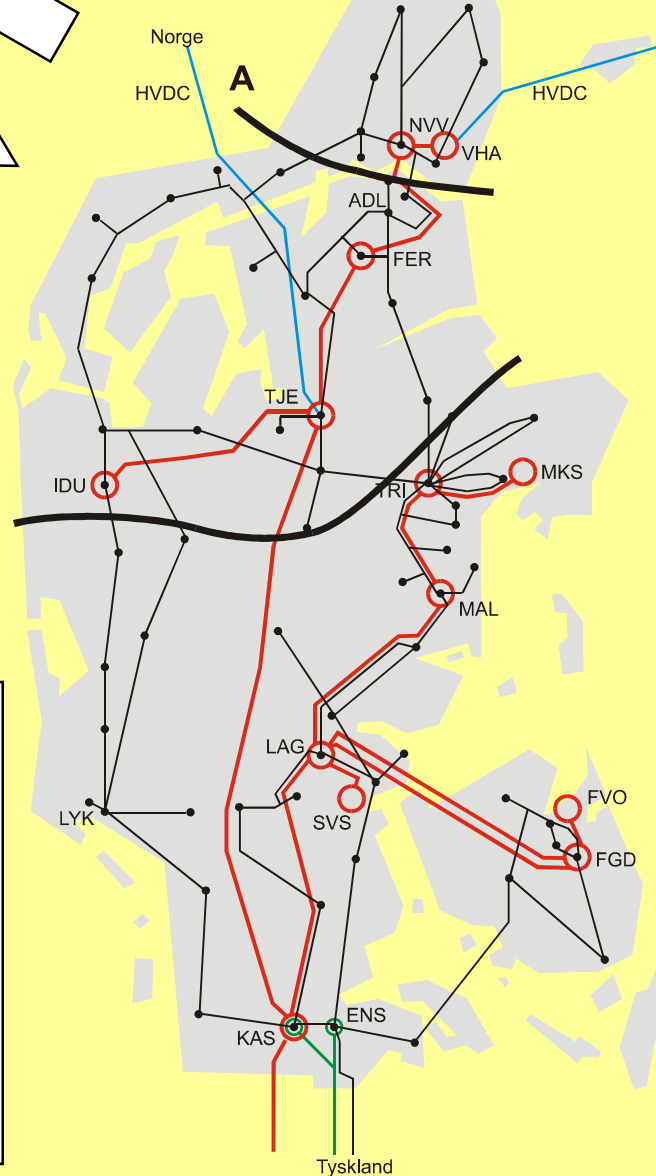
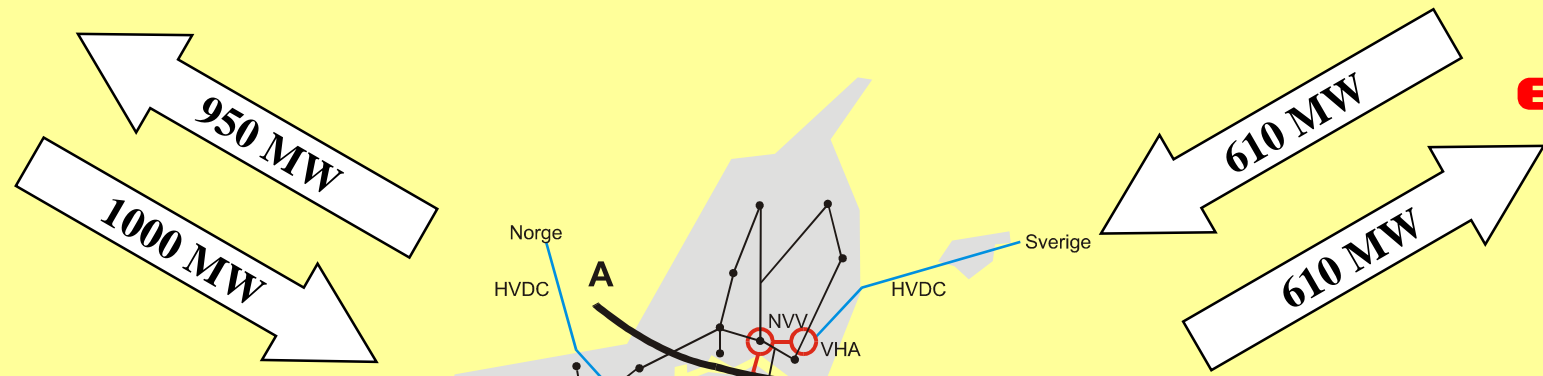
## The Free Electricity Market in Western Denmark

- **Market players can trade in the following ways:**
  - Bilaterally across the border between Germany and Eltra before 14:30 d. b.
  - Bilaterally between the market players within Eltra's area before 16:00 d. b.
  - On Nord Pool before 12:00 the d. b.

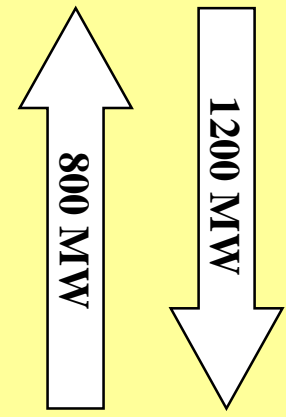


## Items to be covered.

- About Eltra
- The Danish action plan for renewable energy
- The Nordic electricity market
- **Daily handling of wind power in the Eltra area**
- Wind power integration using energy storage



Central:	3330 MW
CHP:	1461 MW
Wind:	1882 MW
Min. Load:	1150 MW
Max. Load:	3800 MW



## Consumption and Production in 2000

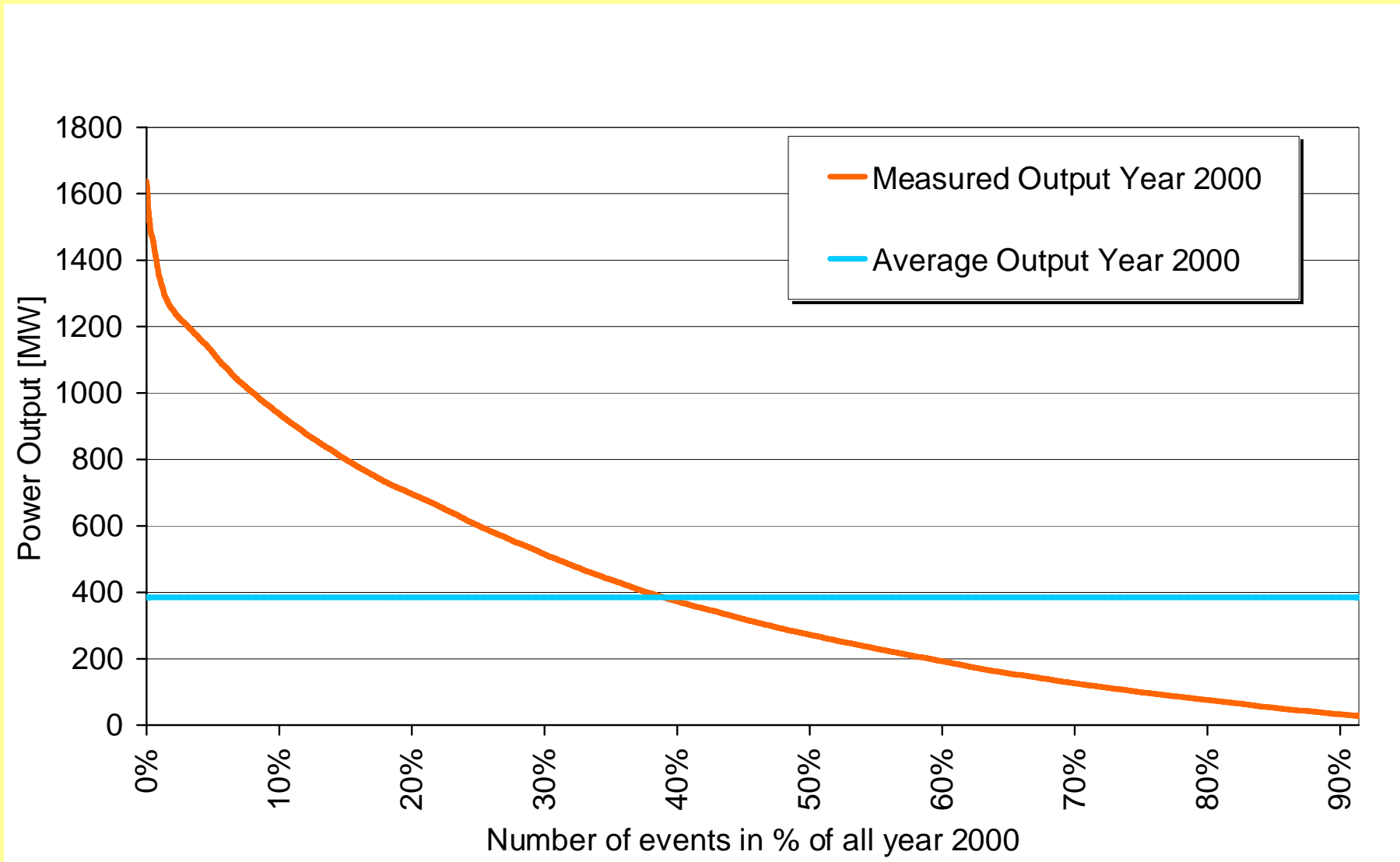
### In GWh:

- Consumption: 20668 GWh
- Central units: 11340 GWh
- **Wind power: 3384 GWh**
- Local combined: 6243 GWh
- Net export: 299 GWh

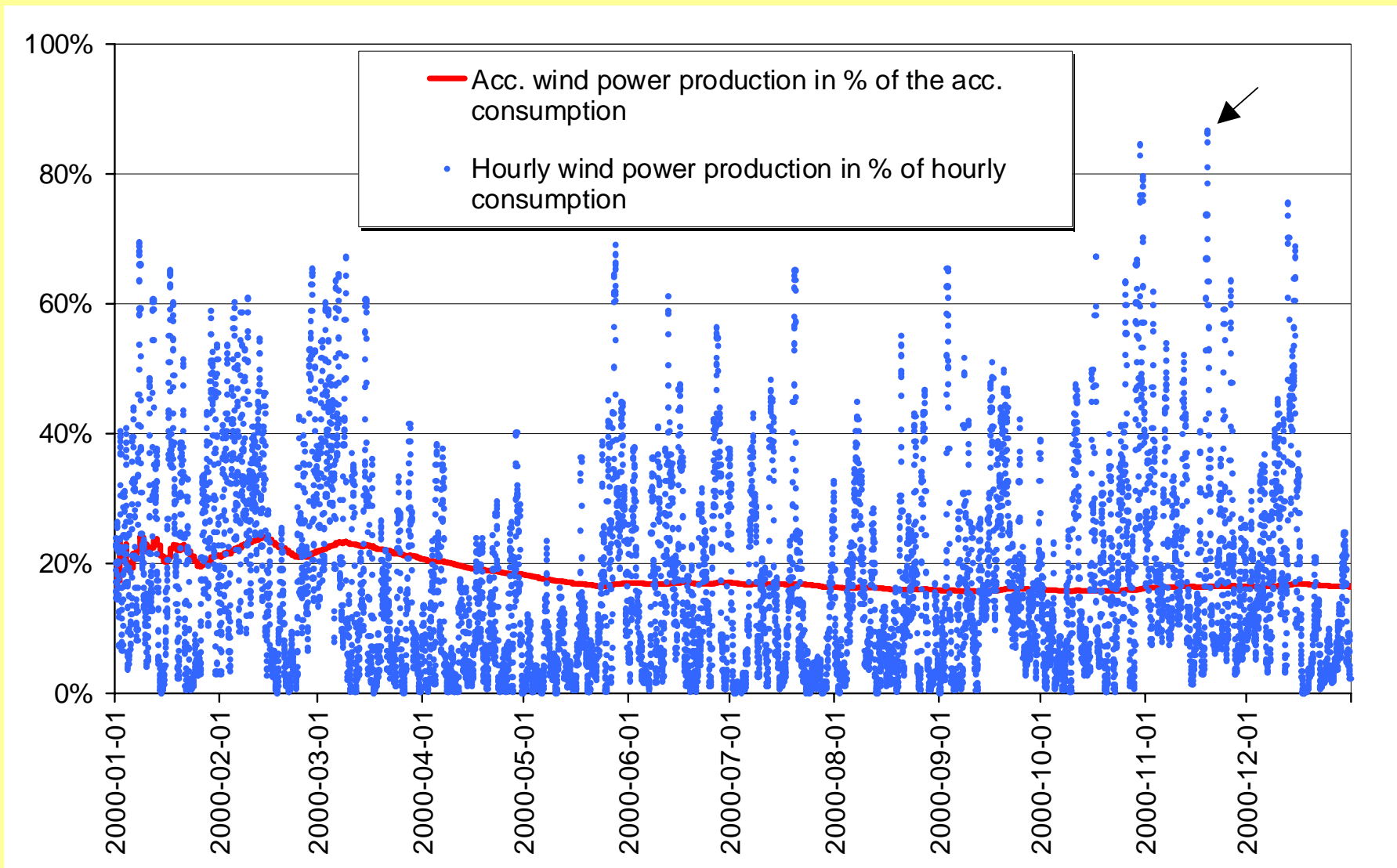
### In per cent of consumption:

- **Wind power: 16.4 %**
- Local combined: 30.2 %

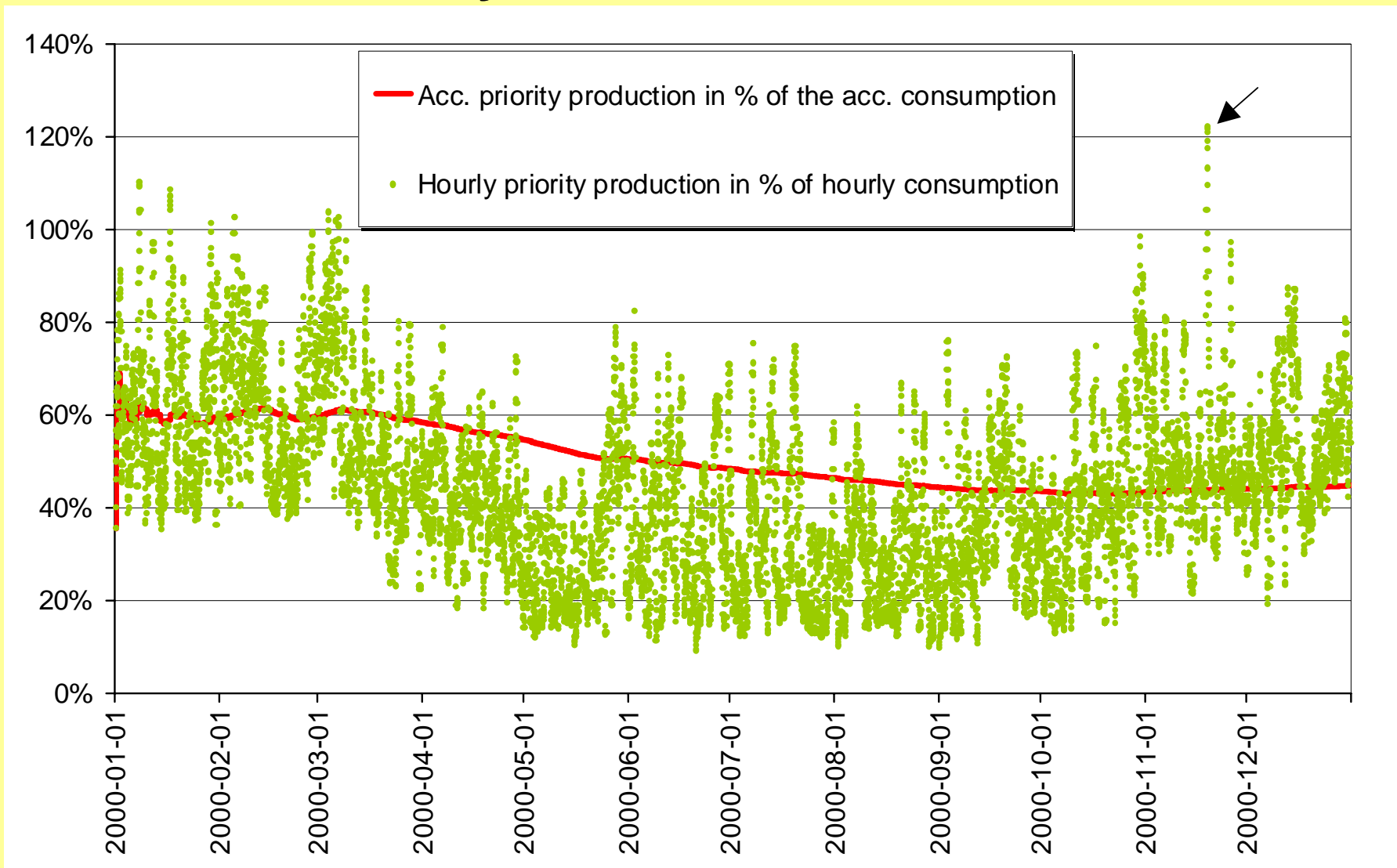
# Wind Power Production Year 2000



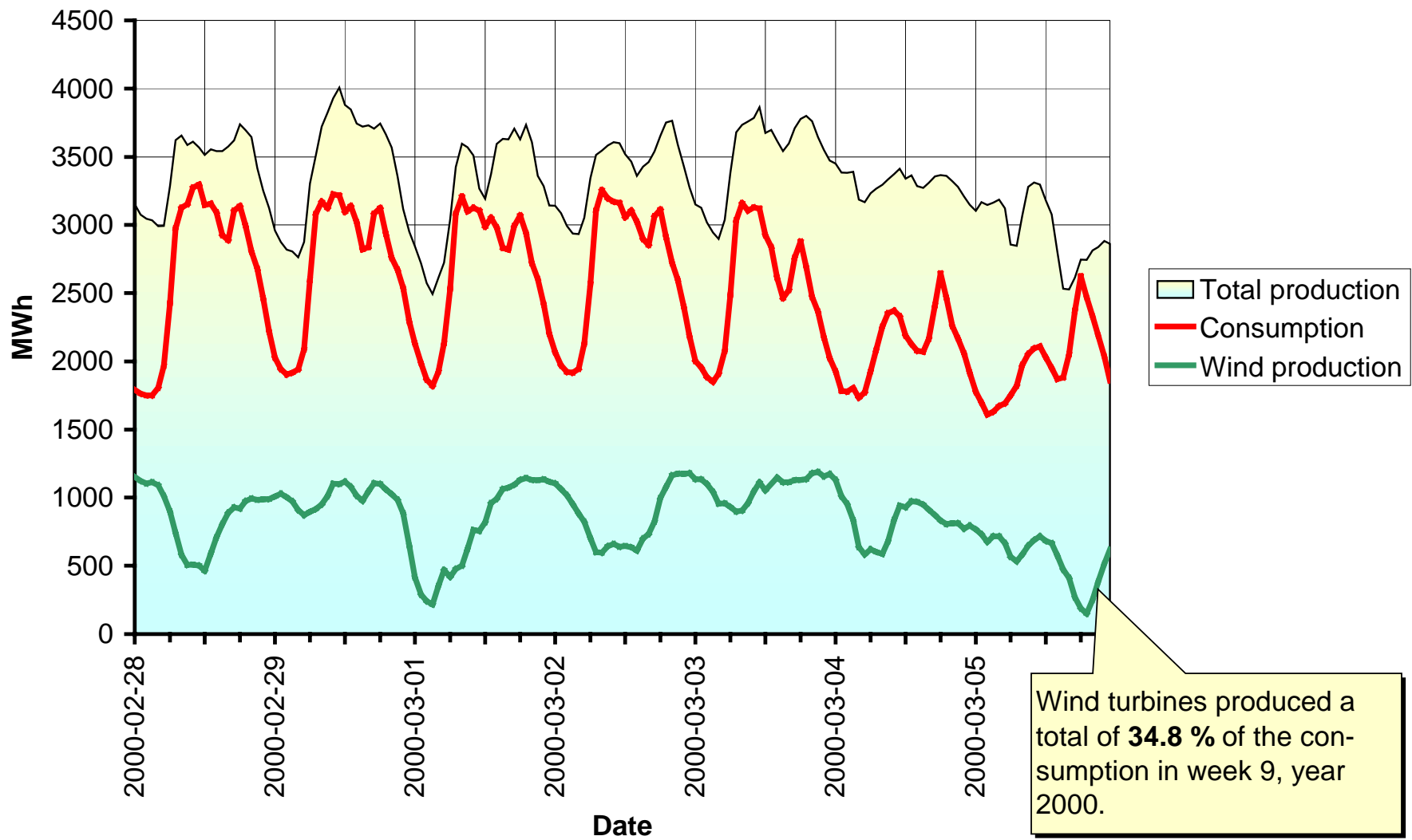
# Wind Power Production Year 2000



# Priority Production Year 2000



# Wind Power Production a Week in Year 2000

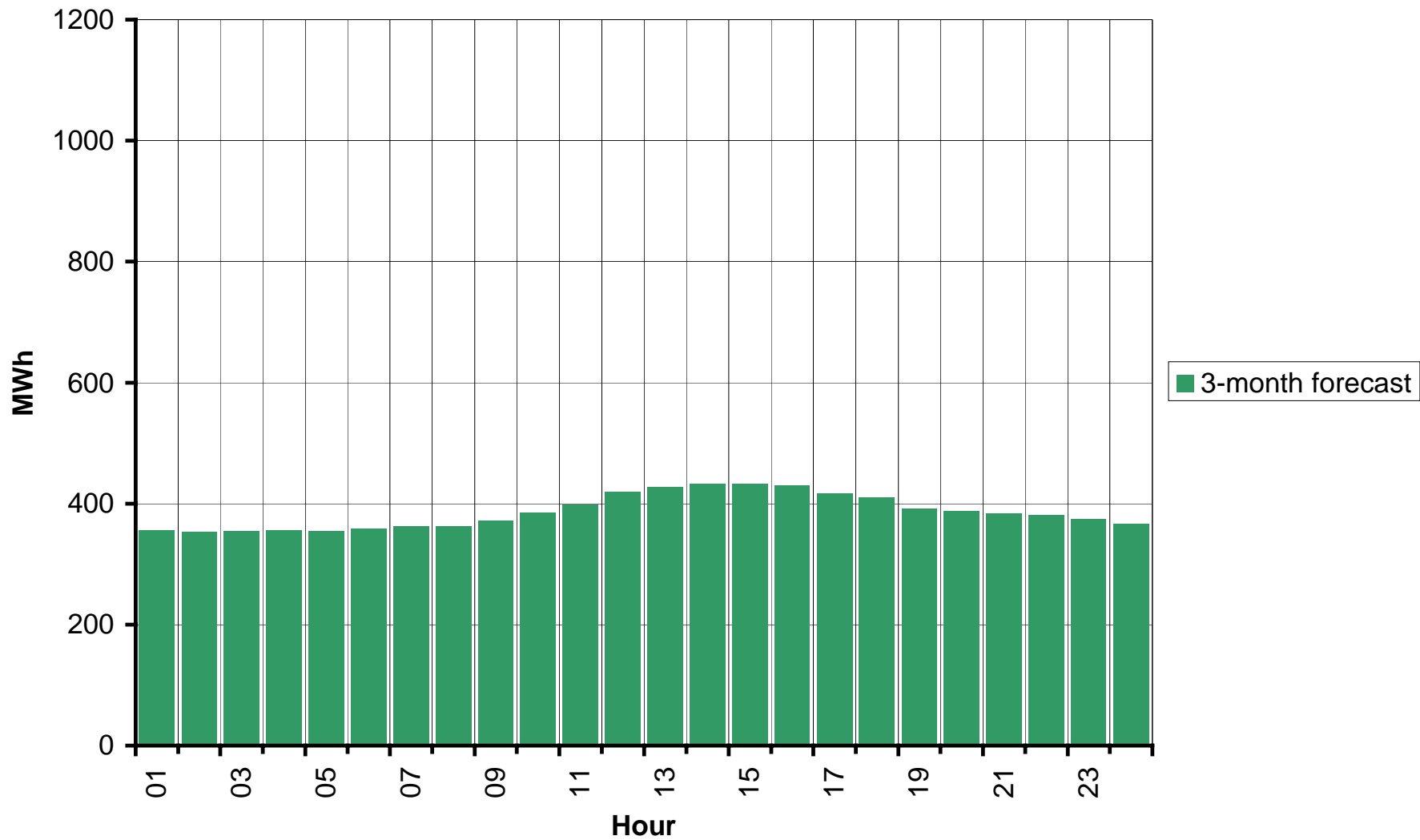


## Procedure for Daily Handling

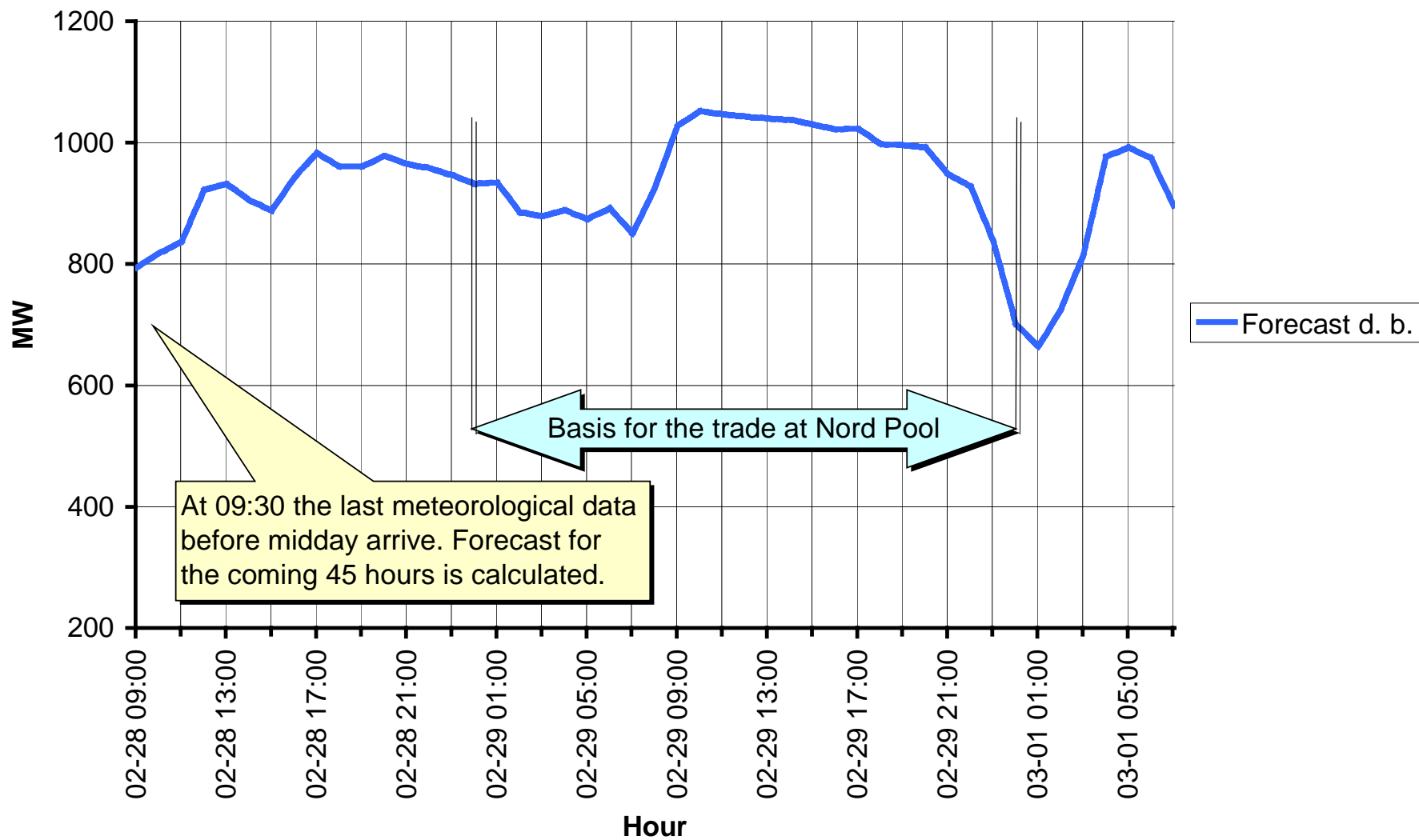
- **3 months before delivery Eltra publishes a forecast of prioritised production, on monthly basis in per cent of load.**
- **The day before delivery, Eltra makes a forecast for the next day's prioritised production and consumption.**
- **Difference between forecast made 3 months before delivery and forecast made the day before delivery is traded at Nord Pool before 12:00.**
- **Up to and in the operation period forecasts are continuously updated.**



