Modeling the economics of intermittent energy

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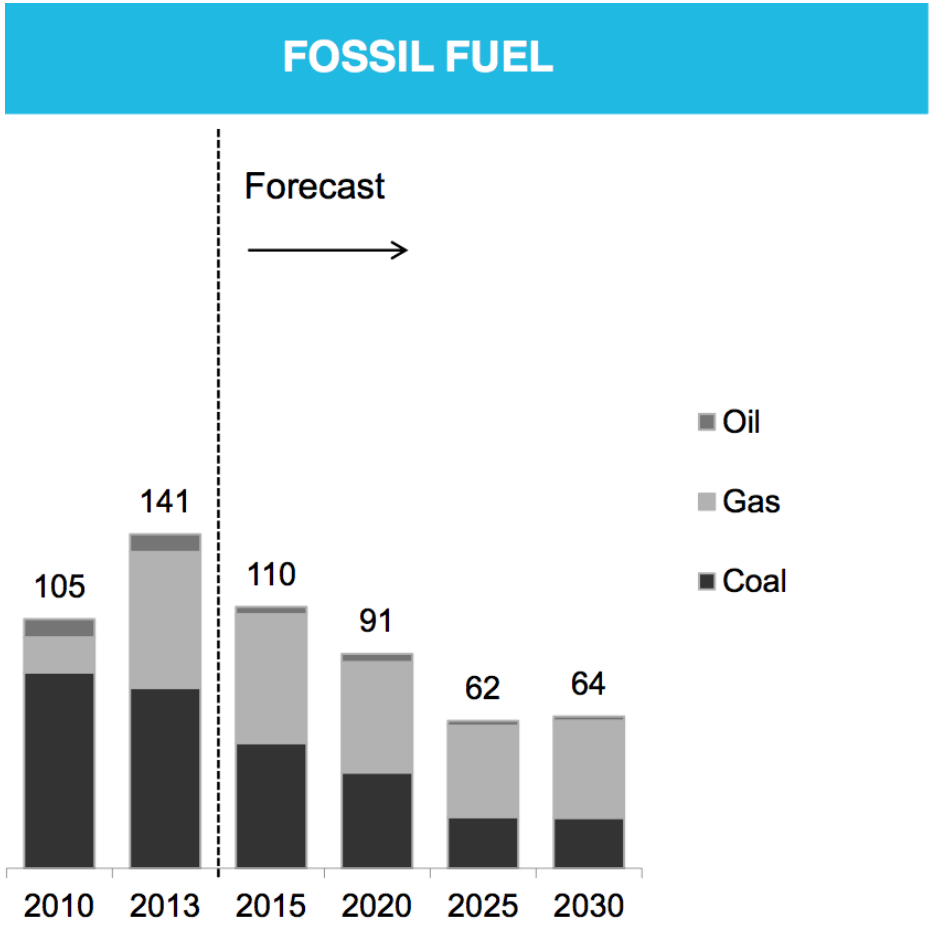
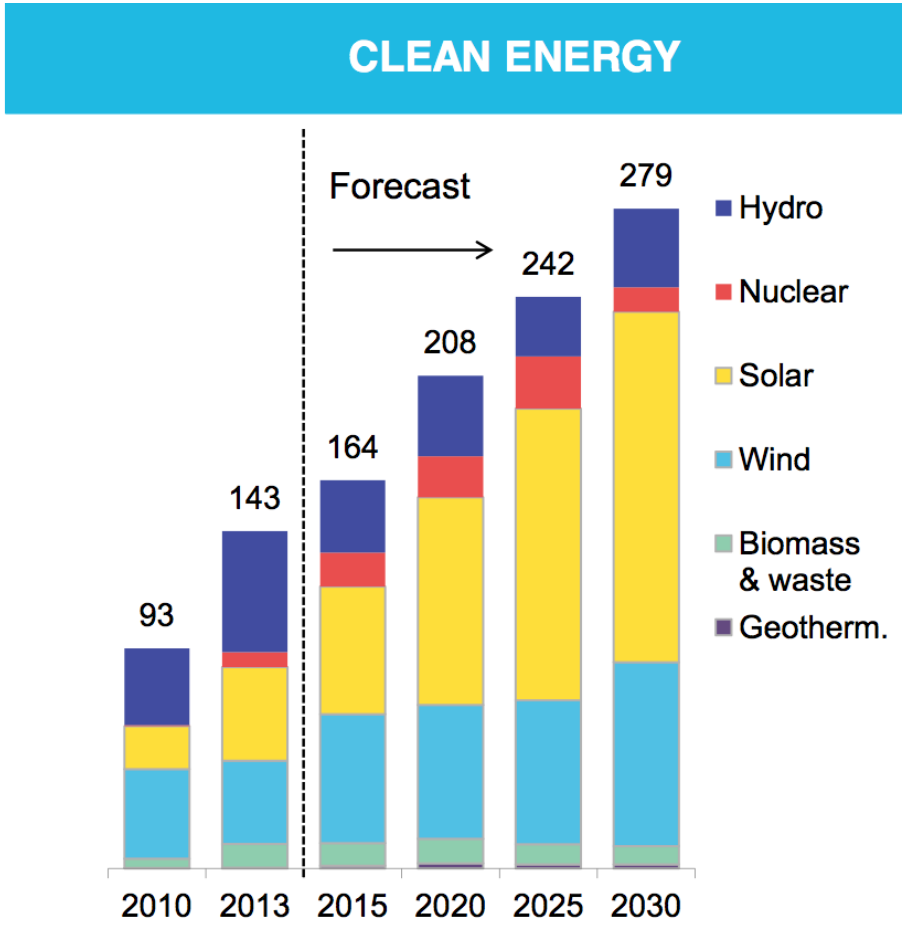
Fossil Fuels Just Lost the Race Against Renewables

