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Klinge Jacobsen, Henrik

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Renewables in power markets

Henrik Klinge Jacobsen
Technical University of Denmark
Energy Systems Analysis

Tartu University
June 5, 2014

Content:

Background – Renewables: Why is fluctuating/intermittent generation an issue in Denmark

Power markets

- Short term marginal costs
- Day ahead power markets
- Average prices
- Price volatility
- Renewable generator revenues
- Interaction with other technologies

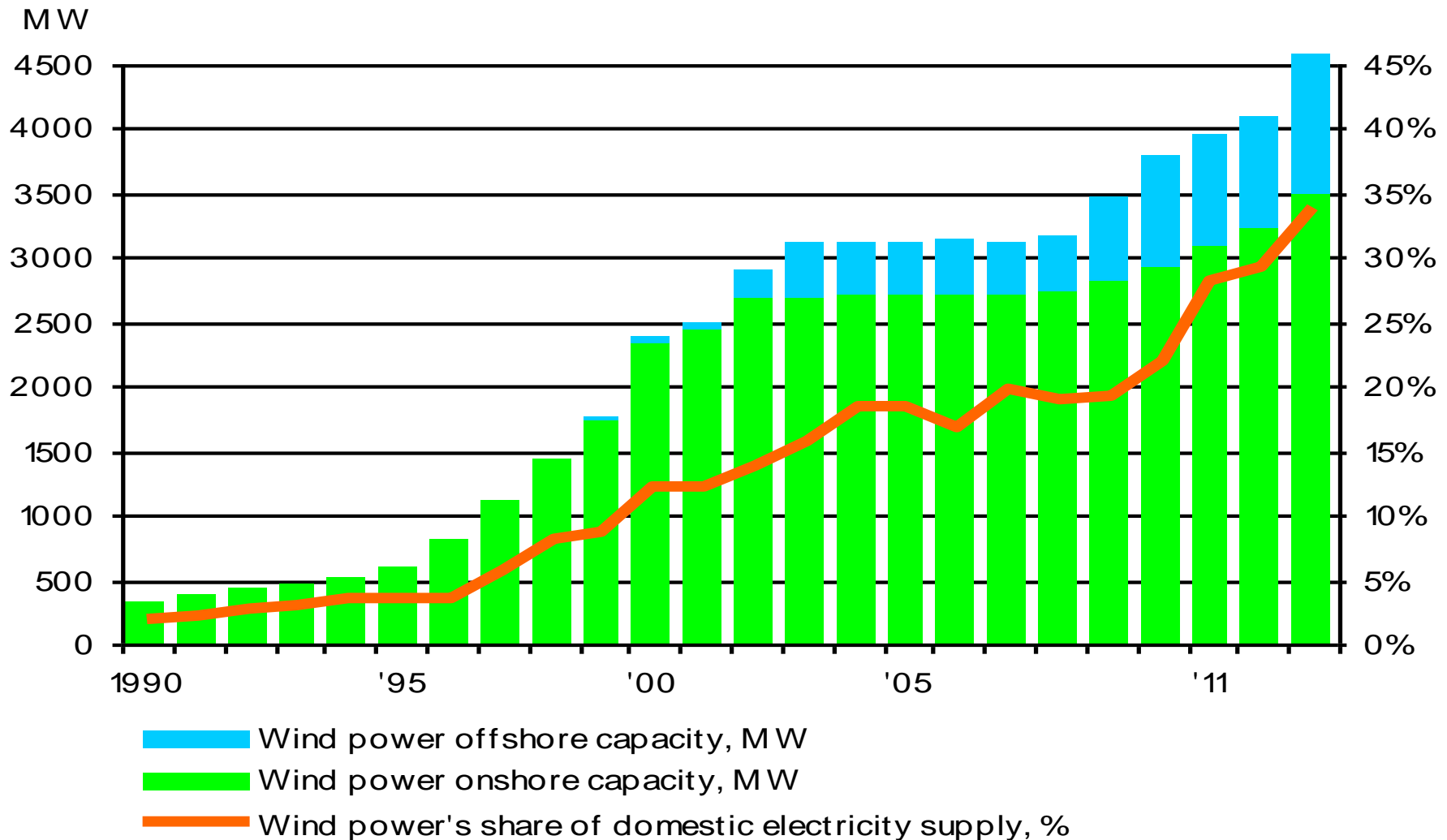
Long term effects on markets and investment incentives

- Support distort the market investment signals?
- The challenge: Does lower market price mean that more capacity is **not** needed?

A price curiosity?

- Negative prices - yes - can be providing correct incentives (solution) for short term dispatch
- A challenge that renewables receive production support

Development of wind power in Denmark and its effect on power prices



Background – Why is fluctuating renewable generation an issue in Denmark



Power markets: should provide correct signals to both producers and consumers - efficient allocation of generation among producers and investment in the system-wise least cost technologies

Renewables:

- Characterised by low variable and high fixed costs (wind, PV, Wawe, CSP etc)
- Day ahead power markets with hourly bids in common market, (uncertainty)
- Renewables supported by primarily production based support (feed-in tariffs or premiums)
- Average prices affected by adding capacity (short term)
- Price volatility - affected
- Renewable generator (market)revenues lower than average generater
- Interaction with other technologies - depends on system characteristics
- Support distort the market investment signals?

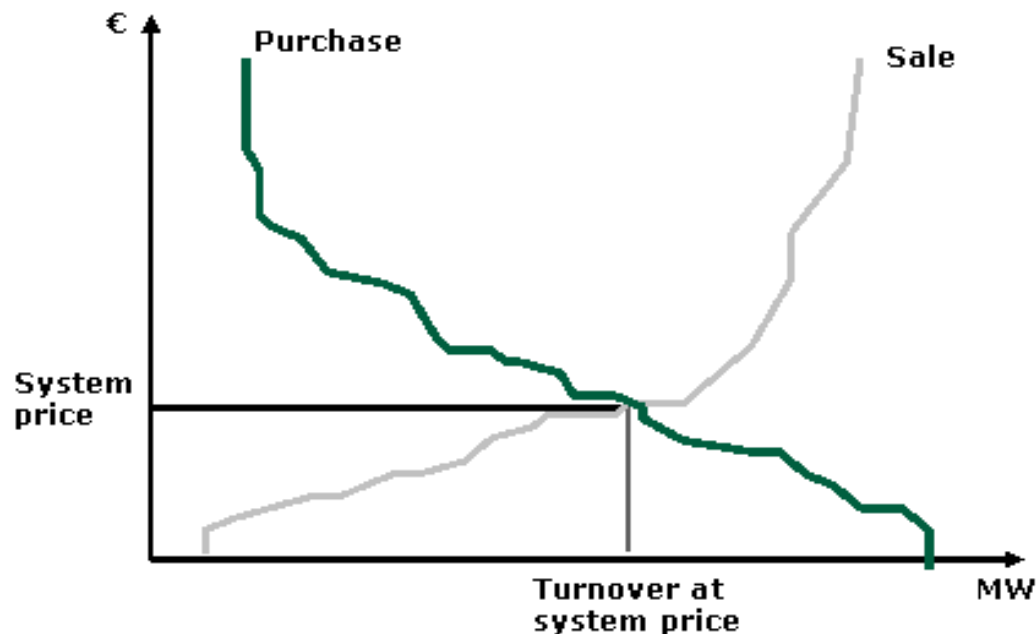
Denmark have a politically agreed target for reaching a fossil fuel free energy consumption in the year 2050

**Wind energy is relatively cheap and will be a main contributor to this development
Target for 2020 is 50% of total electricity**



Electricity markets: standard supply and demand

- Day ahead markets: 24 periods of 1 hour from 12 midnight the same day to 12 midnight the following day
- Buyers and sellers bid *stepped curves* based on their short term marginal costs
- A marketplace clears the market at 12 noon and instruct generators to follow the corresponding generation plan the following day - area prices dependent on transmission constraints