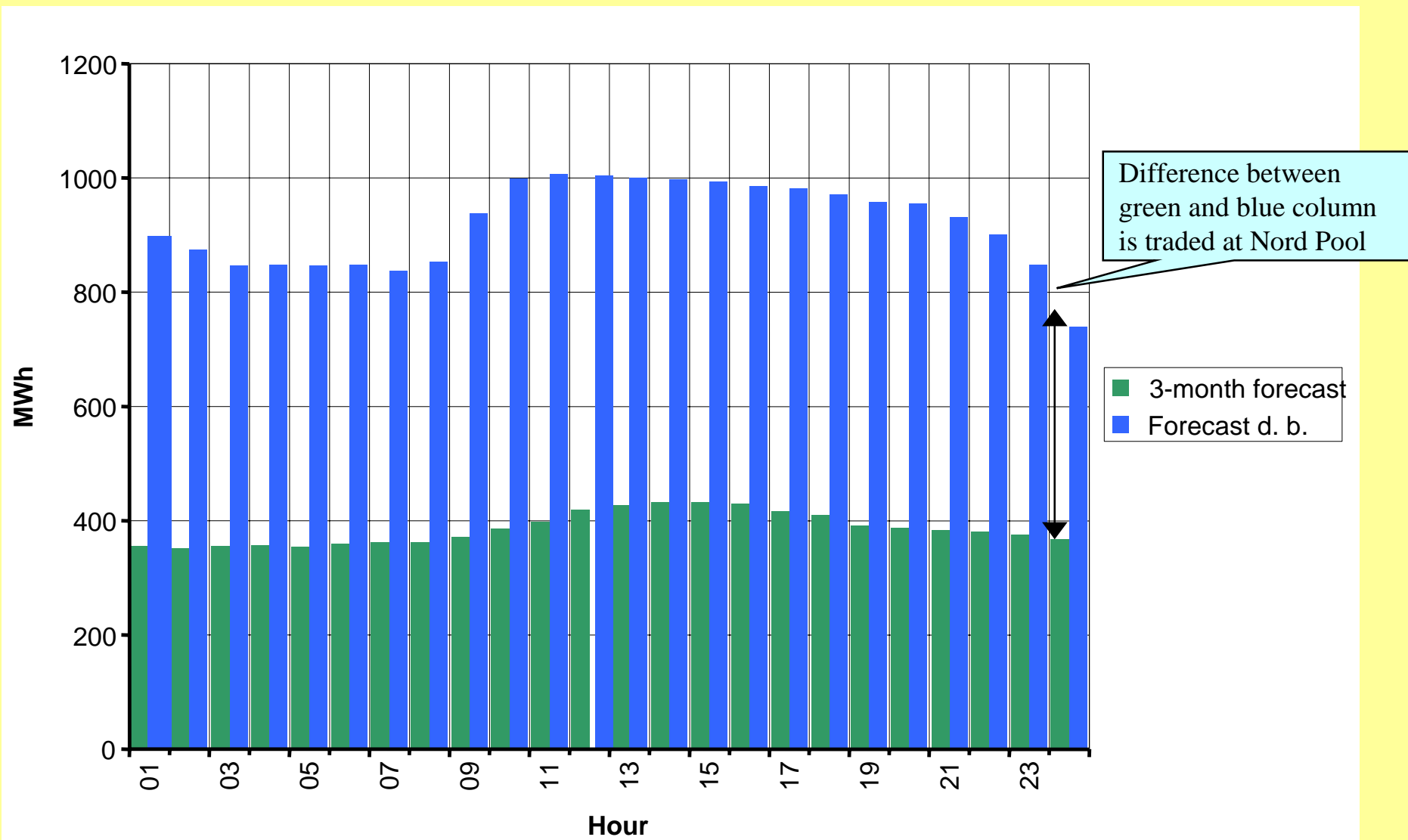
# Forecast Made 3 Months Before Delivery



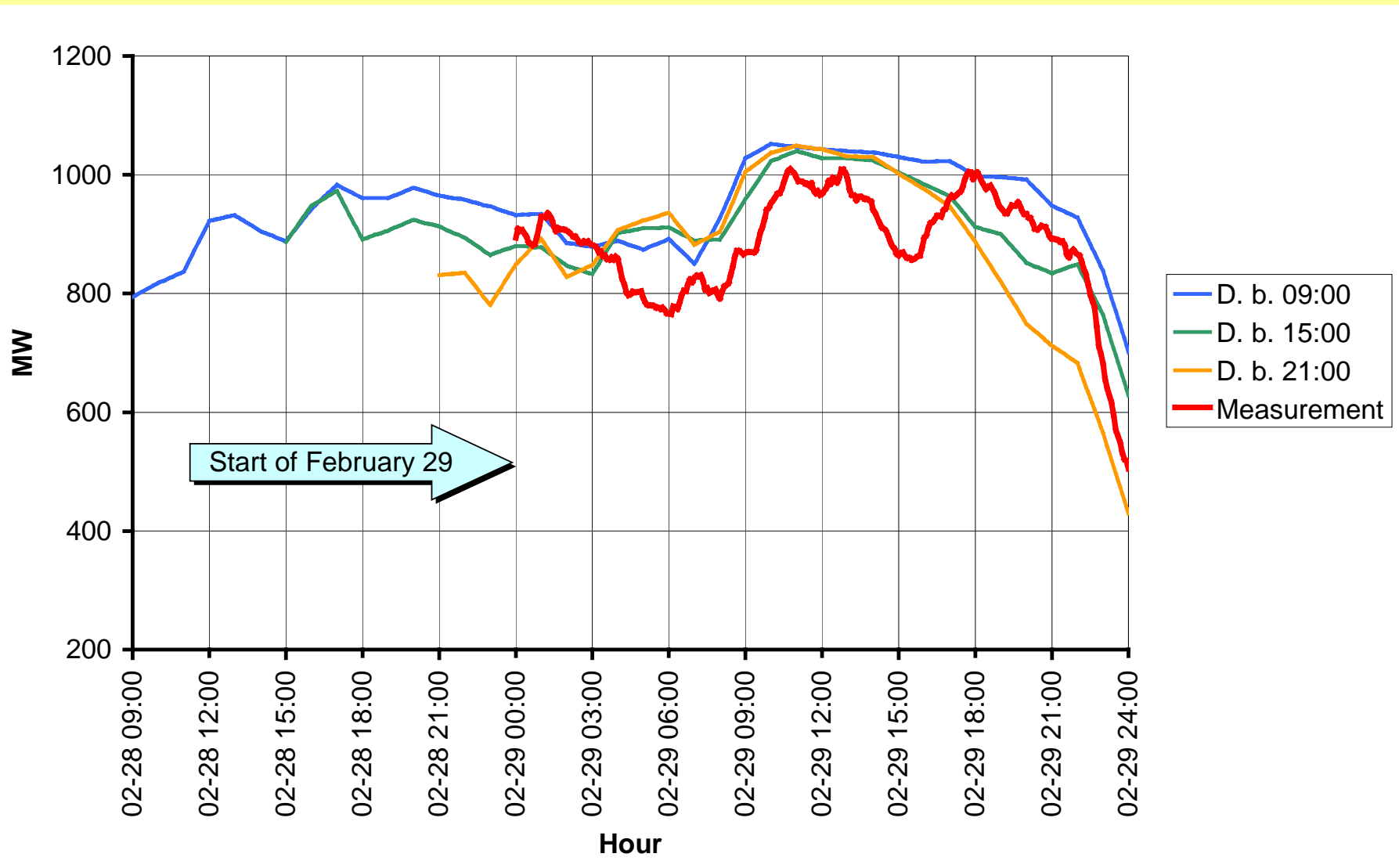
# Forecast the Day Before Delivery



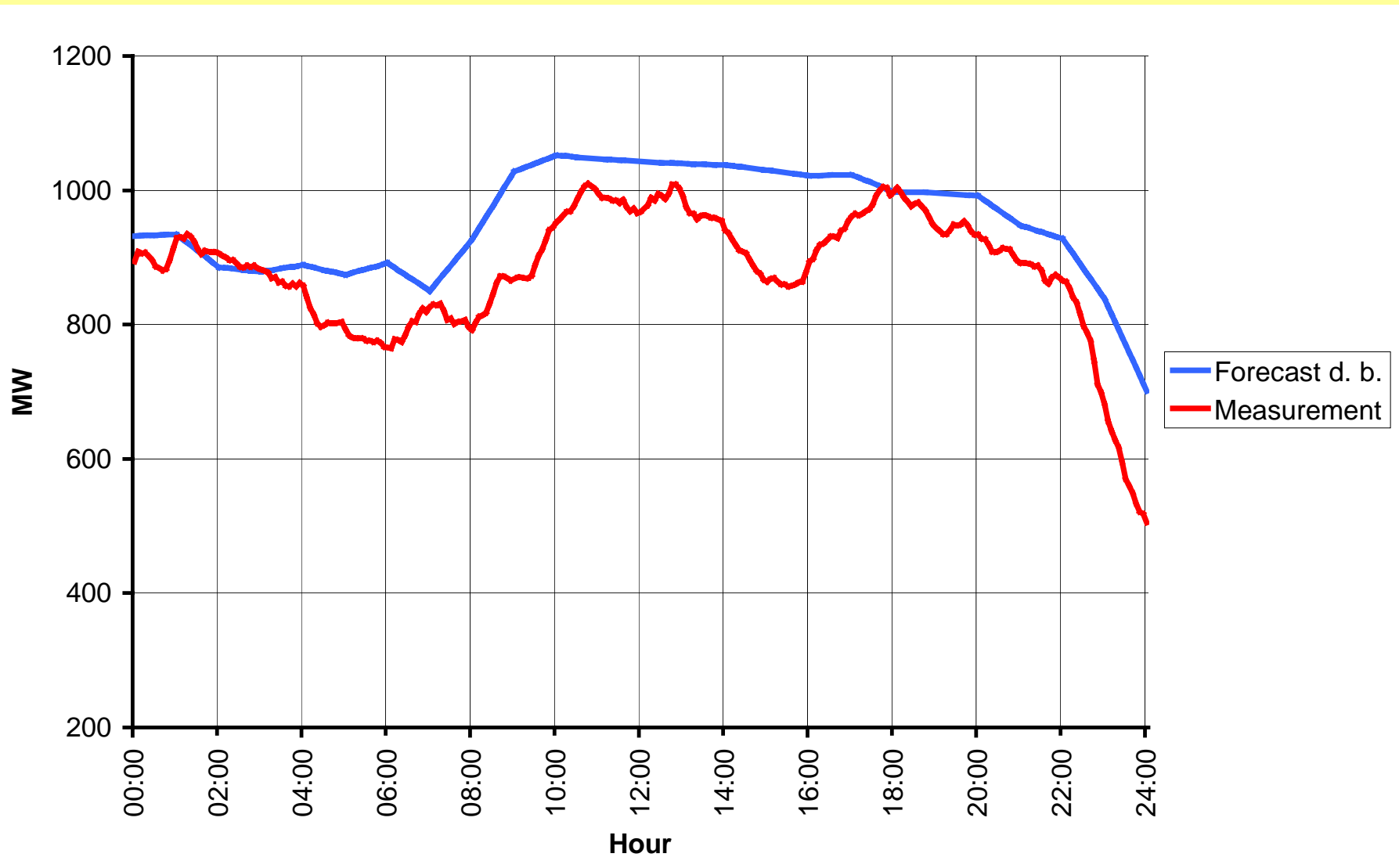
# Forecast Day Before Delivery and Nord Pool