This is the beginning of the end.

Source: http://www.bloomberg.com/news/articles/2015-04-14/fossil-fuels-just-lost-the-race-against-renewables

New installed capacity each year, in GW





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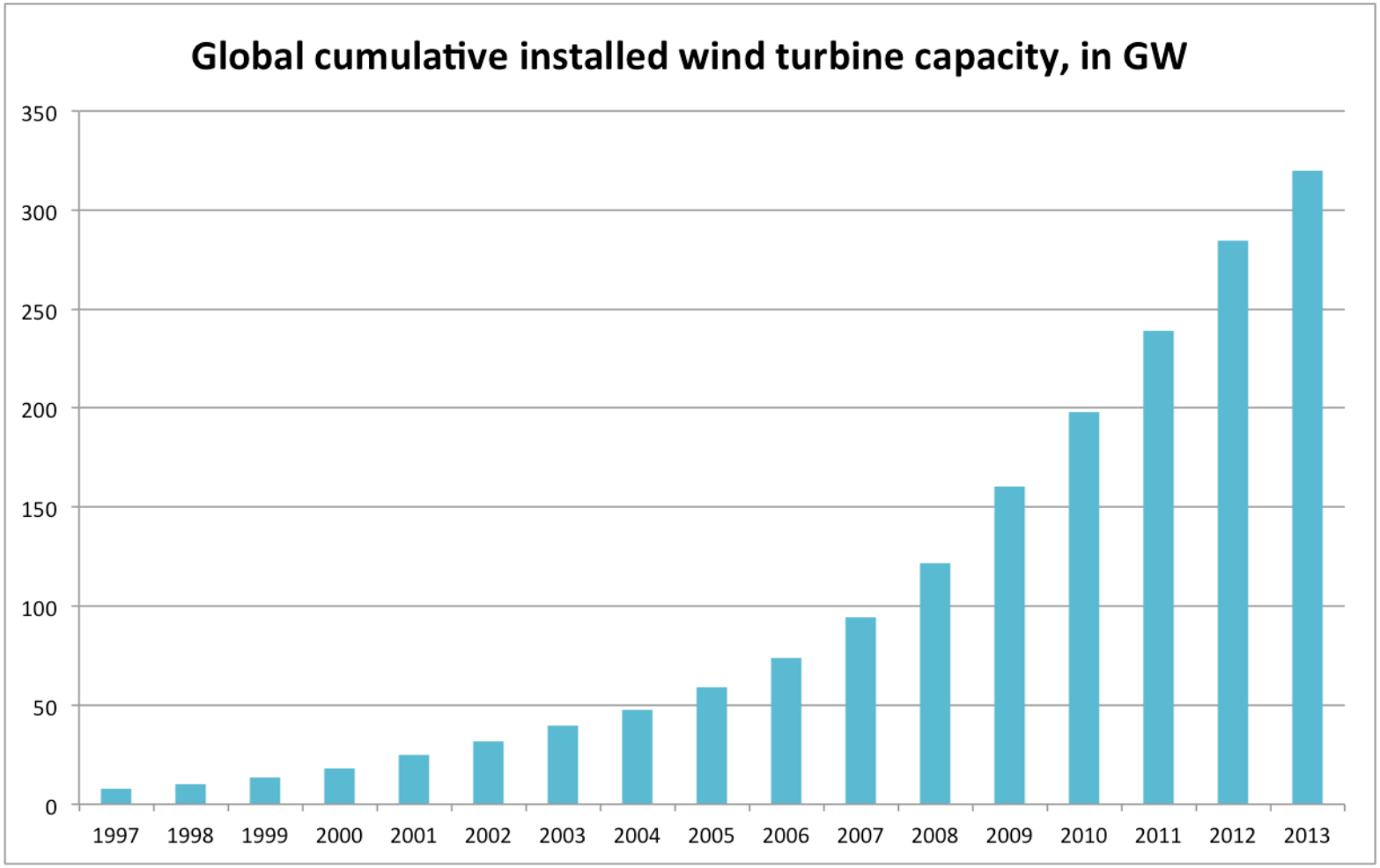
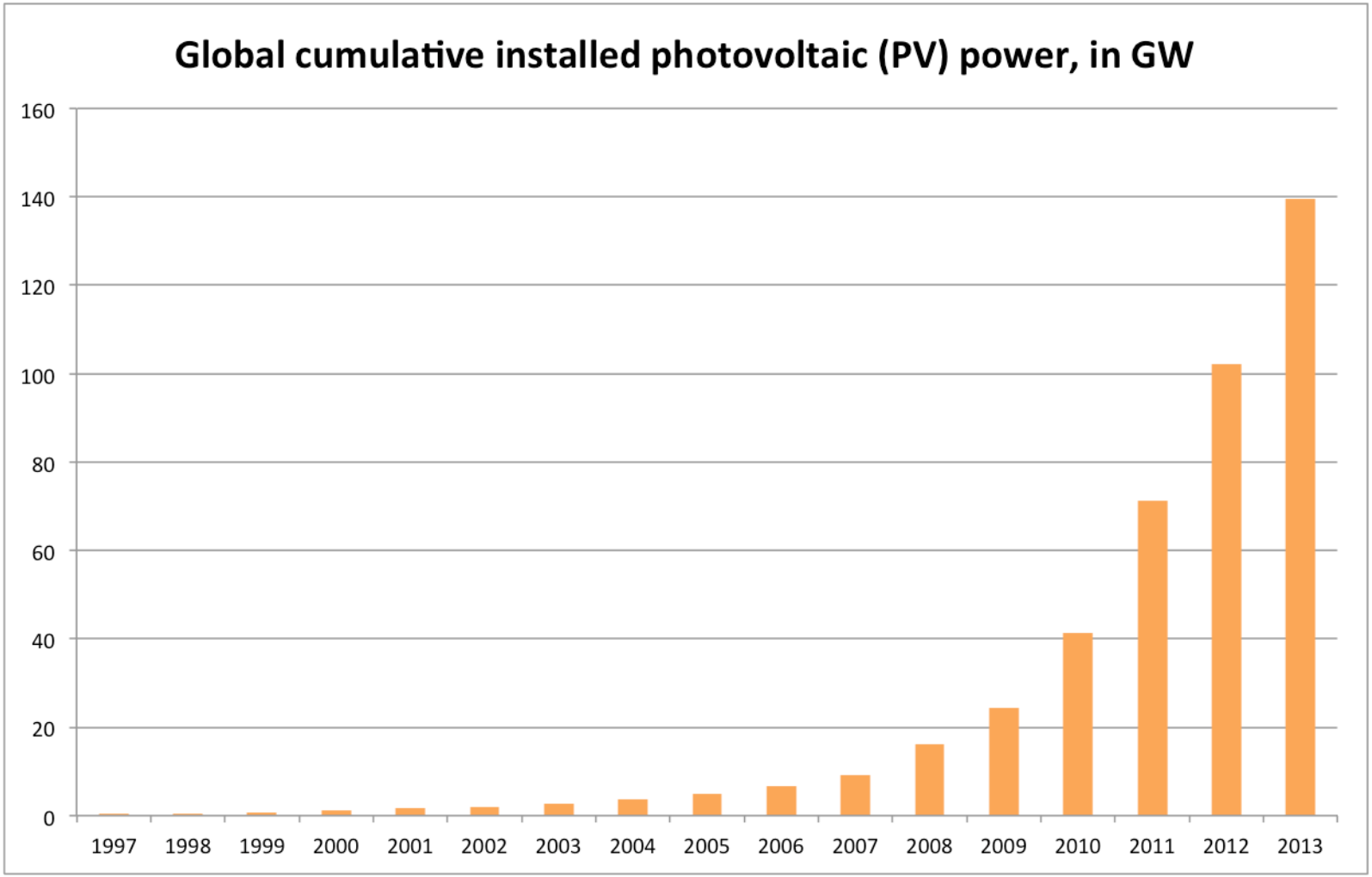
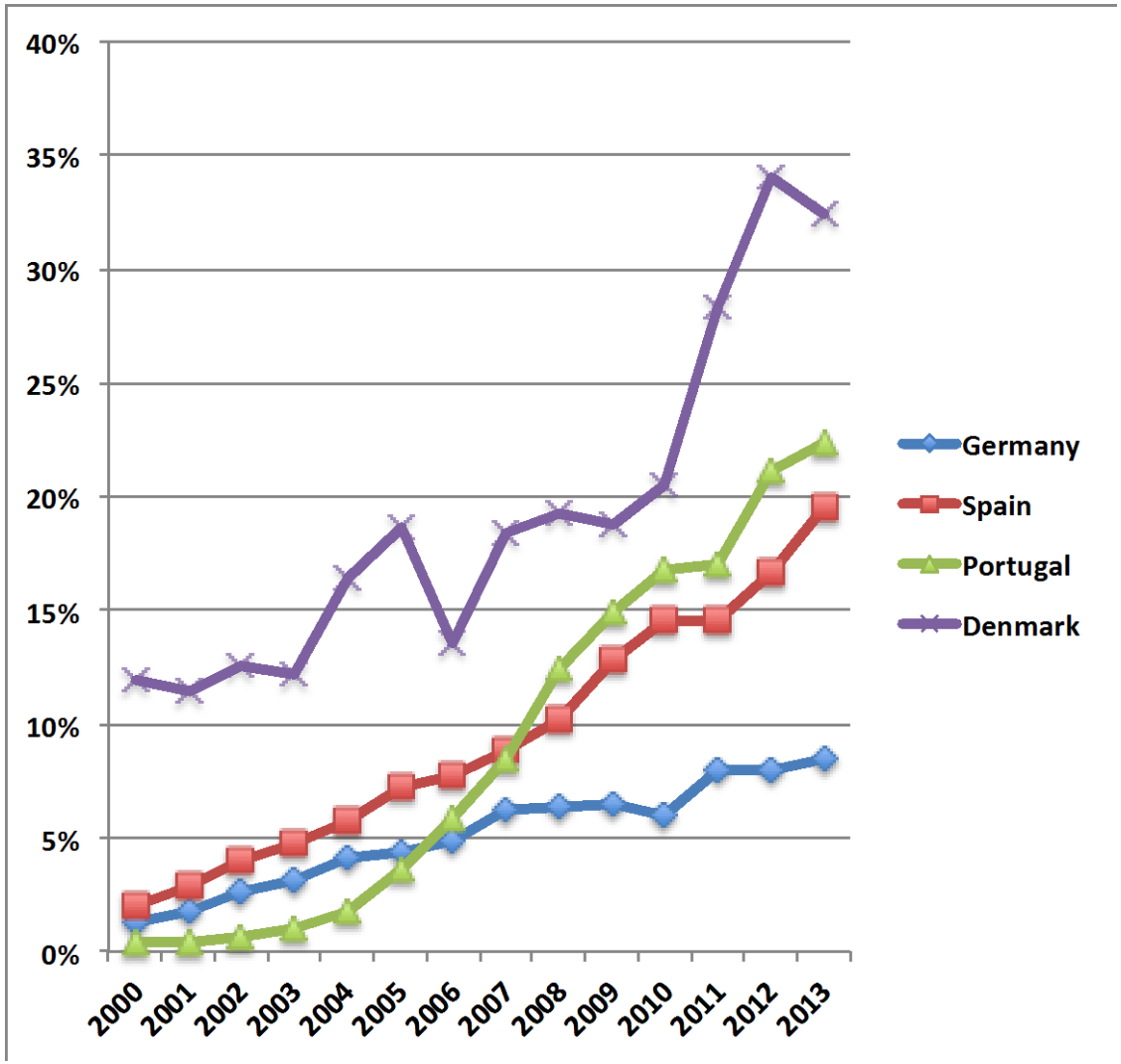