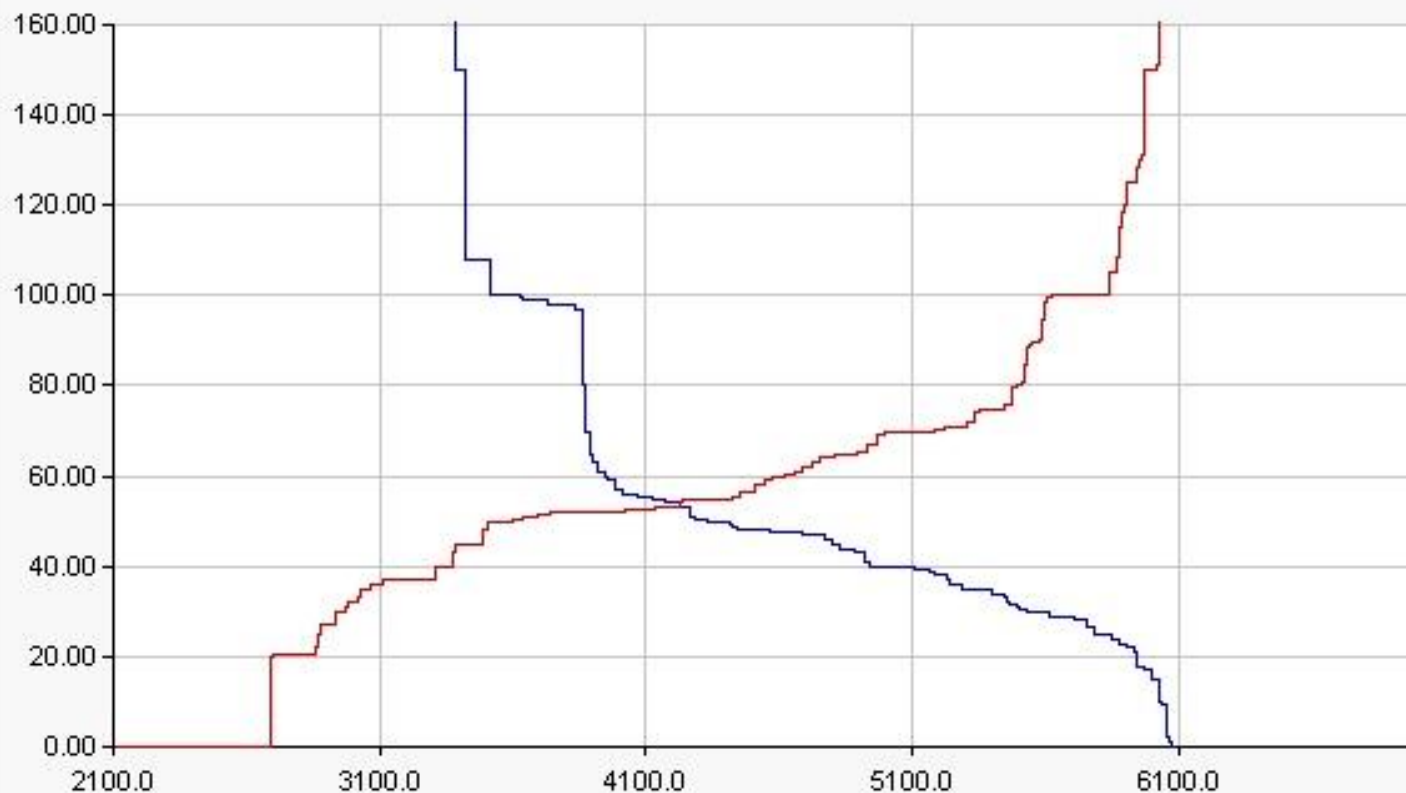


Nordpool homepage/NASDAQ

AGGREGATED CURVES

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 Zoom

Applying date:23-10-2009 Hour:07 MCV:4230.3 MWh MCP: 53.46 Euro



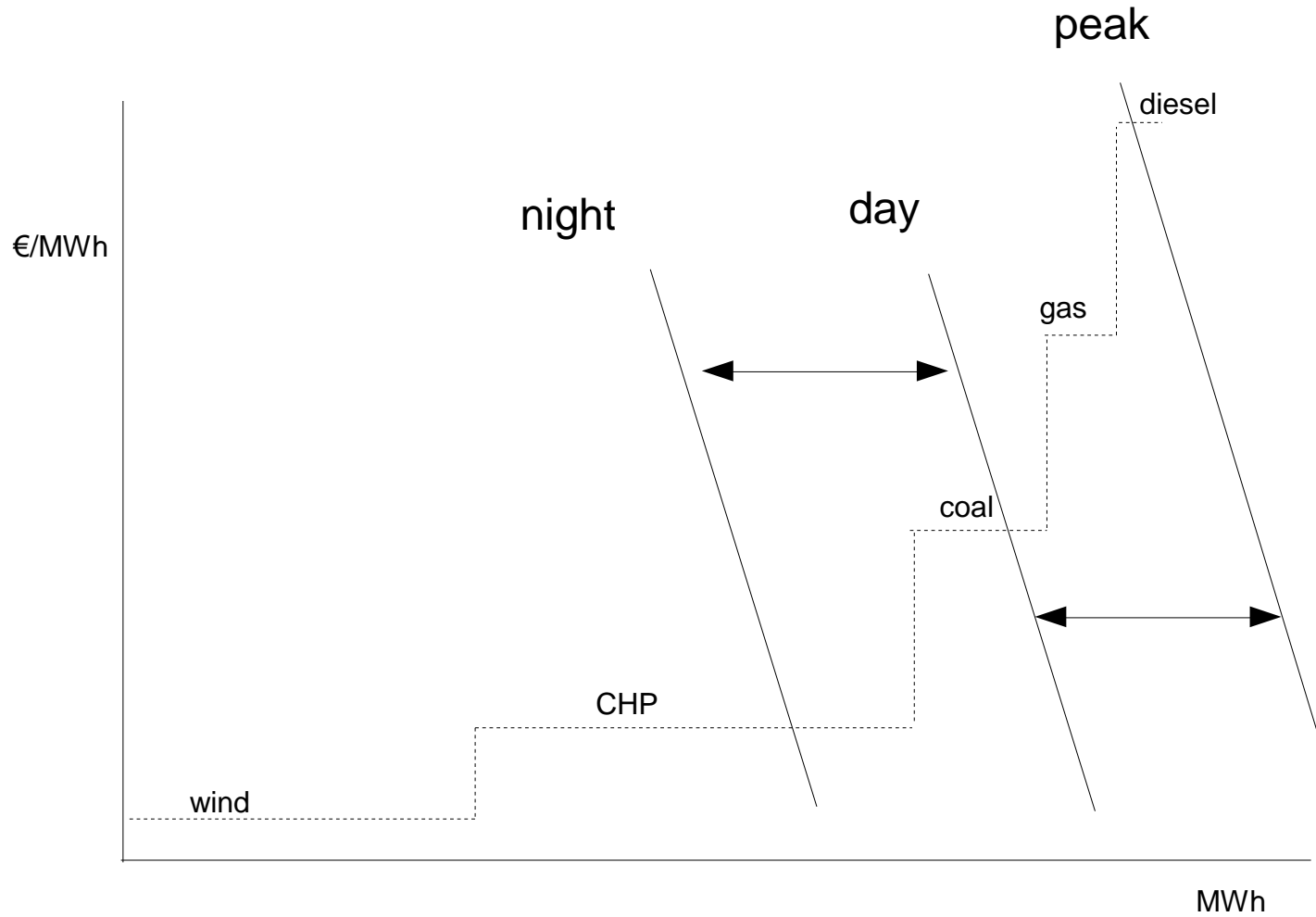
— — Cross Border Flow
 — Purchase Block Orders
 — Purchase Limit Orders
— Sale Block Orders
 — Sale Limit Orders