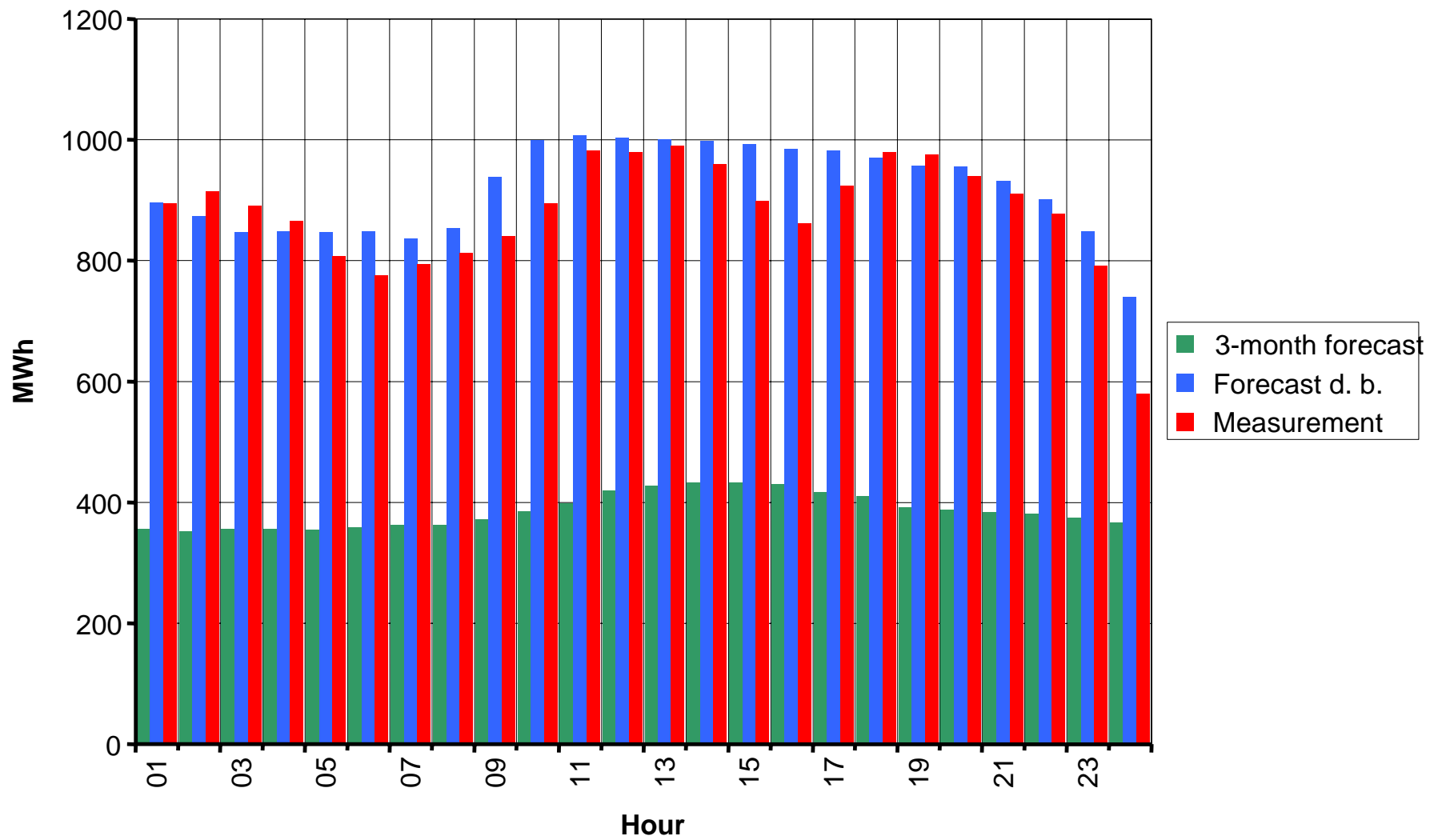
# Continuous Updating of Forecast



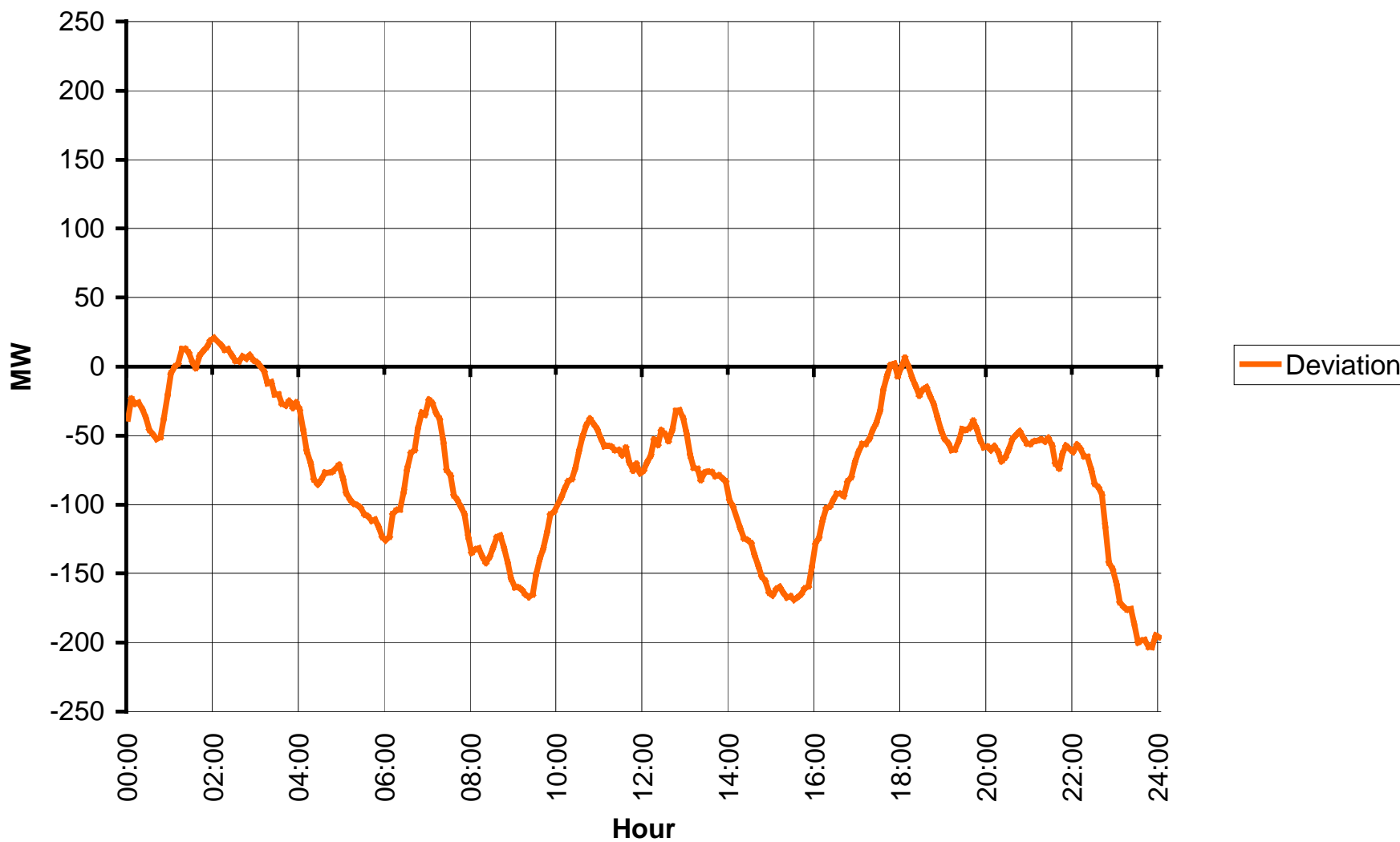
# Forecast and Measured Output



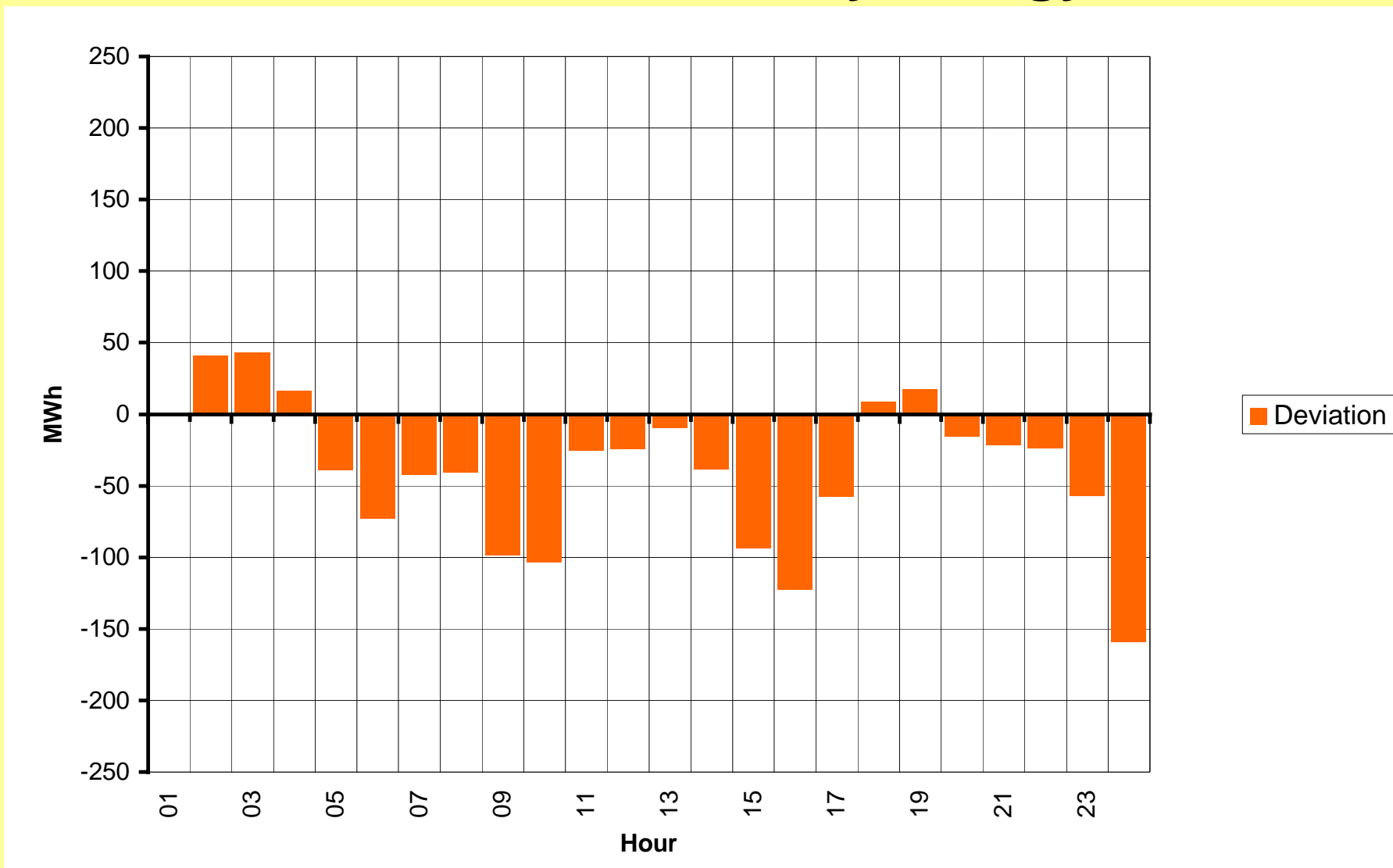
# Measured Production



# Deviation between Forecast and Measurement



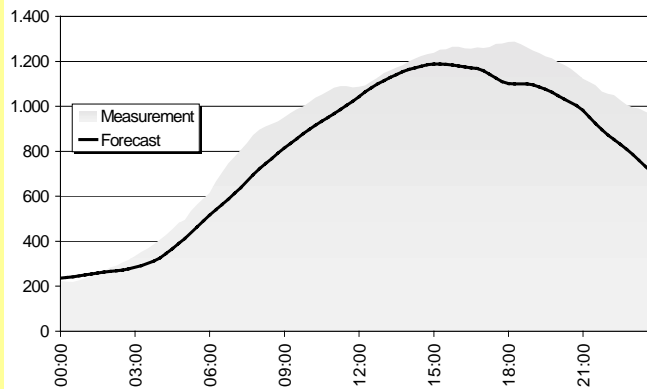
# Deviation as Hourly Energy



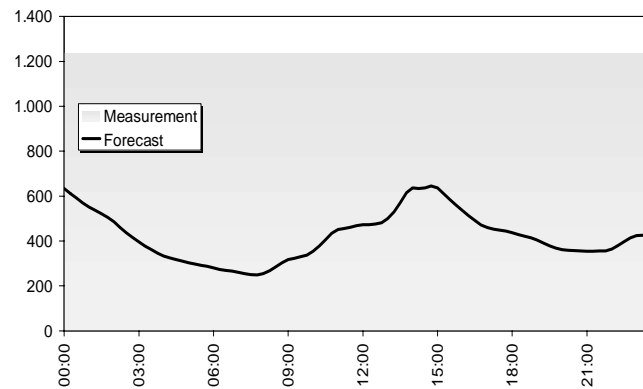


# Three Typical Cases Year 2000

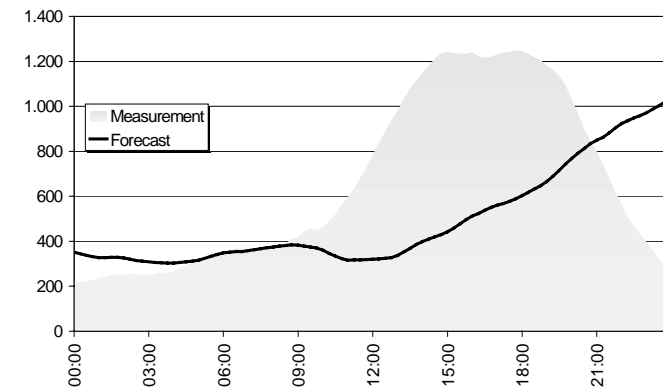
WMPP average quarter-hour power output 6 November 2000  
Forecast calculated 5 November at 11:00



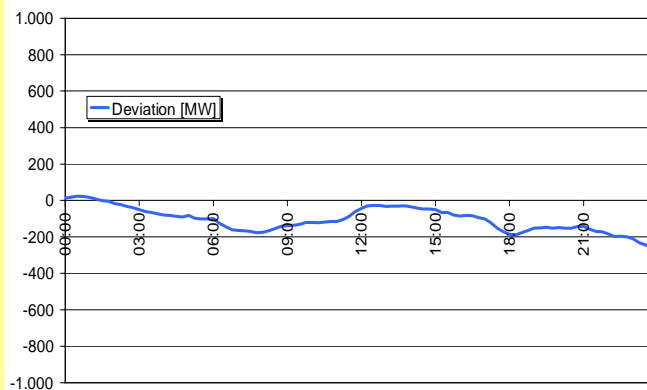
WMPP average quarter-hour power output 25 October 2000  
Forecast calculated 24 October at 11:00



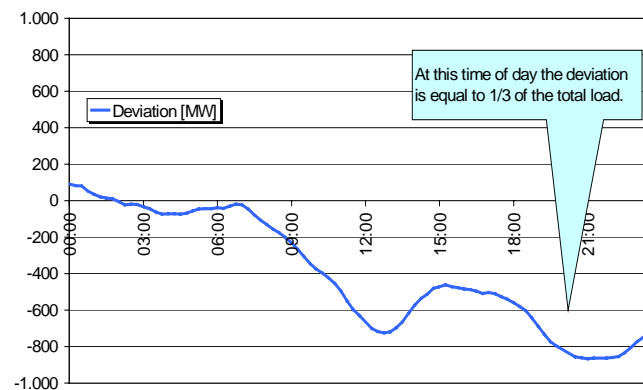
WMPP average quarter-hour power output 11 December 2000  
Forecast calculated 10 December at 11:00