Data from BP Statistical Review of World Energy, June 2014



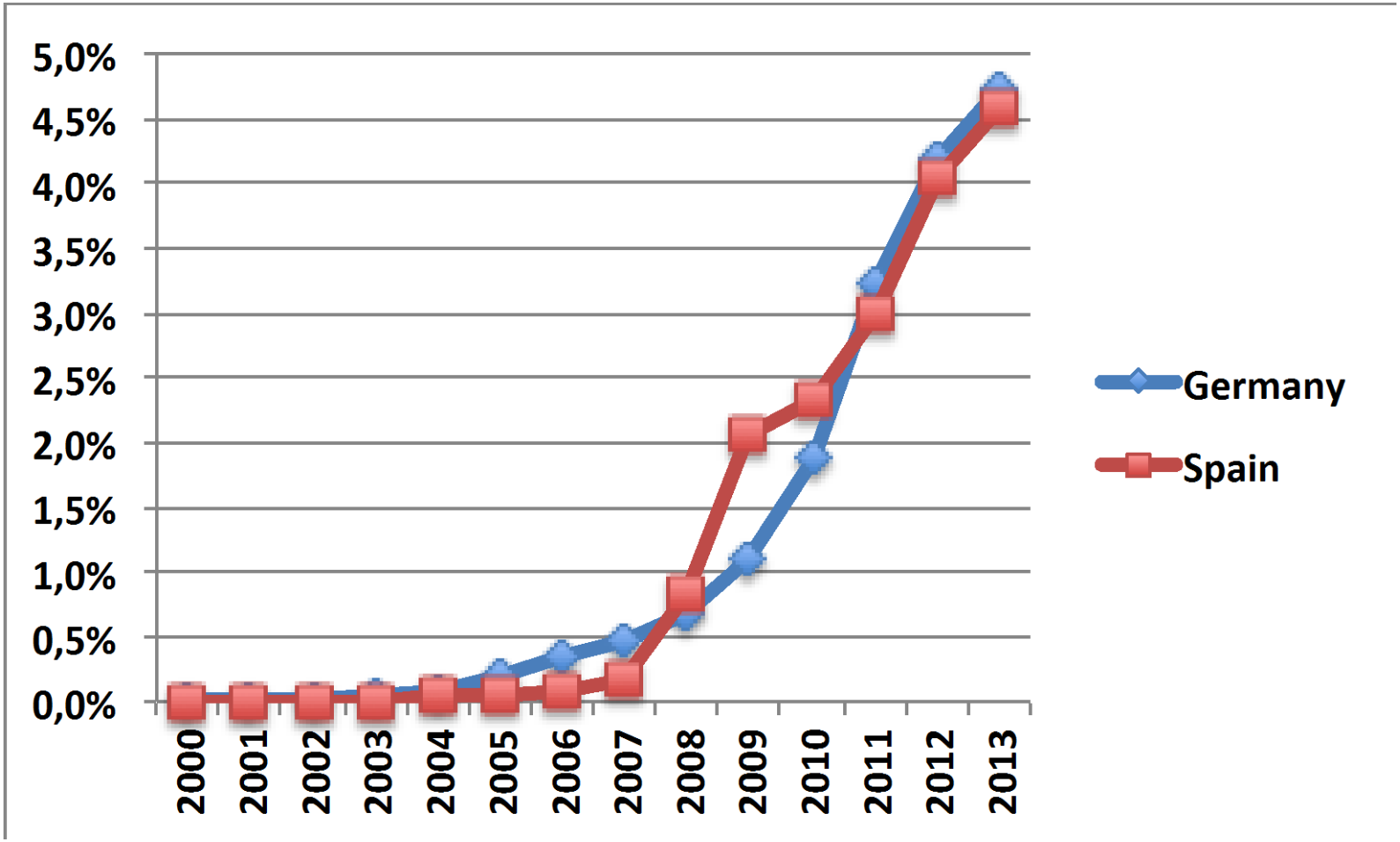
Data from BP Statistical Review of World Energy, June 2014