Short term marginal costs determine power price

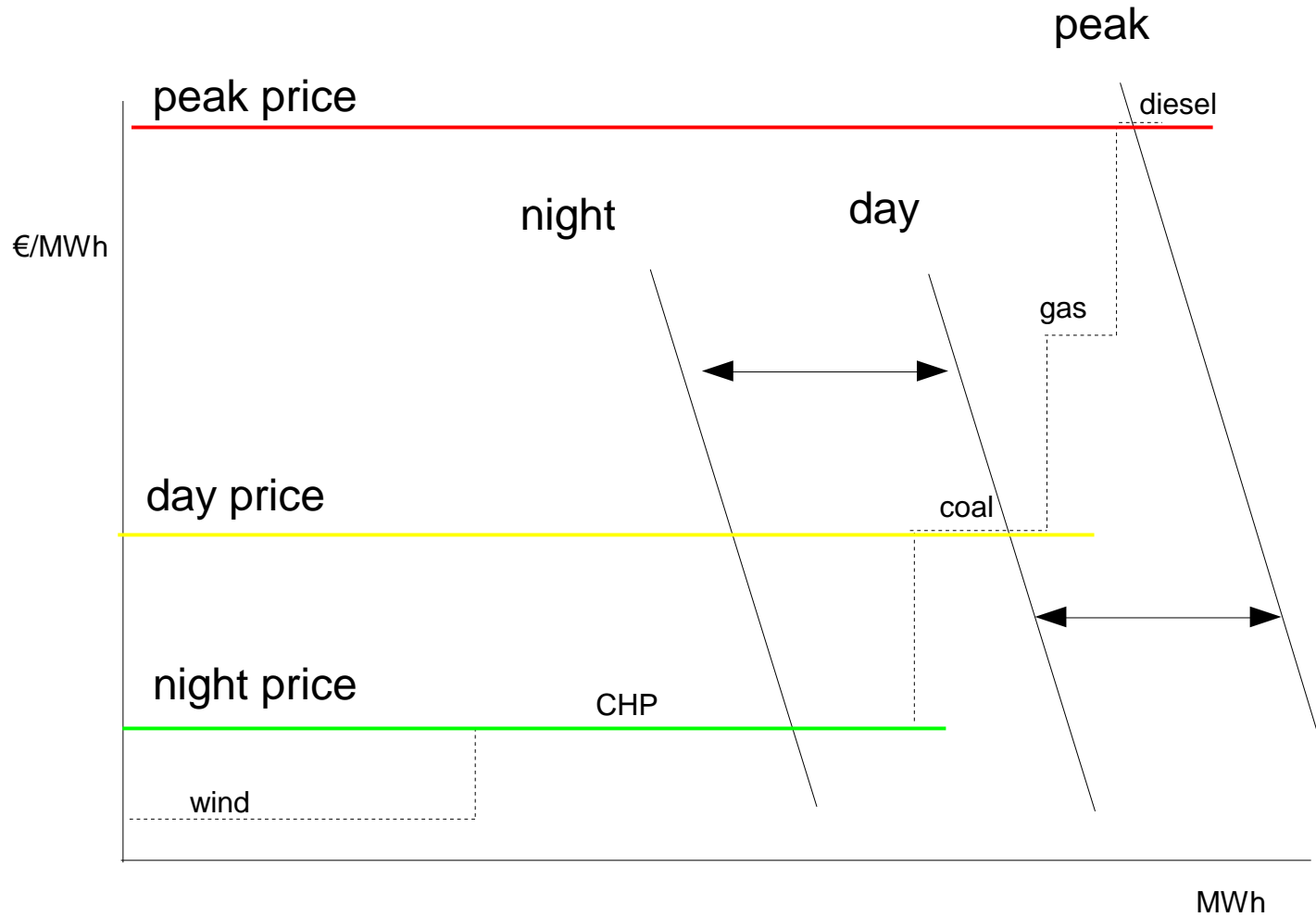


- The supply curve in day ahead market is reflecting the short term marginal costs - mainly the fuel costs per MWh supplied
- Generation technologies differ with regard to the mix of variable and fixed costs (and joint production in case of CHP)
- Fluctuating renewable generation forms the *lower left part of the supply curve*
- Variation in generation from renewables will thus shift the entire supply curve
- Demand is *price inelastic* in the short term