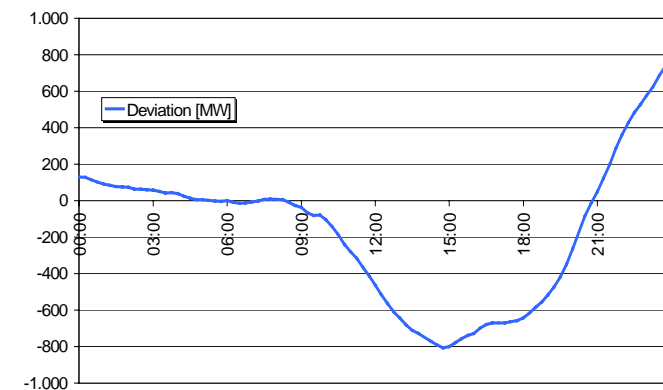
Deviation = (Forecast calculated 5 November at 11:00) - (Measurement)



Deviation = (Forecast calculated 24 October at 11:00) - (Measurement)

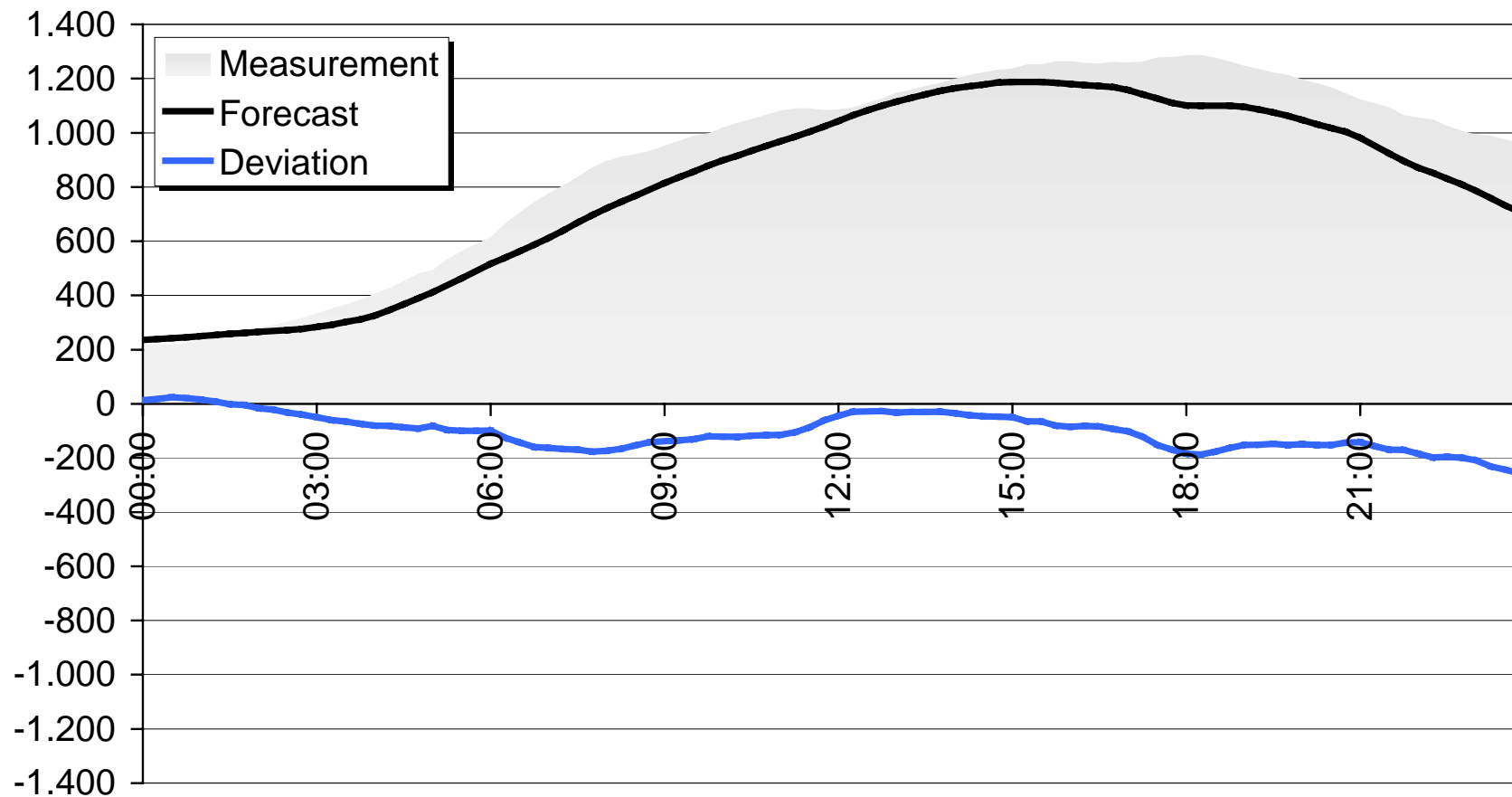


Deviation = (Forecast calculated 10 December at 11:00) - (Measurement)



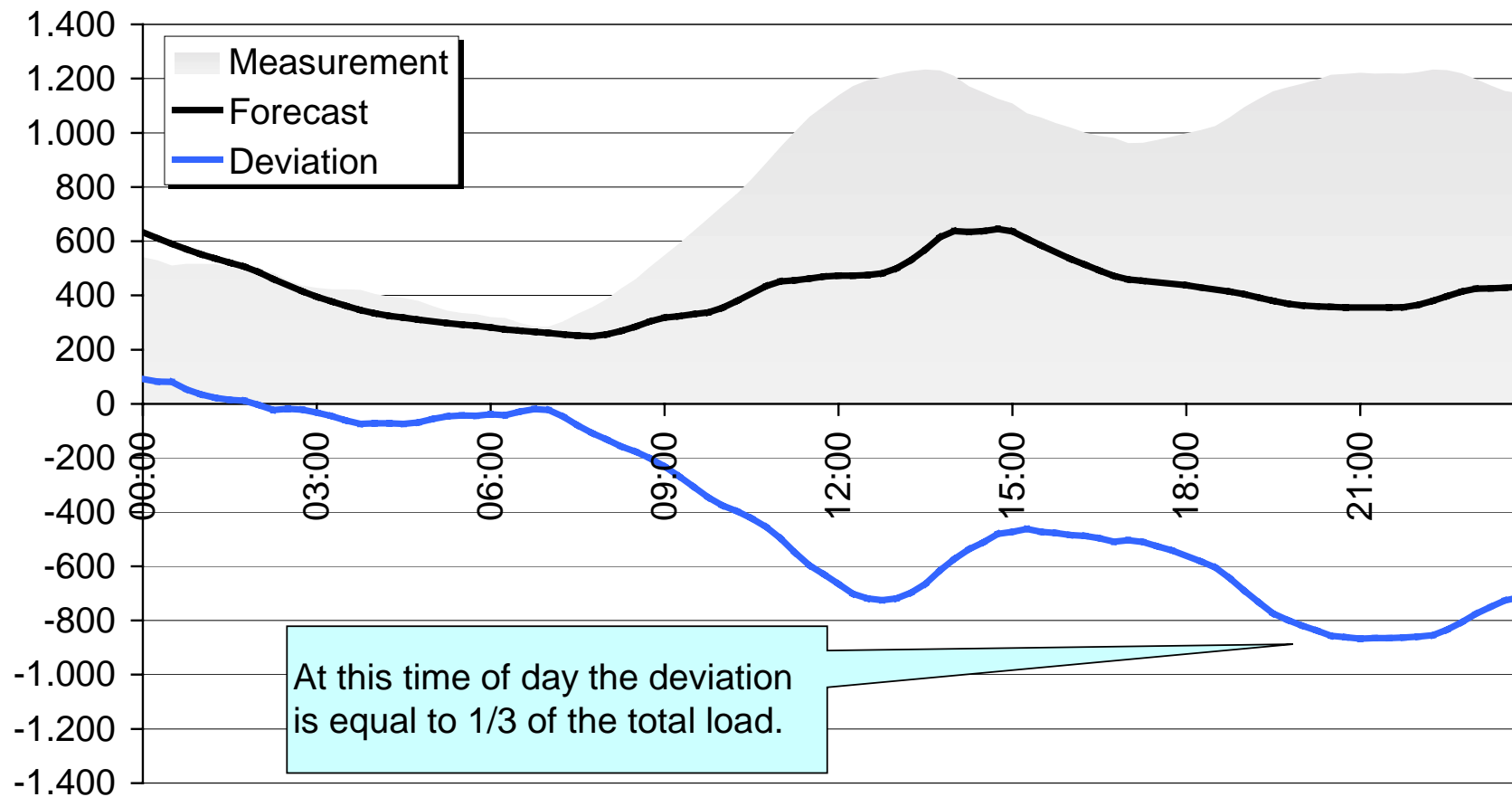
# The Good Case

WMPP average quarter-hour power output 6 November 2000  
 Forecast calculated 5 November at 11:00



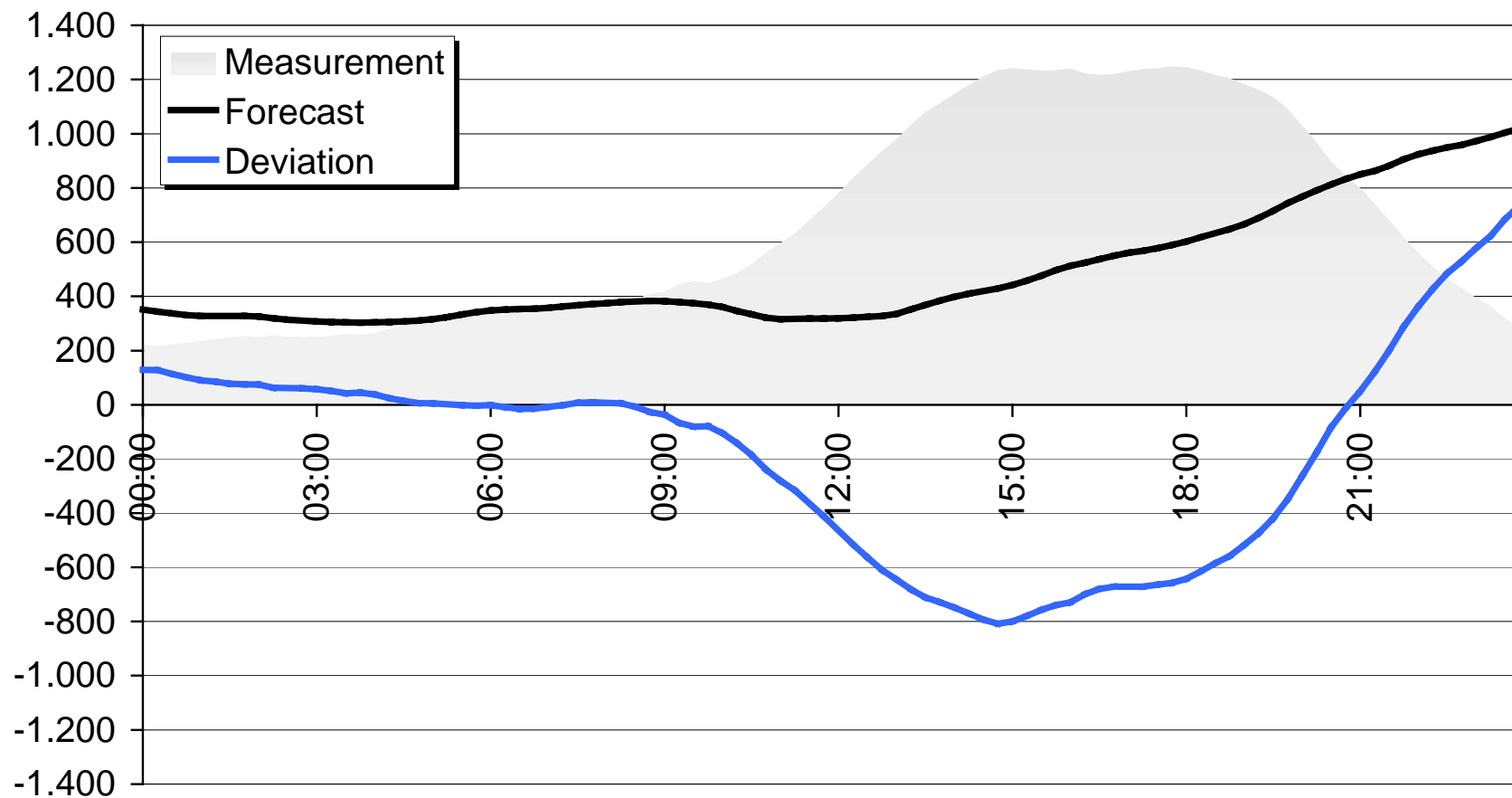
# The Bad Case

WMPP average quarter-hour power output 25 October 2000  
Forecast calculated 24 October at 11:00