Wind power as a share of total electricity production in the country



Data from BP Statistical Review of World Energy, June 2014

Solar power as a share of total electricity production in the country

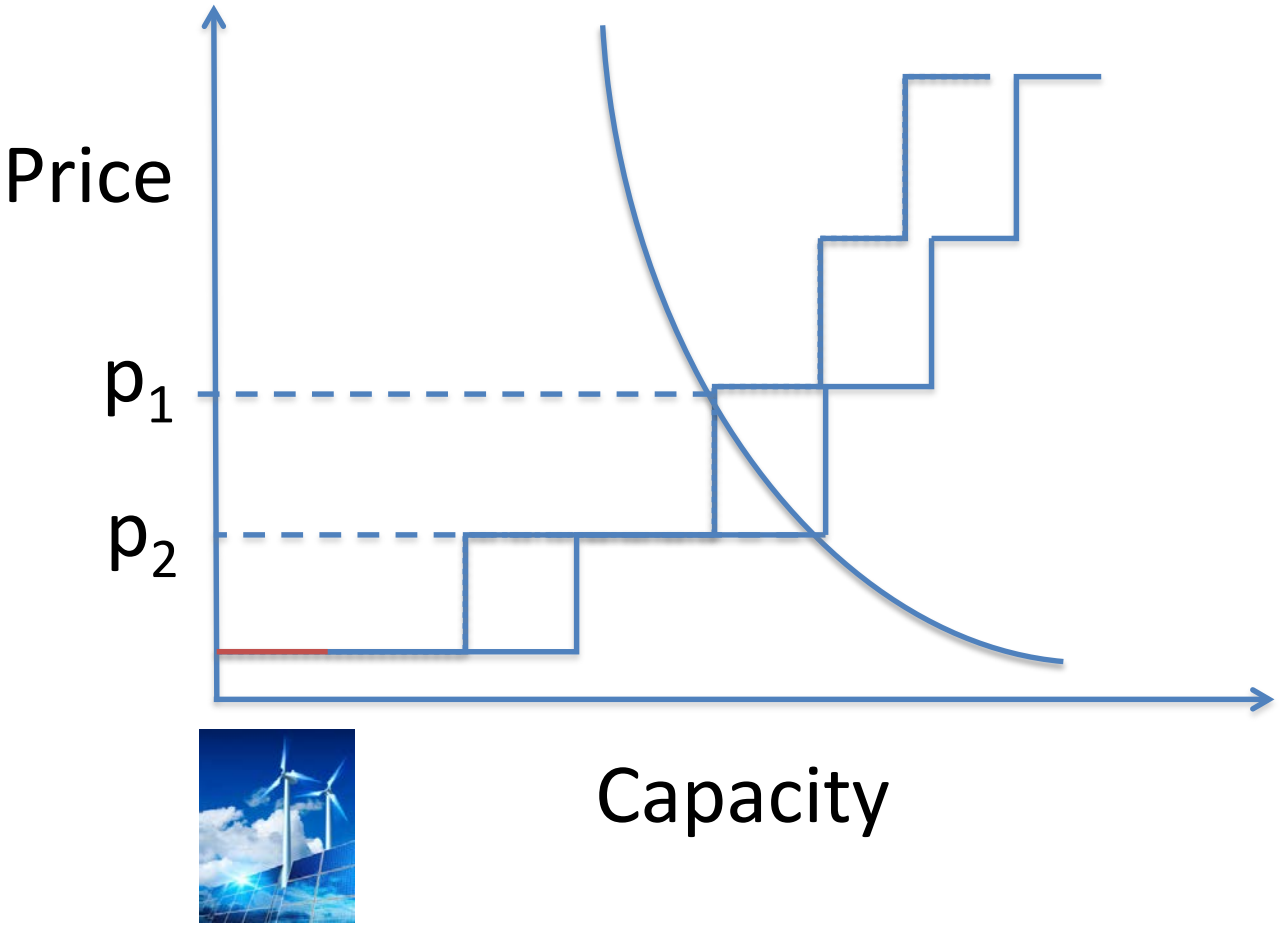


Data from BP Statistical Review of World Energy, June 2014

Characteristics of Variable Renewable Electricity (VRE)