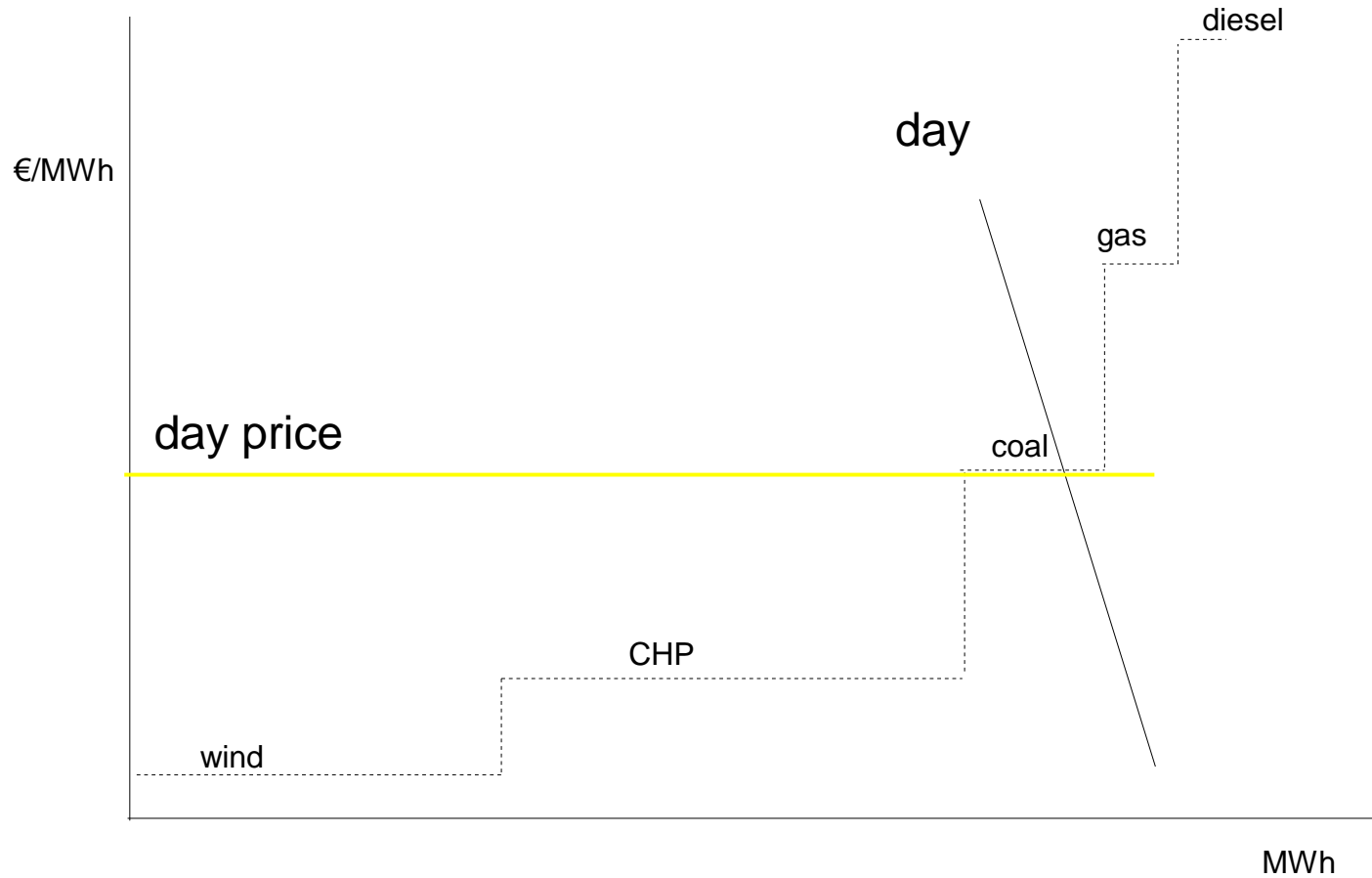
Electricity Prices



Electricity Prices



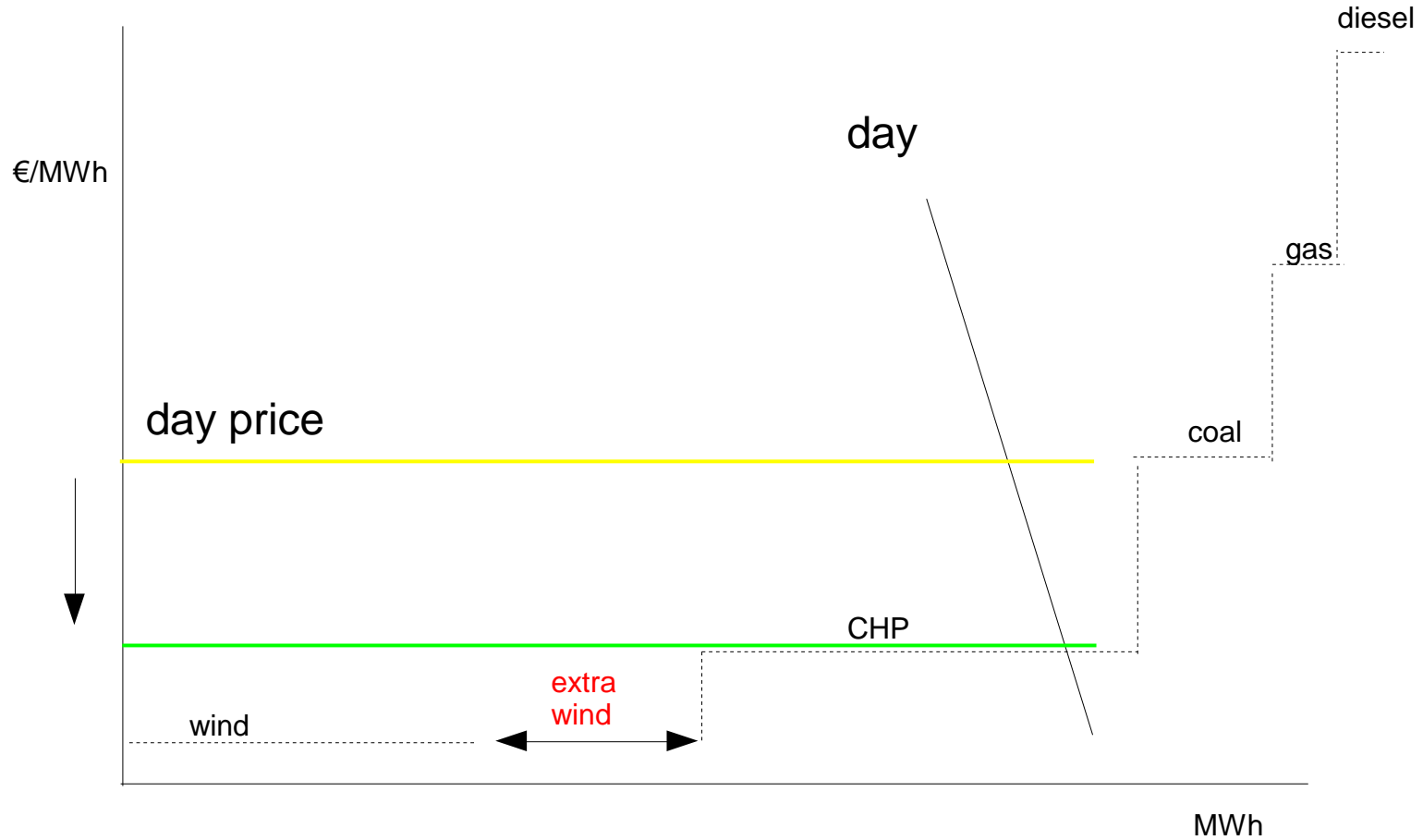
Electricity Prices



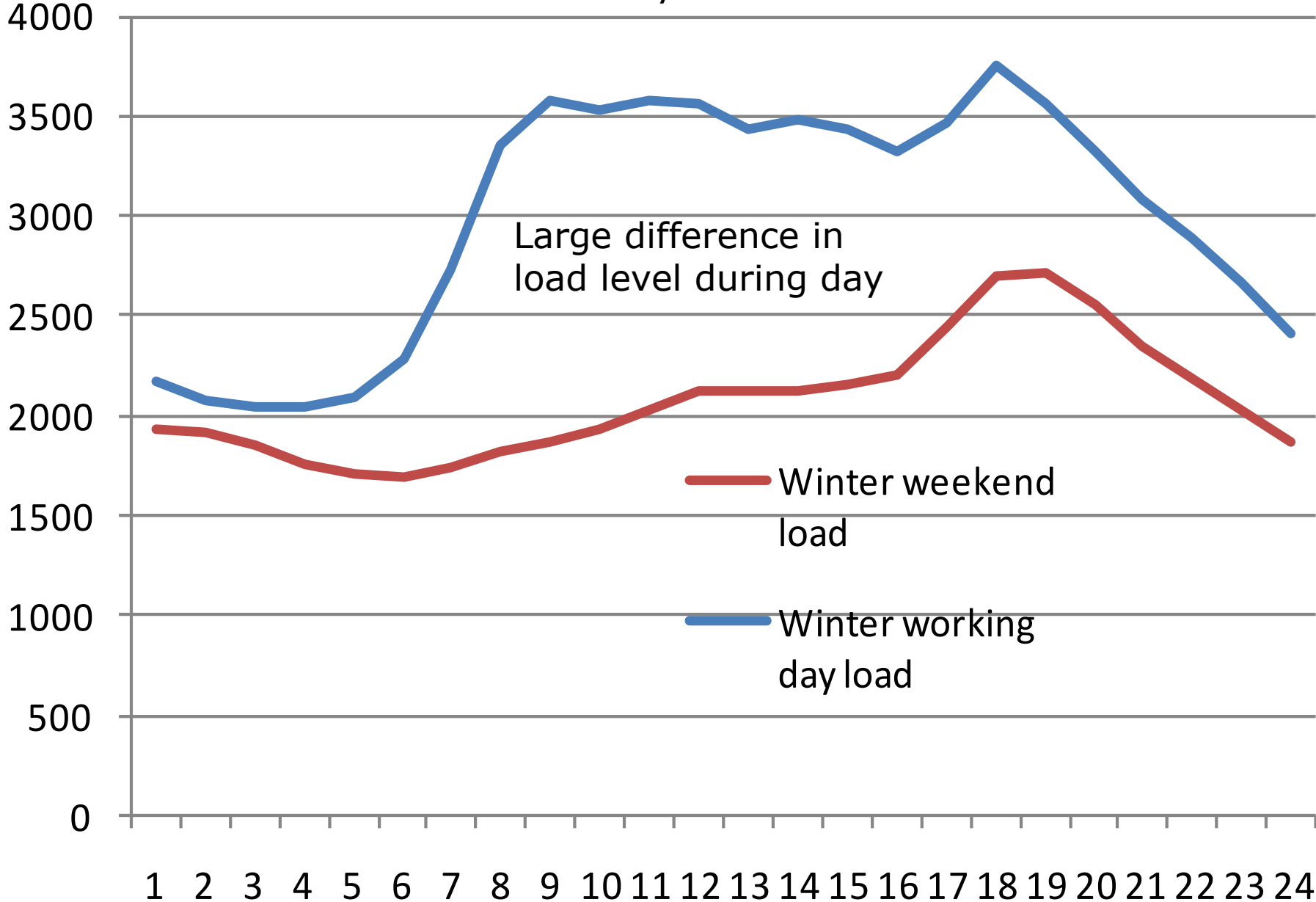
Adding renewable capacity and the short term price effect

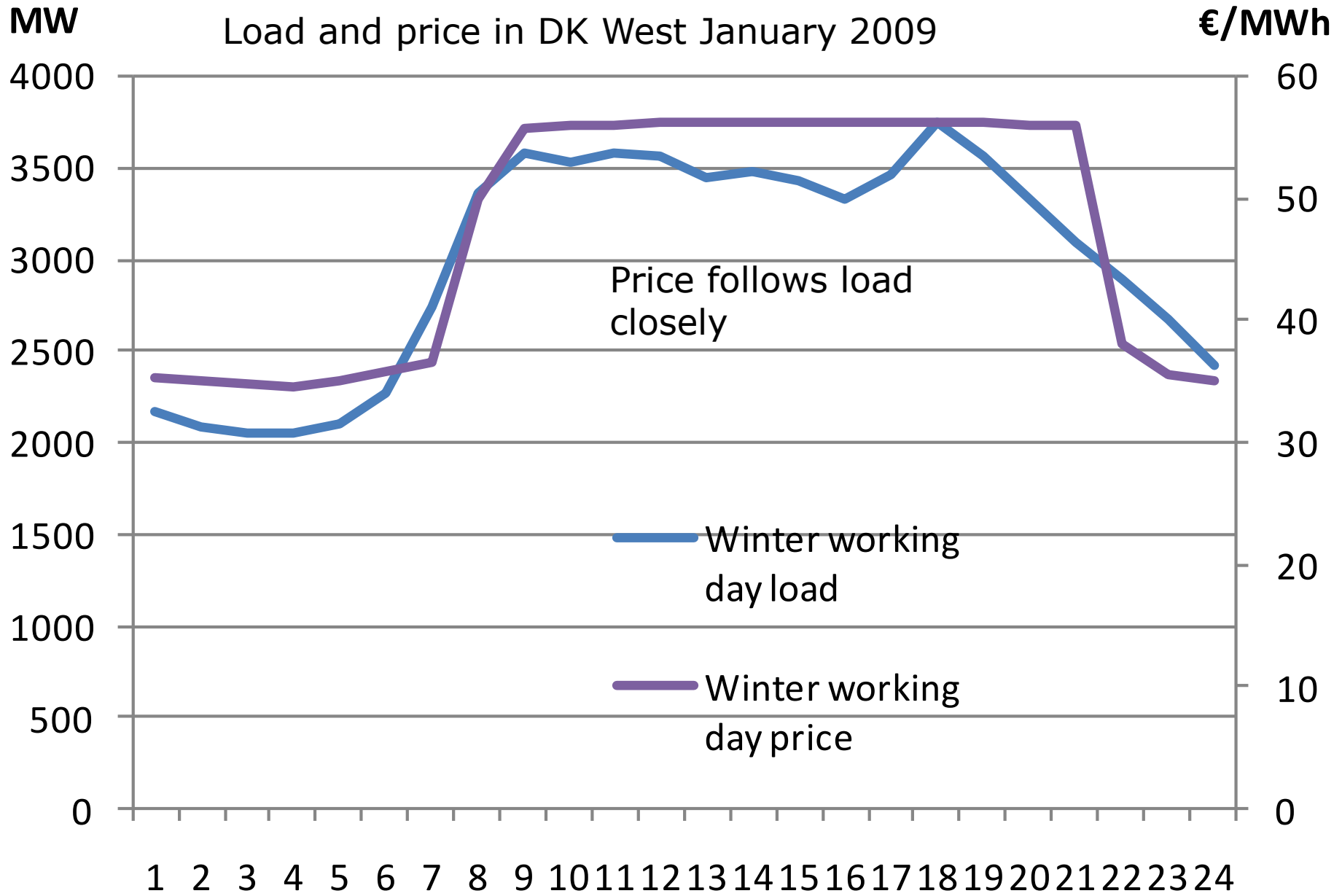
- Average wholesale power price is reduced
- Price is reduced the most when demand is high (peak load) and the least when demand is low
- Other generation with low variable cost (base load technologies) would also shift the supply curve to the right. (nuclear)
- The relative effect for the consumer price is much less, since the network costs, the renewable support and all the taxes are added to the wholesale price
- The wholesale market does not provide the investment incentives to renewable generators - this is provided outside the market