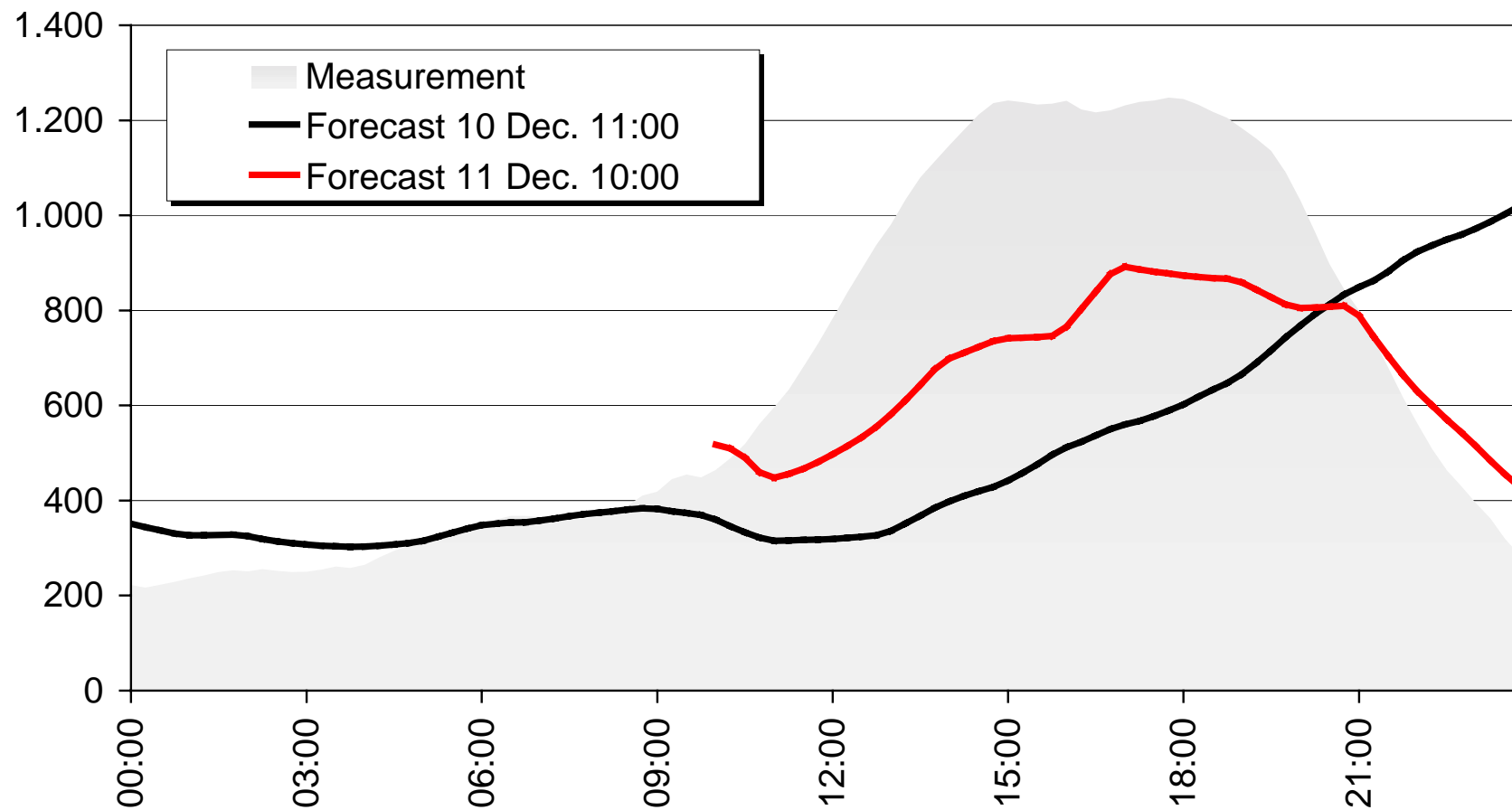
# The Ugly Case

WMPP average quarter-hour power output 11 December 2000  
Forecast calculated 10 December at 11:00



# Why Ugly ?

WMPP average quarter-hour power output 11 December 2000  
 Forecast calculated 10 December at 11:00 and 11 December at 10:00



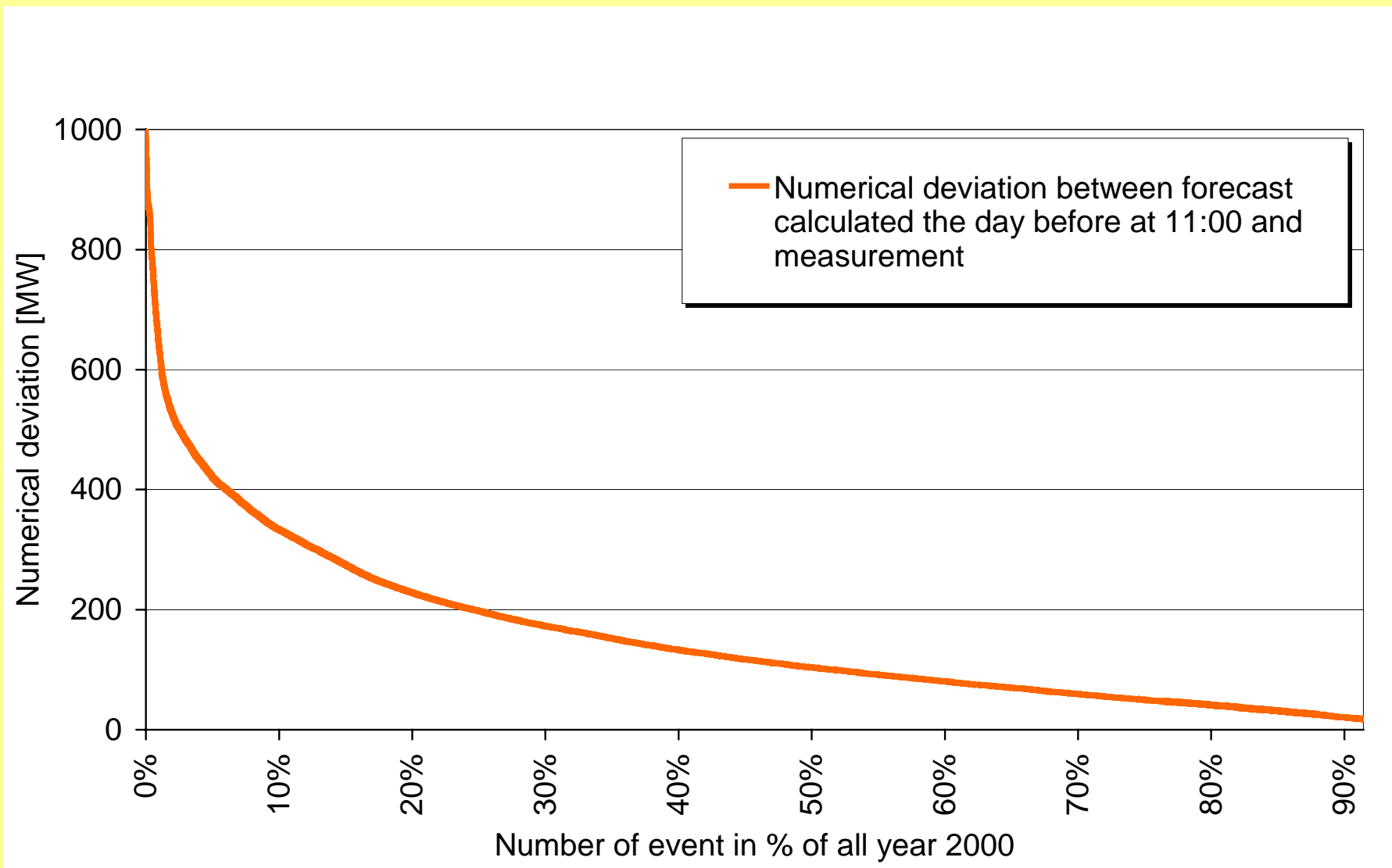
## Forecast Statistics Year 2000

- **Energy**

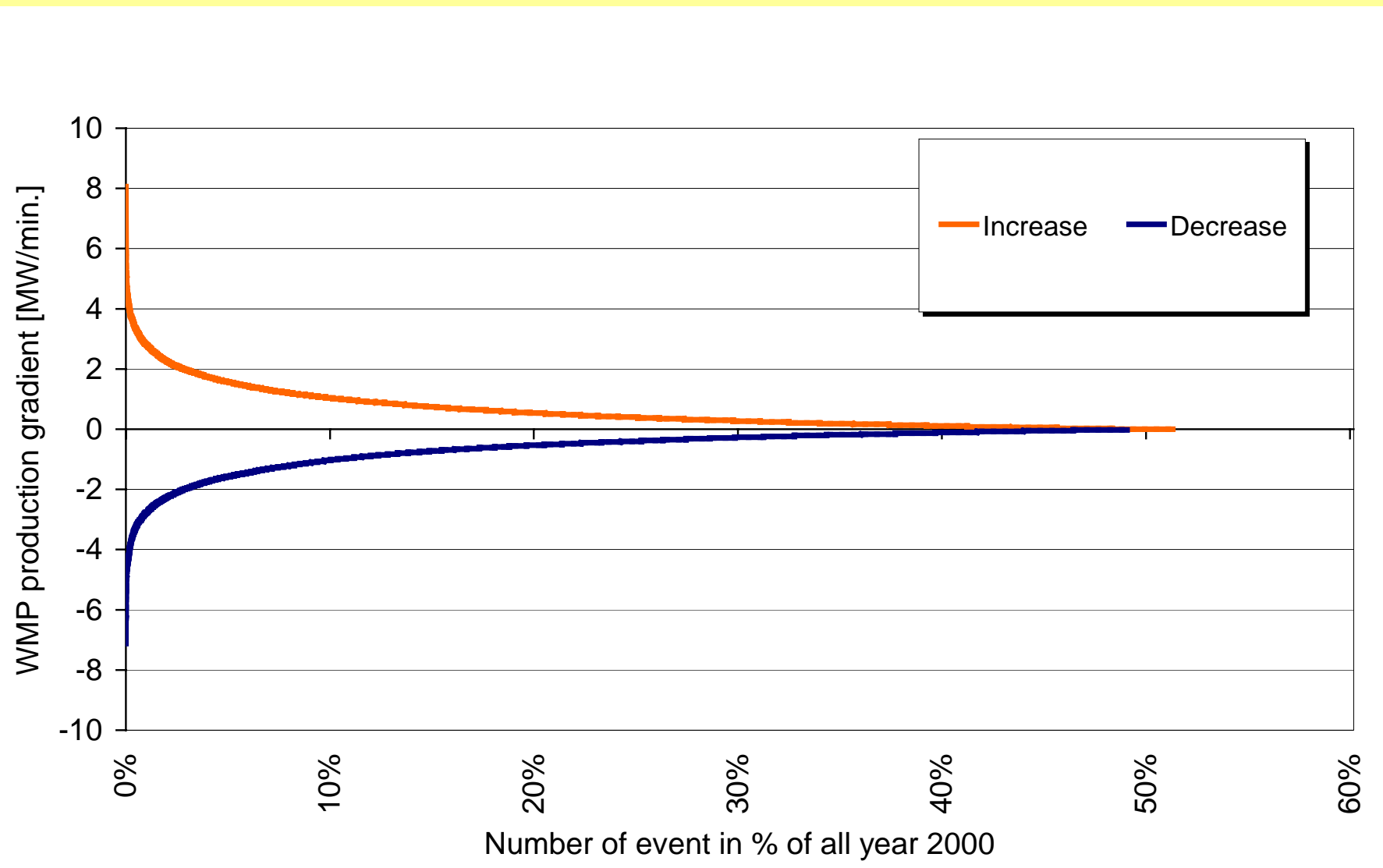
<b>Total produced Wind Power</b>	<b>3.4 TWh</b>
<b>Total numerical deviation (d.b)</b>	<b>1.3 TWh</b>
- **Power**

<b>Average output</b>	<b>385 MW</b>
<b>Average error (d.b.)</b>	<b>148 MW</b>
- **Error i per-cent** **approximately 38 %**

# Forecast Wind Power Year 2000



# WMP Production Gradient





## System Limits !?

**At any given time:**

- **Installed WMP Cap.  $\leq$  Total load + export capacity ?**
  - How to control Load
  - Capacity to Neighbouring Systems
  - Spinning reserve
  - Storage
  - Short Circuit Capacity

## Items to be covered.

- About Eltra
- The Danish action plan for renewable energy
- The Nordic electricity market
- Daily handling of wind power in the Eltra area
- **Wind power integration using energy storage**

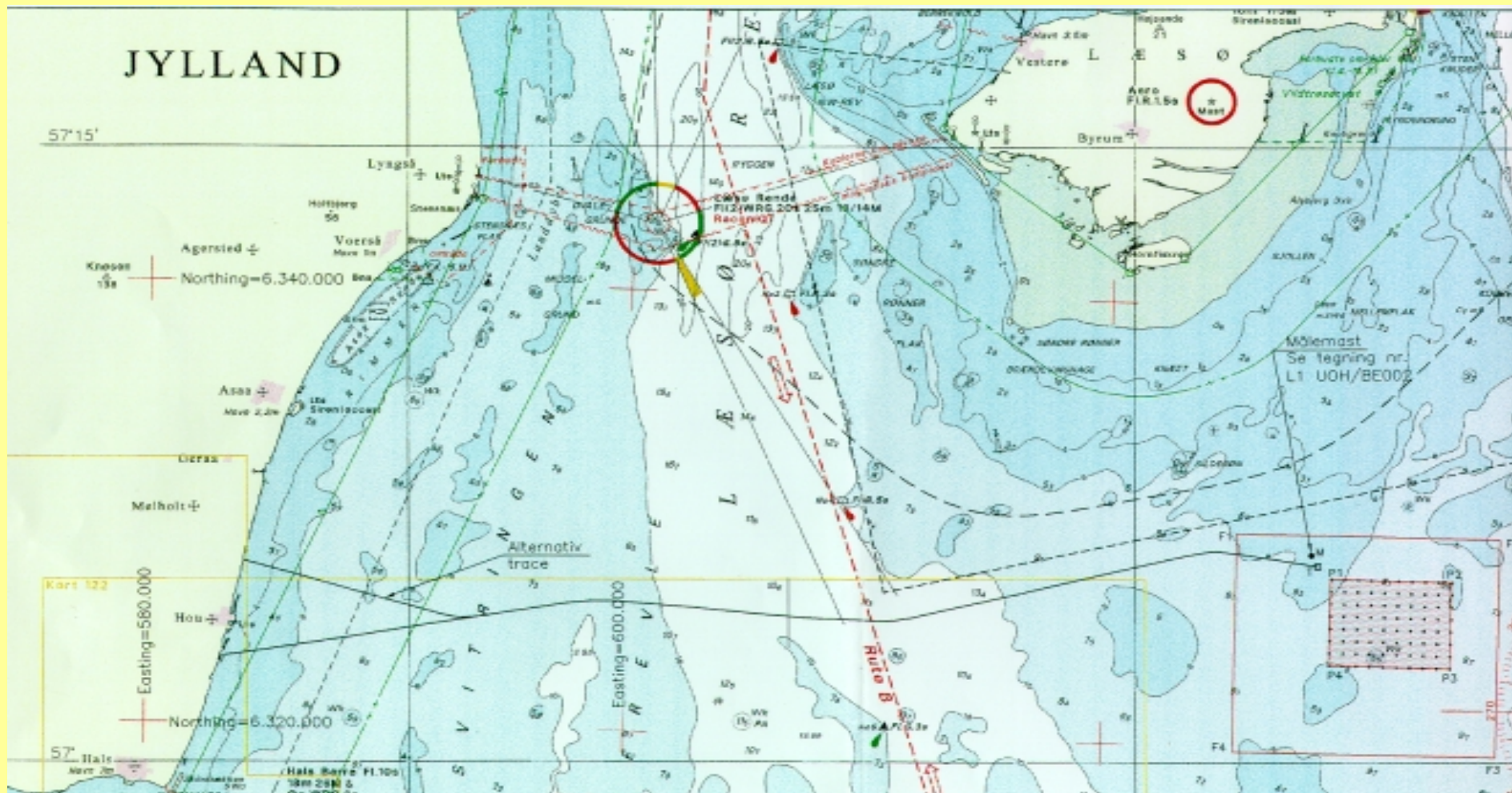
# Offshore Wind Power Plant

- **Power/frequency control**
- **Reactive power / voltage control**
- **Good transient capability**
- **Good output power quality**

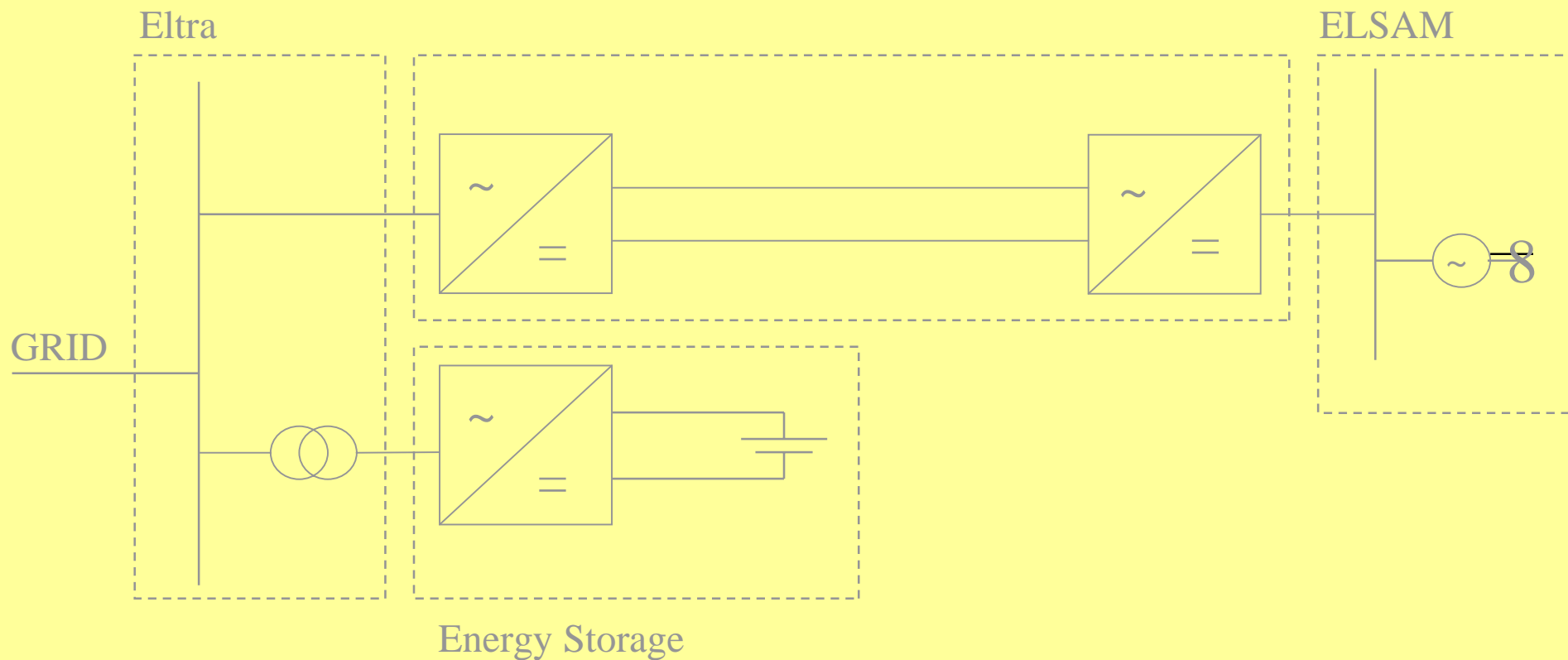
# Integration of Wind Power using Energy Storage

- Regulating power
- "Spinning reserve"
- Start of black network
- Power / frequency control
- Reactive power / voltage control
- Providing short circuit power
- Network stabilisation
- System damping
- System support at contingencies

# Læsø Syd Offshore Site

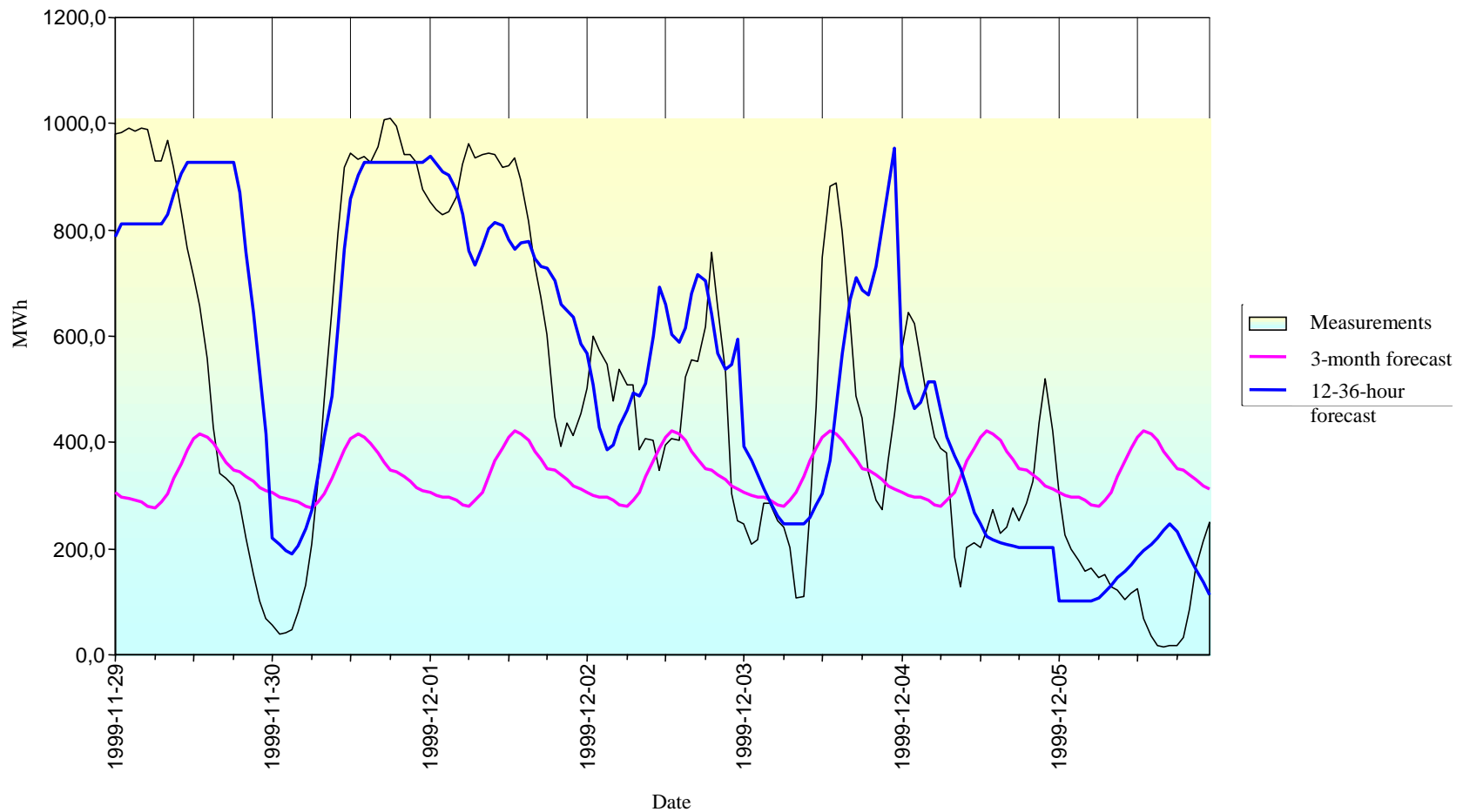


# Læsø Syd, HVDC-VSC and Energy Storage

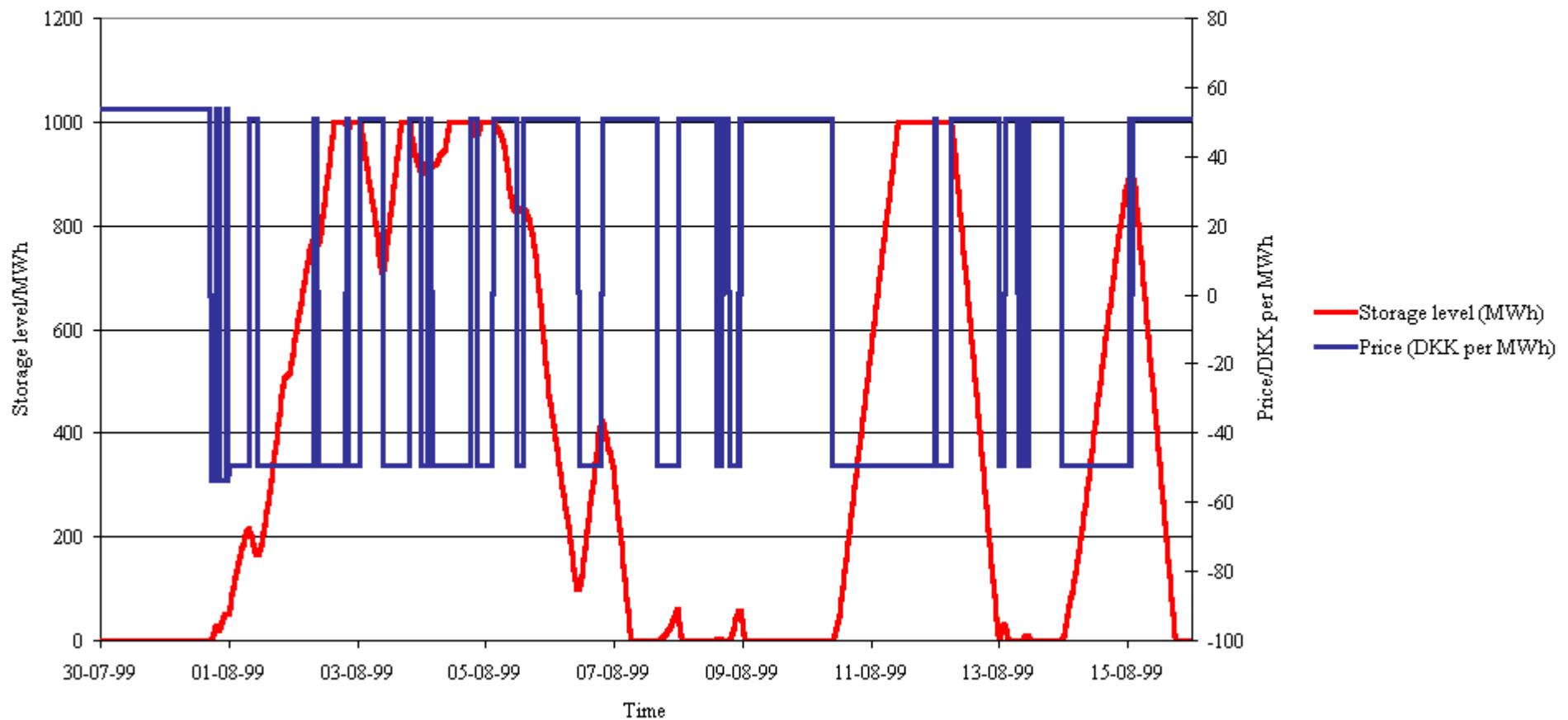


# Wind power production

## Forecasts and measurements

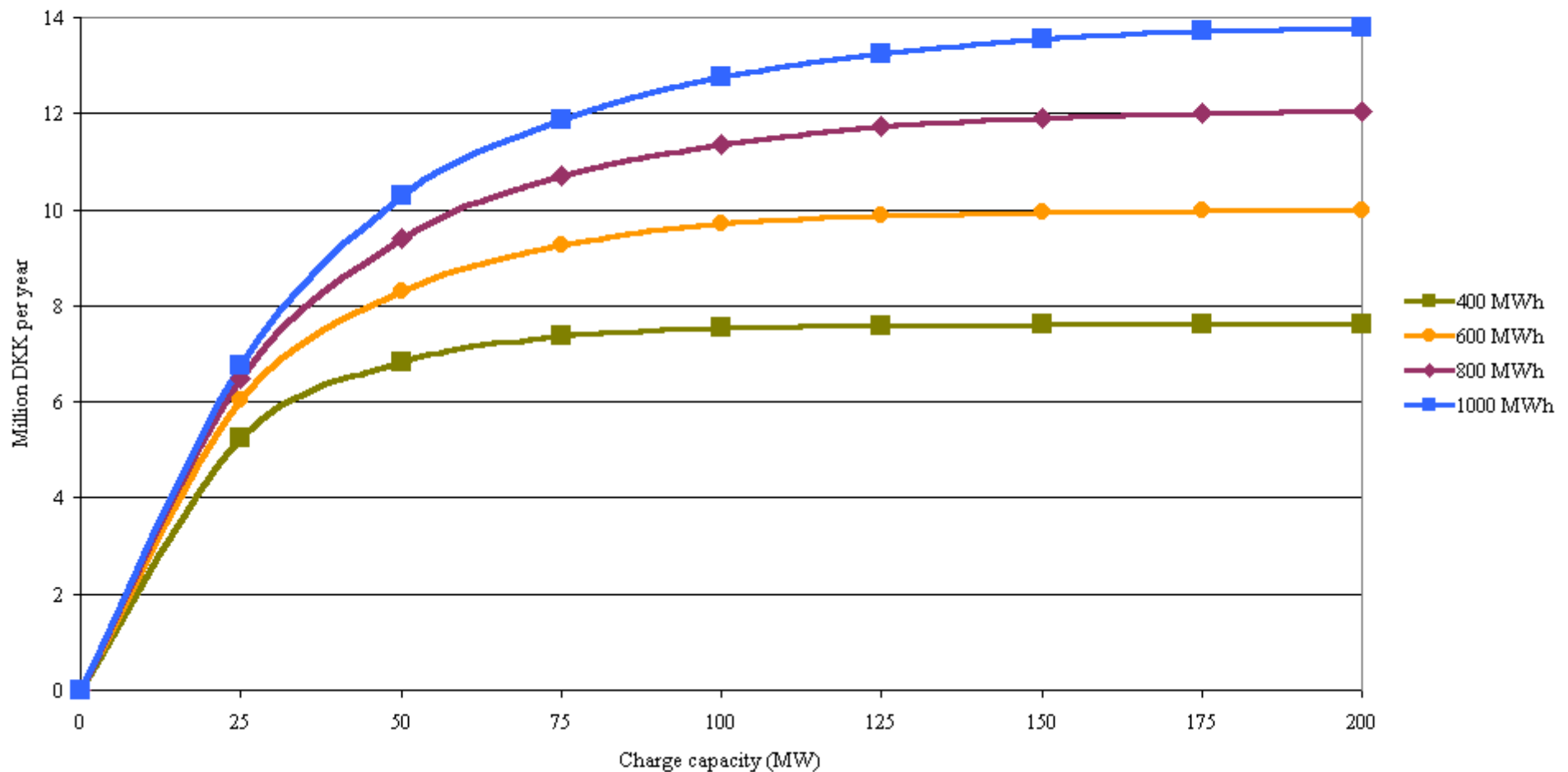


Operation of storage  
 Real-time imbalance prices: 1999-2000  
 Storage capacity: 1000 MWh; Charge capacity: 50 MW