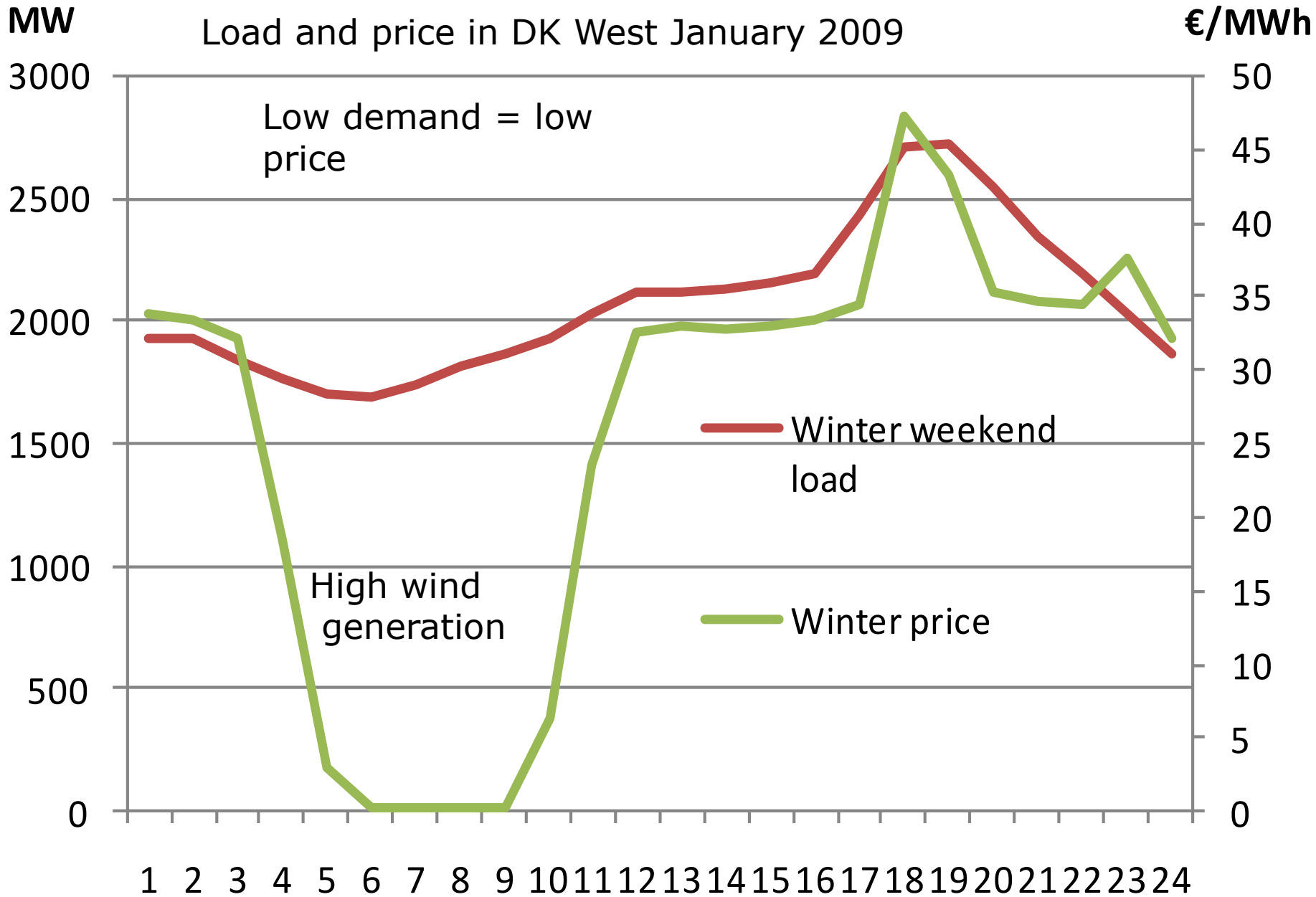
Electricity Prices



MW Load in DK West January 2009







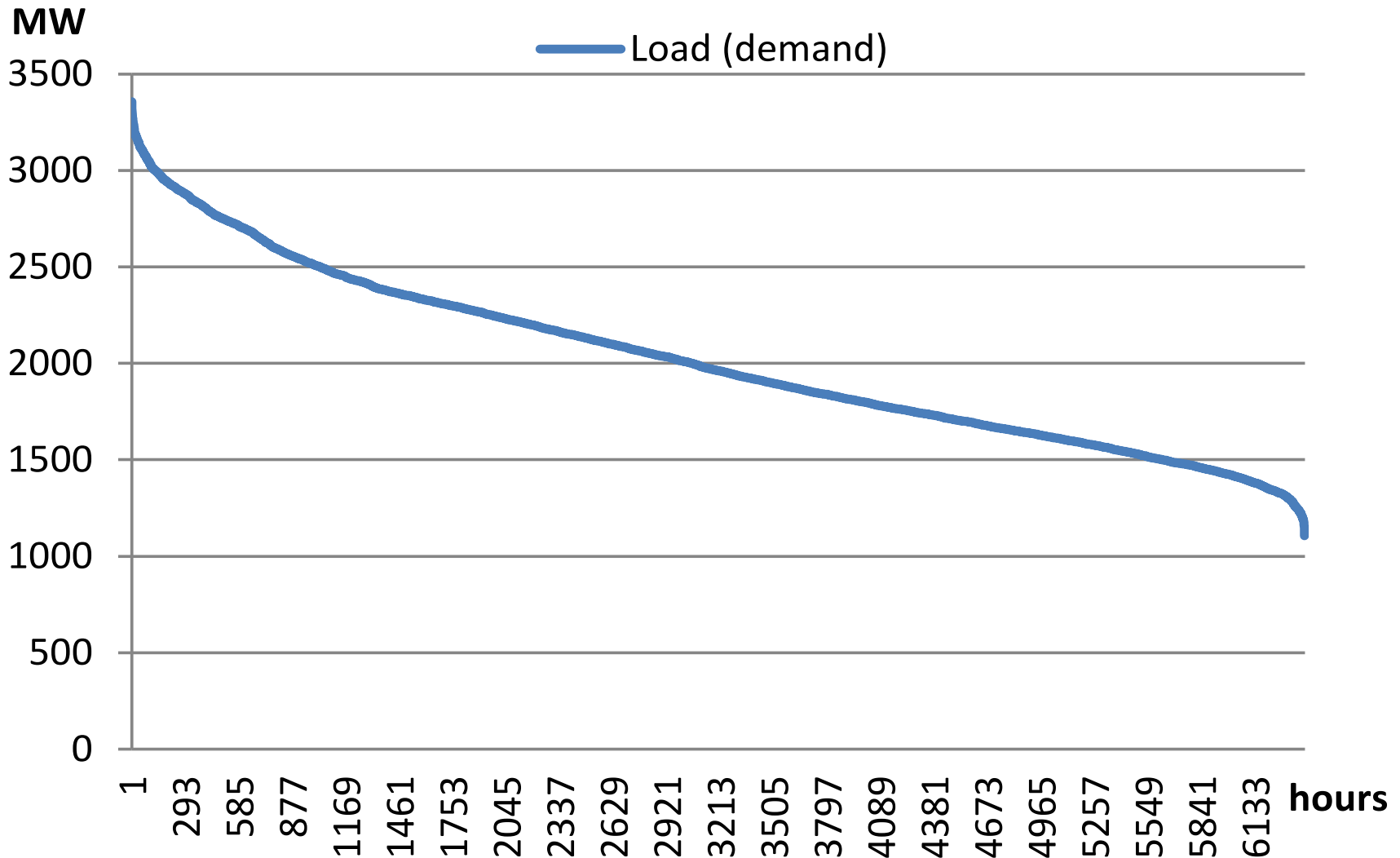
Price effect and volatility effect depends on demand variation and composition of power system



- Intermittent generation will affect prices most in systems with few flexible generation resources – nuclear, baseload coal etc.
- Intermittent generation will affect prices most if demand variation is large
- Price effect is high if short term demand flexibility (elasticity) is low

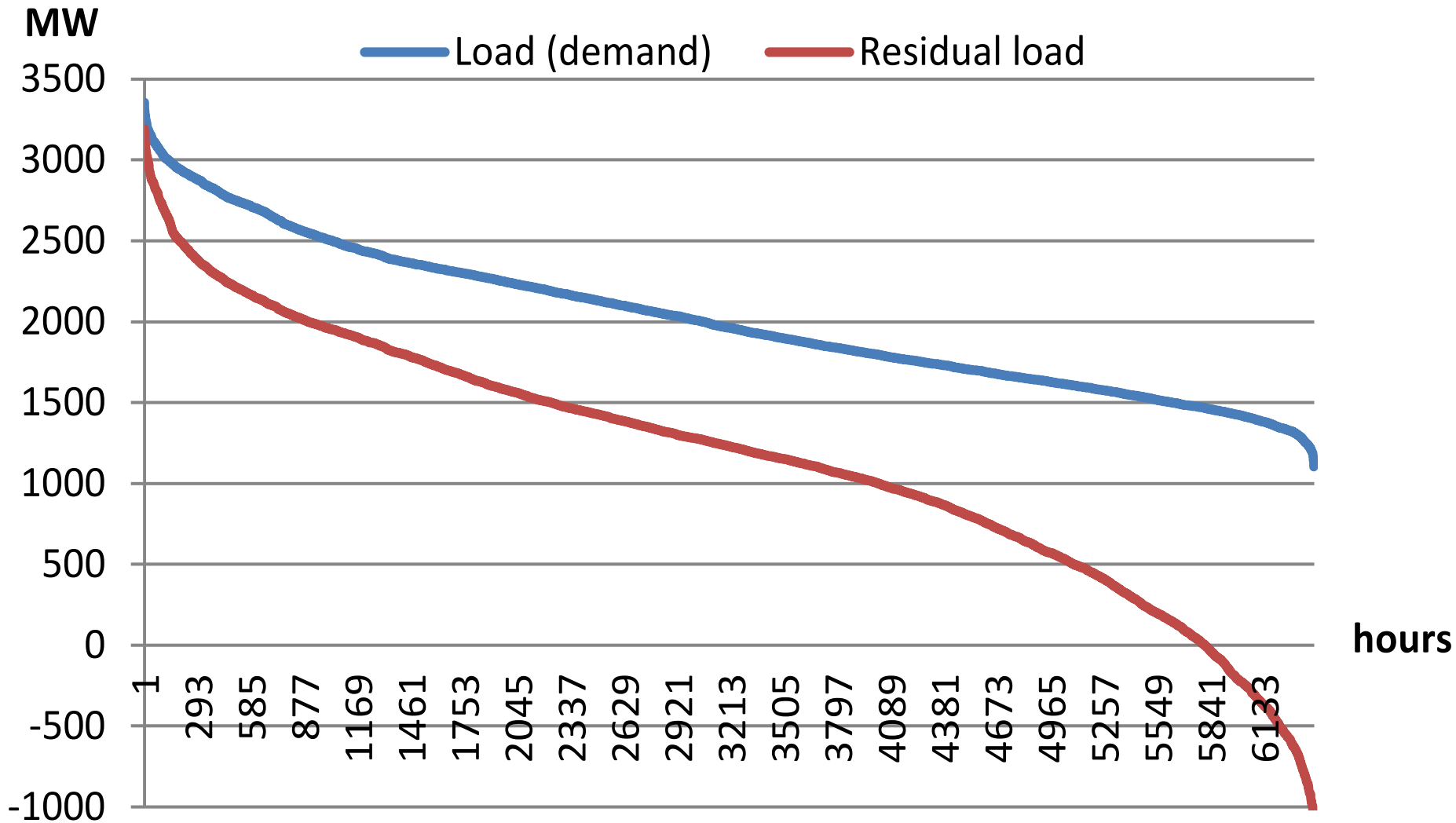
The price effect and the volume effect has an impact on all generation technologies