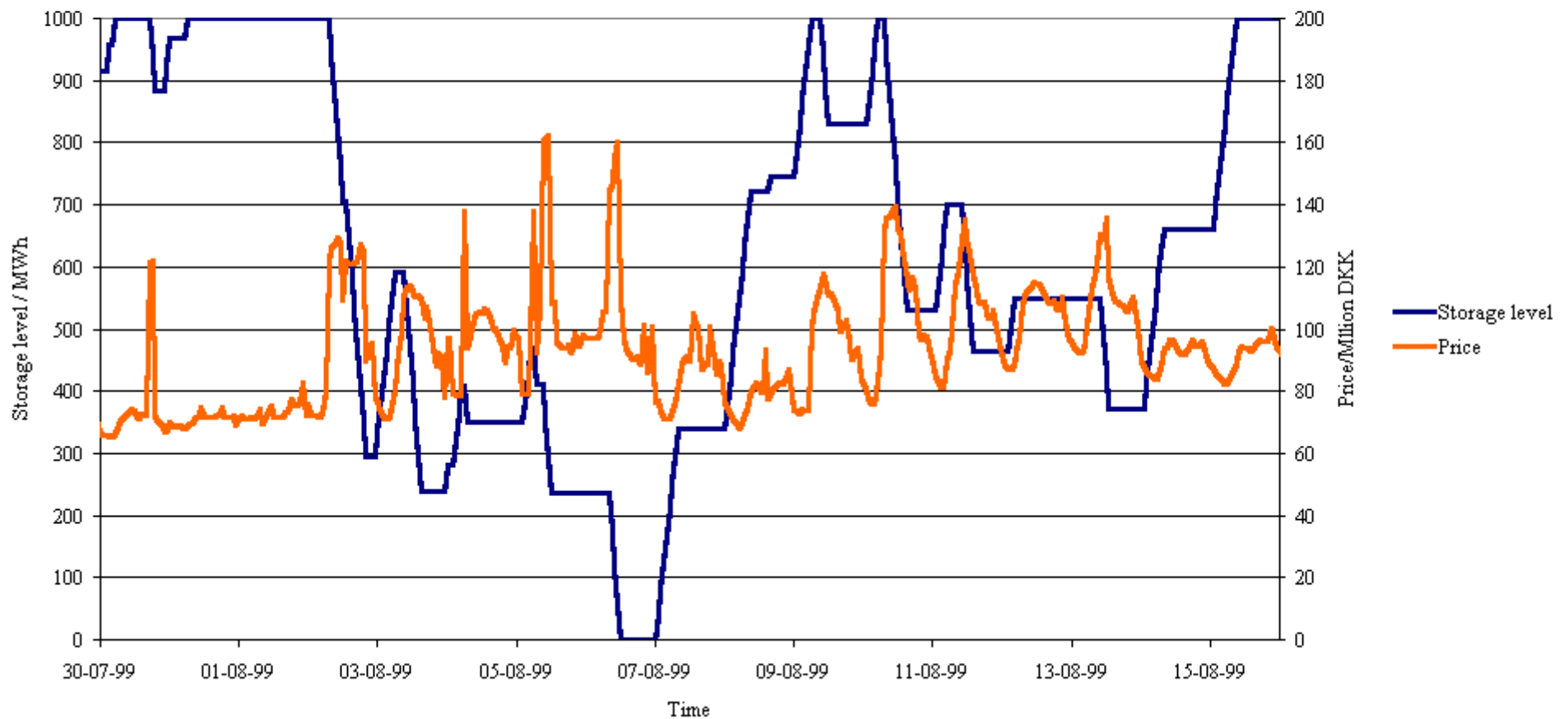




## System value of electricity storage in the real-time imbalance market Real-time imbalance power prices (1999-2000 ) Odense

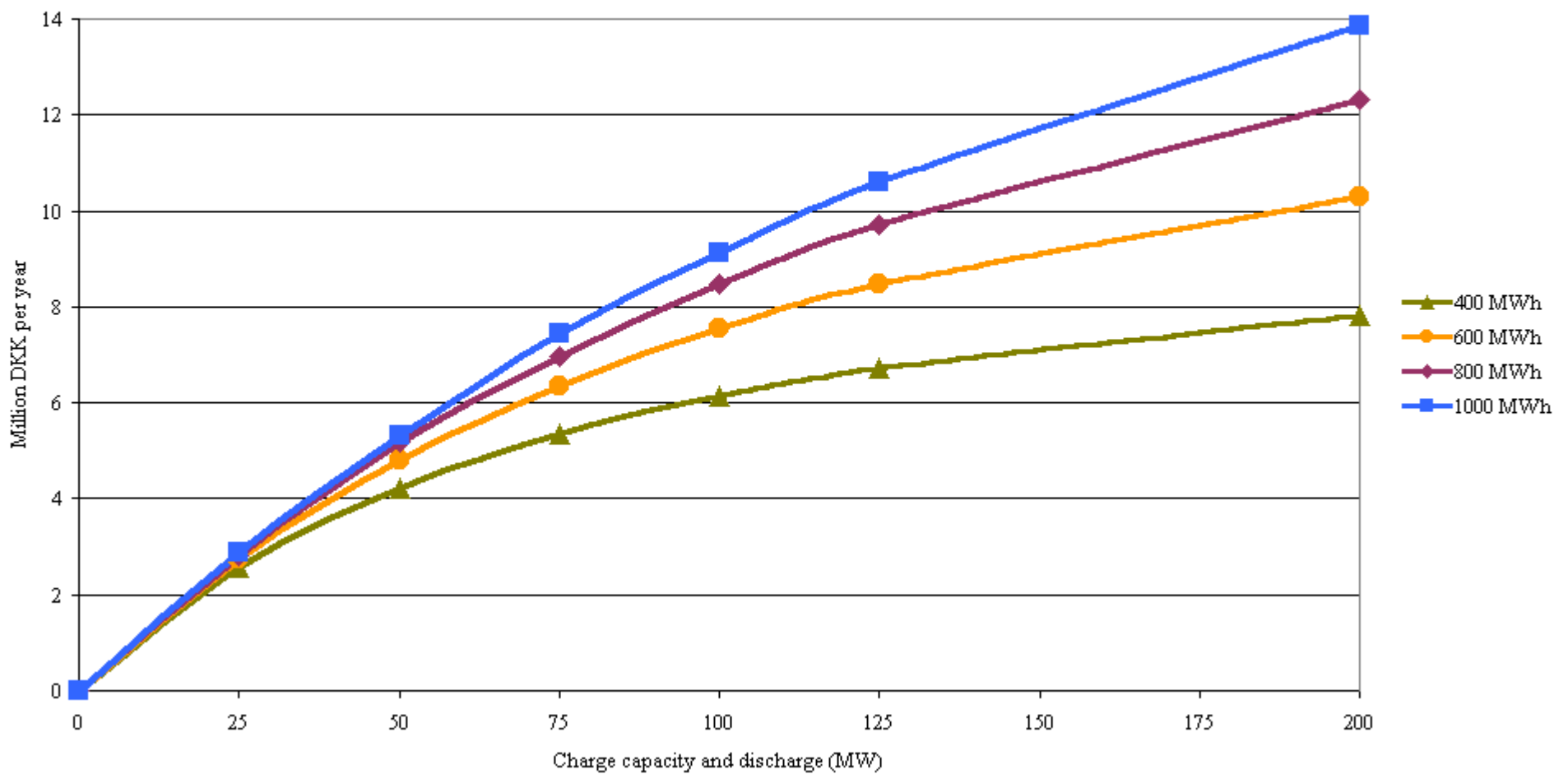


Operation of storage  
 Spot market prices: Odense 1999-2000  
 Storage capacity: 1000 MWh; Charge capacity: 50 MW

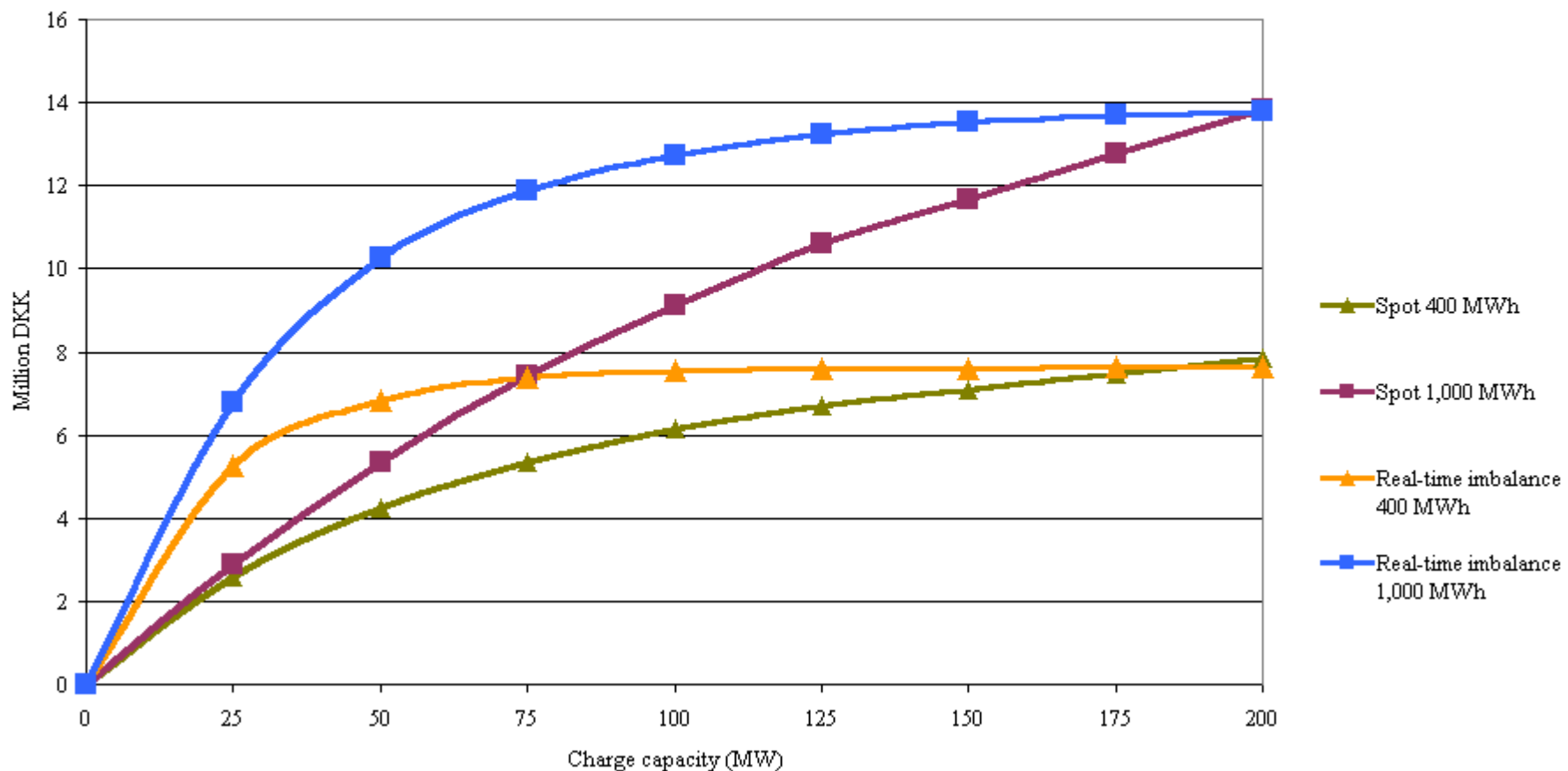


## System value (upper limit) of electricity storage in spot market

### Spot market prices: Odense, 1999-2000



Comparison of electricity storage value in the spot market and real-time imbalance market, respectively (400 and 1,000 MWh)  
 Spot and real-time imbalance power prices (1999-2000), Odense



## Feasibility study

- Technical description
- Economy
- Environmental issue
- Practical Experiences from Existing Plants
- Potential for Technical Improvements
- Technical System Services
- Modelling and System Studies
- System Value of Energy Storage
- Planning of Demonstration Plant

## Key figures for a Demonstration Plant

- **Power and Storage Capacity MW / MWh**
- **Turnaround efficiency - Loss at charge and recharge**
- **Availability**
- **Power Density**
- **Environmental Issues**
- **Economy**
  - Installation costs
  - Maintenance costs
  - Operational costs
  - Market value and value of system services

## Summary

- The wind power capacity today is 1882 MW (160 % of min. Load)
- Expected wind power capacity year 2004 is 2542 MW
- Today the daily handling of wind power is extremely difficulty
- Average need for regulating power is 148 MW
- Strong connections to neighbouring countries is a necessity
- The need for a big energy storage plant is obviously
- A feasibility study will be accomplished this year
- A 10 MW/200 MWh energy storage plant is considered



**eltra**

*Thank you for your attention*