Load duration curve Denmark West January-September 2013



Subtracting the wind generation

Denmark West January-September 2013



Electricity price and renewable generator revenues

- Renewable generators receive support
 - feed-in tariffs
 - premiums
 - green certificates
 - investment grants or tax credits

So why does prices matter for renewables?

- First
 - premiums create some market dependence
 - green certificates imply high market price dependence
 - feed-in given as fixed term (15 years) support and afterwards 100% market!
- Secondly
 - Most utilities portfolios include intermittent generation and conventional generation
 - Investment in intermittent generation will influence the revenue of the entire portfolio of generation technologies

Annual revenue effects for generators

- For the average generator lower prices are unattractive
- For the peak plants this is even less attractive as peak prices are reduced the most and they have the major part of revenue from these hours
- Wind generators (expired support) have a disadvantage to controllable generation as their output is negatively correlated with prices - high output at low price hours

Wind generator revenue

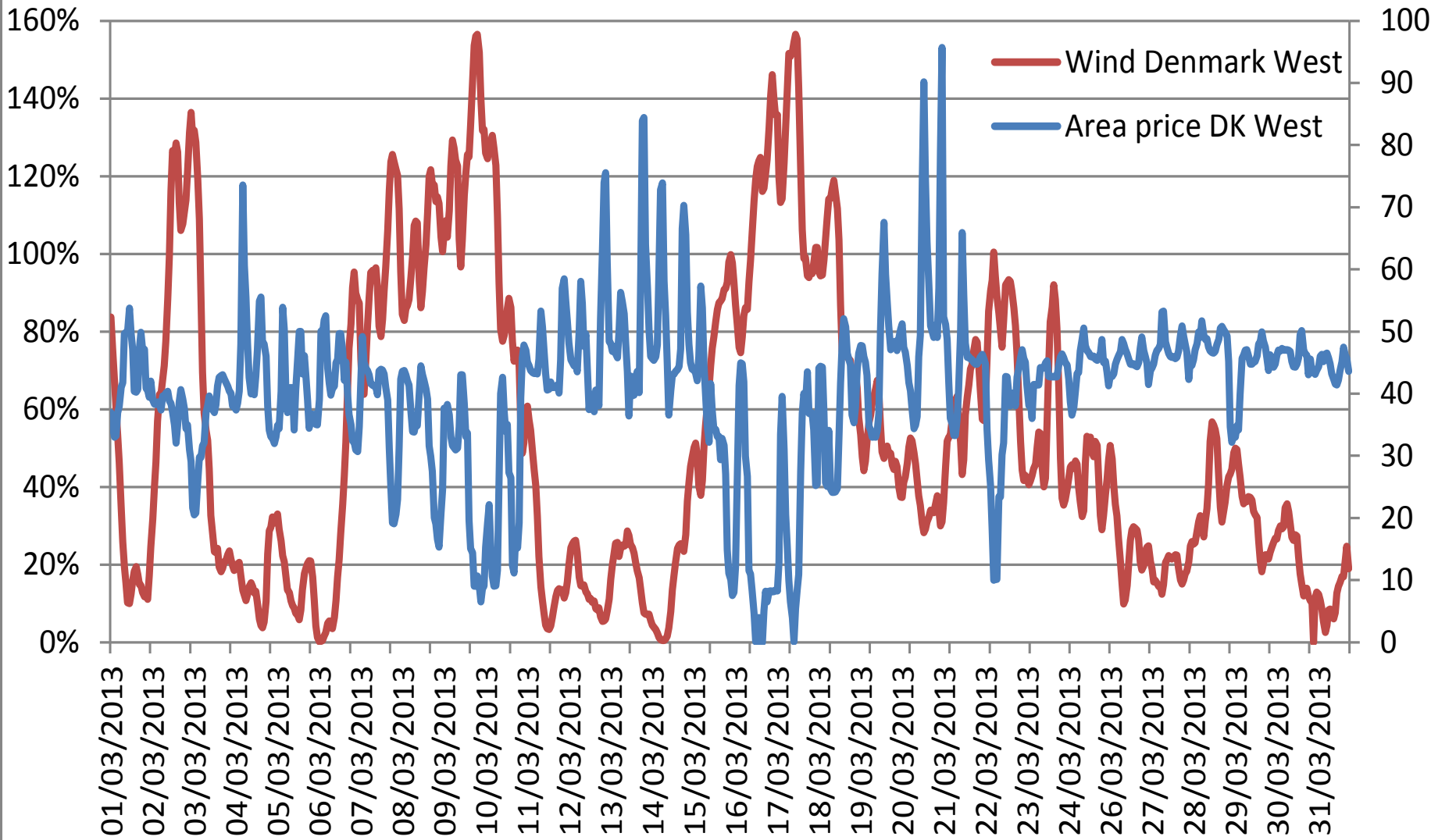
Table 1 Wind generators market based revenues in the Western Denmark price area

	Area Price €/MWh (direct average of hours)	Wind average price €/MWh	Difference €/MWh	Wind price relative to market	Wind generation (GWh)	Potential loss mill. €
2006	44.19	40.54	3.64	92%	4614	16.8
2007	32.40	28.66	3.74	88%	5562	20.8
2008	56.42	51.20	5.22	91%	5190	27.1

Power price is negatively correlated with generation

Wind share and price March 2013

Euro/MWh



The long term challenge
How to make investment in conventional
technology (back-up/flexibility) profitable
with low wholesale prices

Long term marginal costs

- Intermittent renewable technologies have **low short term** marginal costs *but* **high long term** marginal costs (high investment costs)
- Therefore they require financial support to compete as the preferred investment technology
- The investment in renewables affects the short term power prices downwards
- The investment incentive provided through the short term power markets are thus reduced and
- The conventional capacity will be reduced

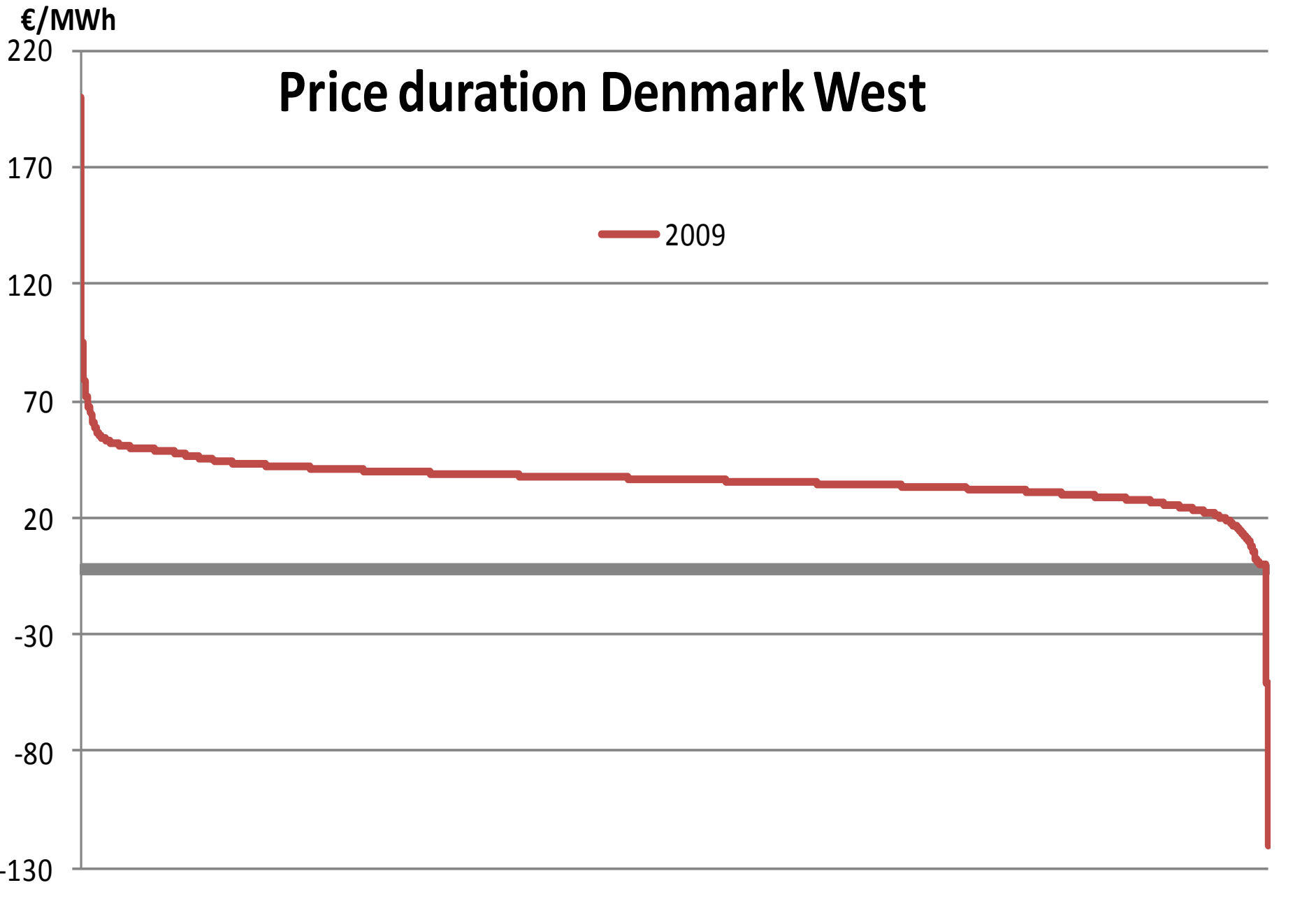
Negative prices

Negative prices for electricity



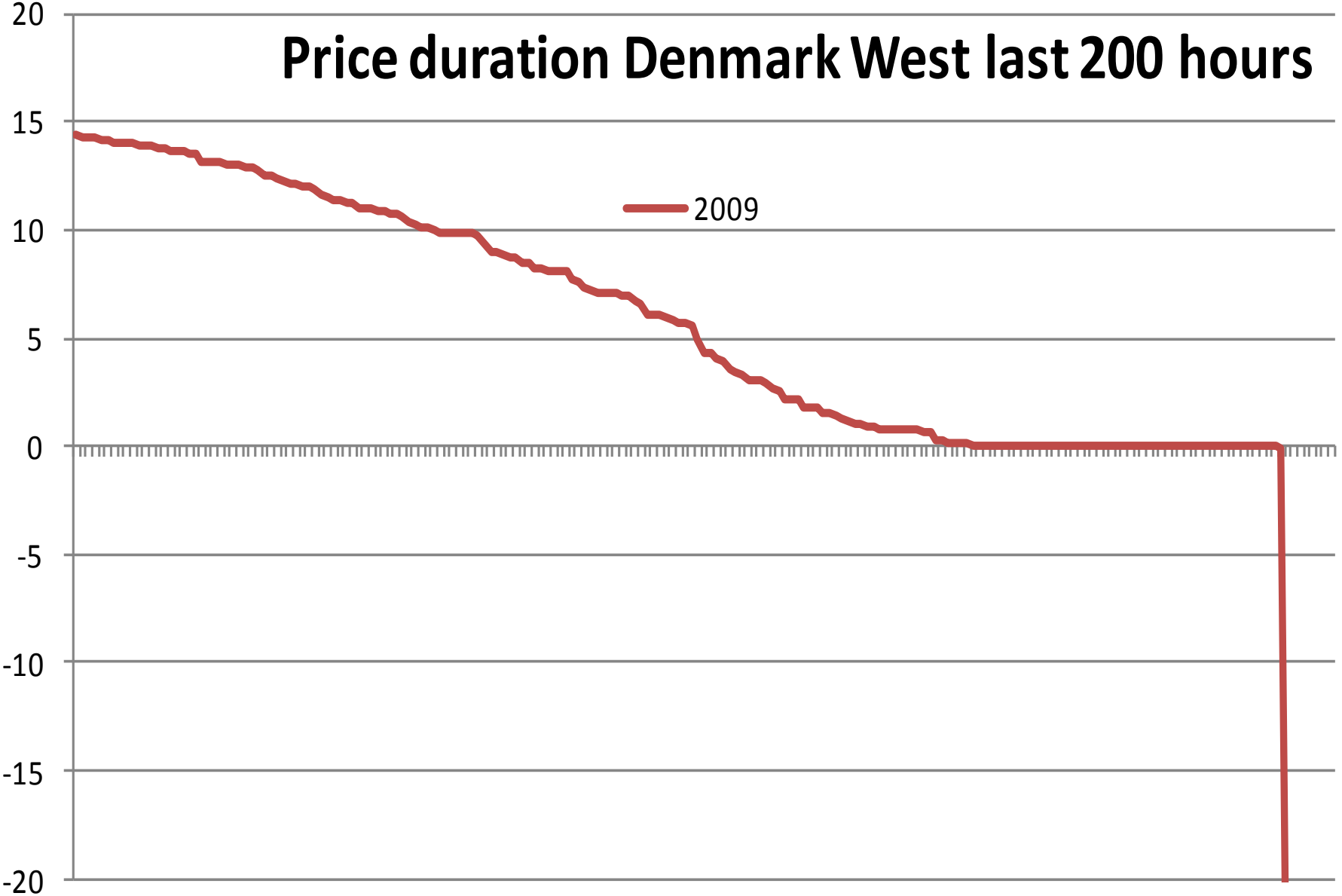
- The marginal value of using more electricity is negative?
- Does not fit with normal assumptions in the long run
- There are good explanations for negative prices in power markets
- Important to allow the negative price signals passed to all generators for efficient allocation of production

Price duration Denmark West

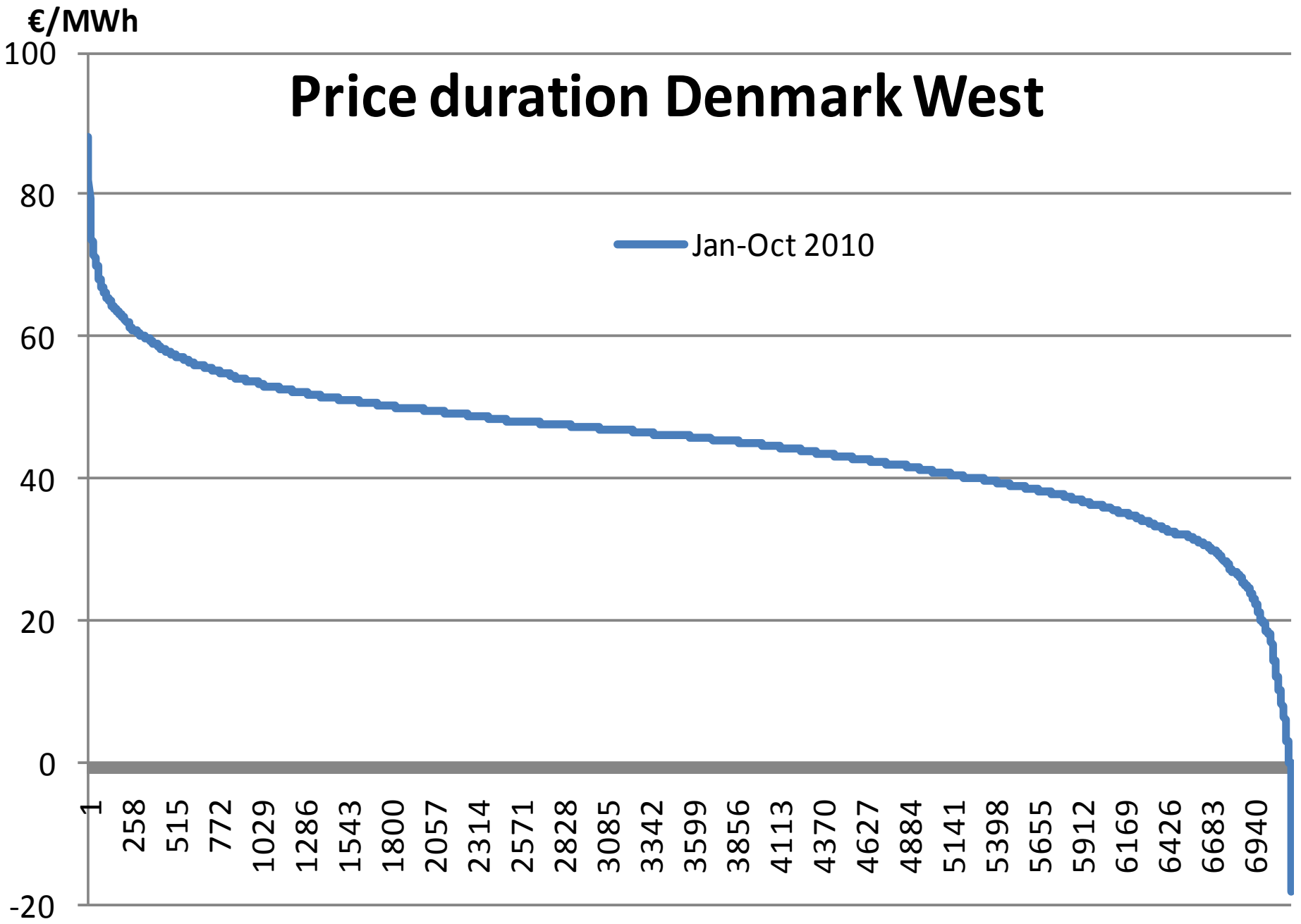


€/MWh

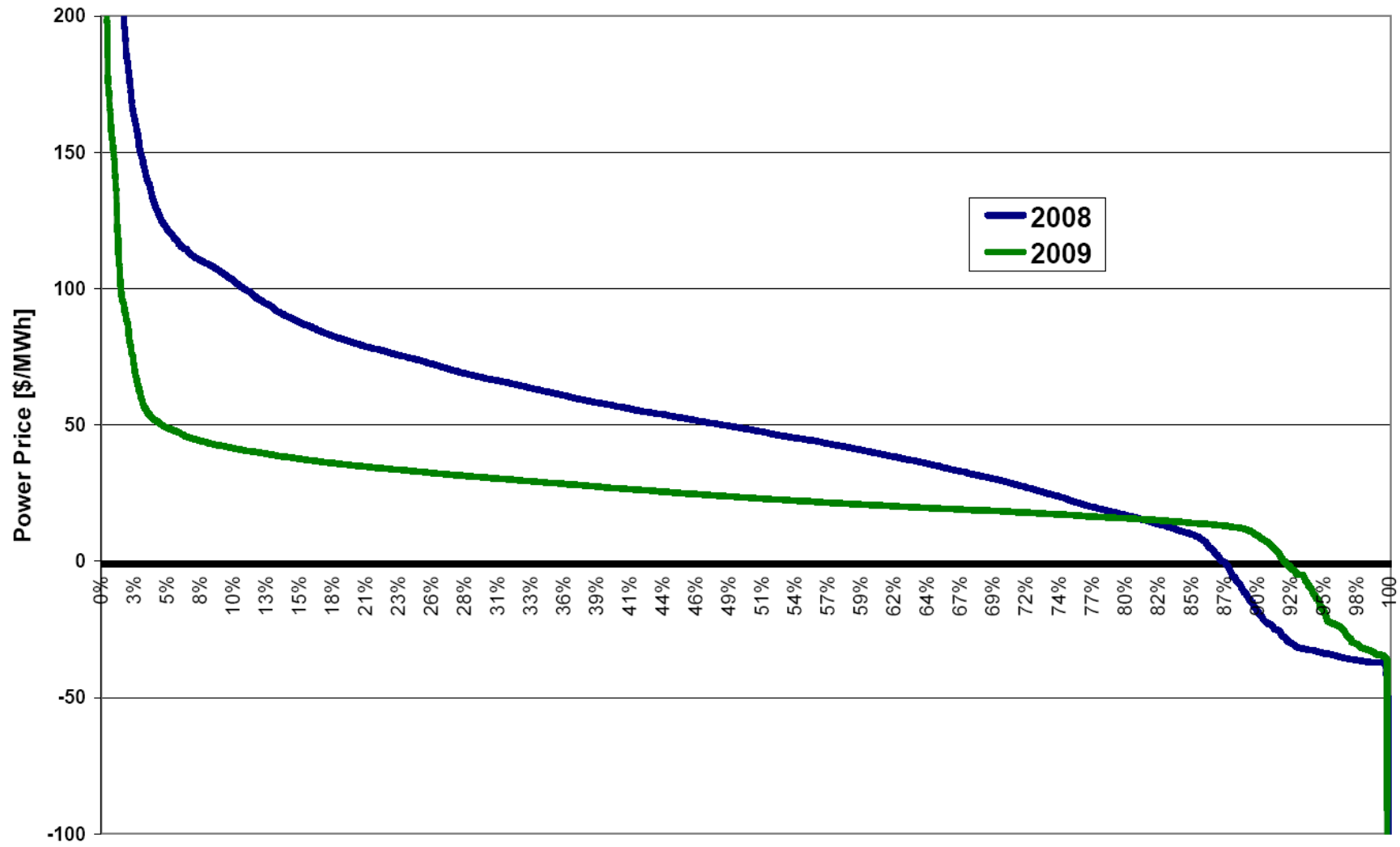
Price duration Denmark West last 200 hours



Price duration Denmark West



Price duration curves – Texas west



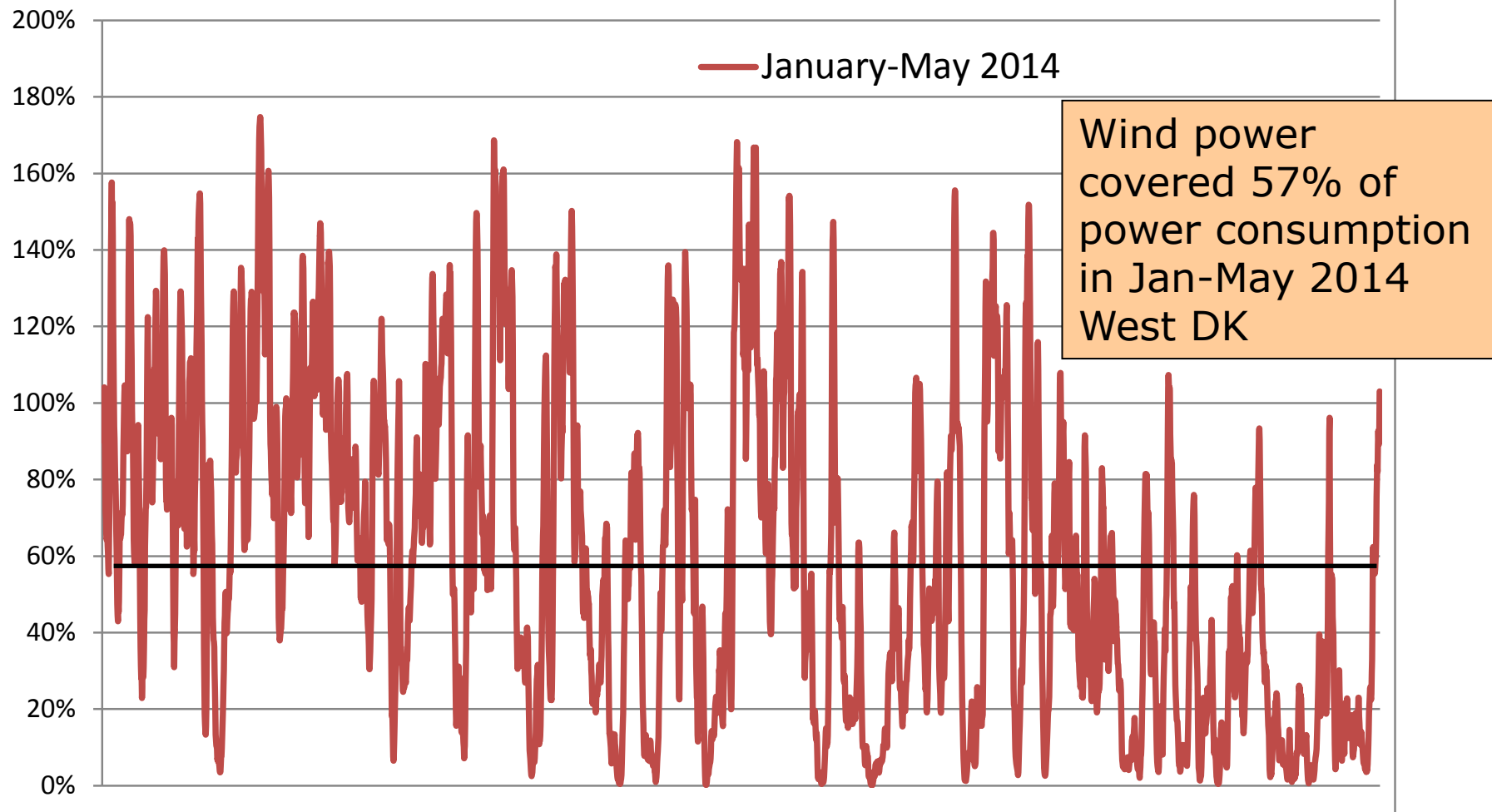
Source: ERCOT (2010)

Negative prices: Explanation and solution



- Stop and start costs for conventional generators (minimum up and down times)
- Renewable generators are subsidised (feed-in tariff or production based tax credits)
- Renewable generation stay online as long as the negative price is less than the support
- Solution:
 - use dynamic tariffs (tax) element of consumer price reduced when zero wholesale price
 - instruct renewables to shut down – involuntarily curtailment
 - reduce/remove the support when power prices are zero or below – voluntary curtailment
- Result: Much less zero and negative prices after a bit of learning

Wind share of consumption DK West



Thank you for your attention!

Henrik Klinge Jacobsen
jhja@dtu.dk

Department of Management Engineering
Technical University of Denmark – DTU
Systems Analysis Division
Building 110, P.O. Box 49
DK-4000 Roskilde, Denmark
www.dtu.dk