- High investment costs
- Low running cost
- Intermittent

The merit order effect



Green Business | Thu Jan 9, 2014 9:42am EST

Related: ENVIRONMENT

Europe's storms send power prices plummeting to negative

LONDON/FRANKFURT | BY KAROLIN SCHAPS AND VERA ECKERT

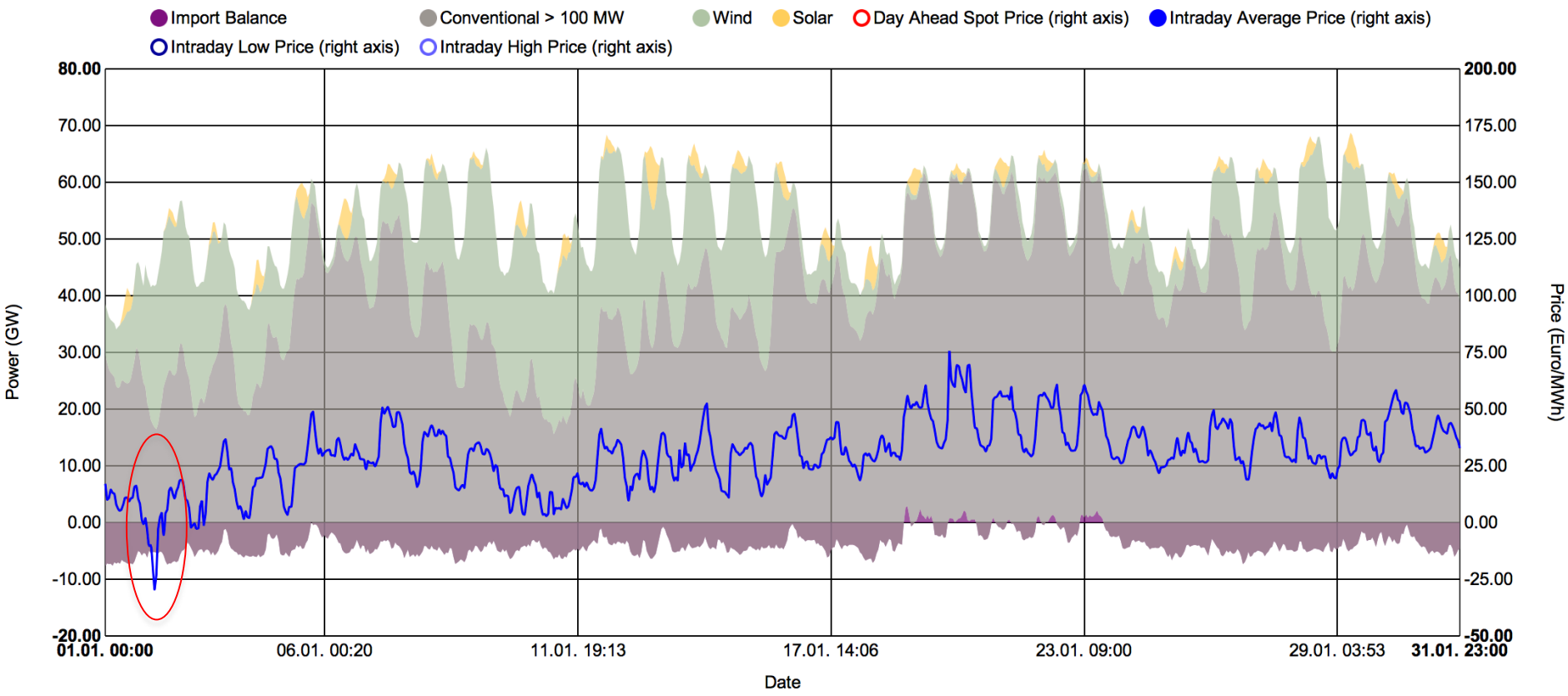
German power prices negative over weekend

13 May 2014 by Craig Morris Comments (2)

Germany set a new record on Sunday, May 11, by getting nearly three quarters of its electricity from renewable sources during a midday peak. Nonetheless, Craig Morris says the resulting negative prices are both good news and bad news.

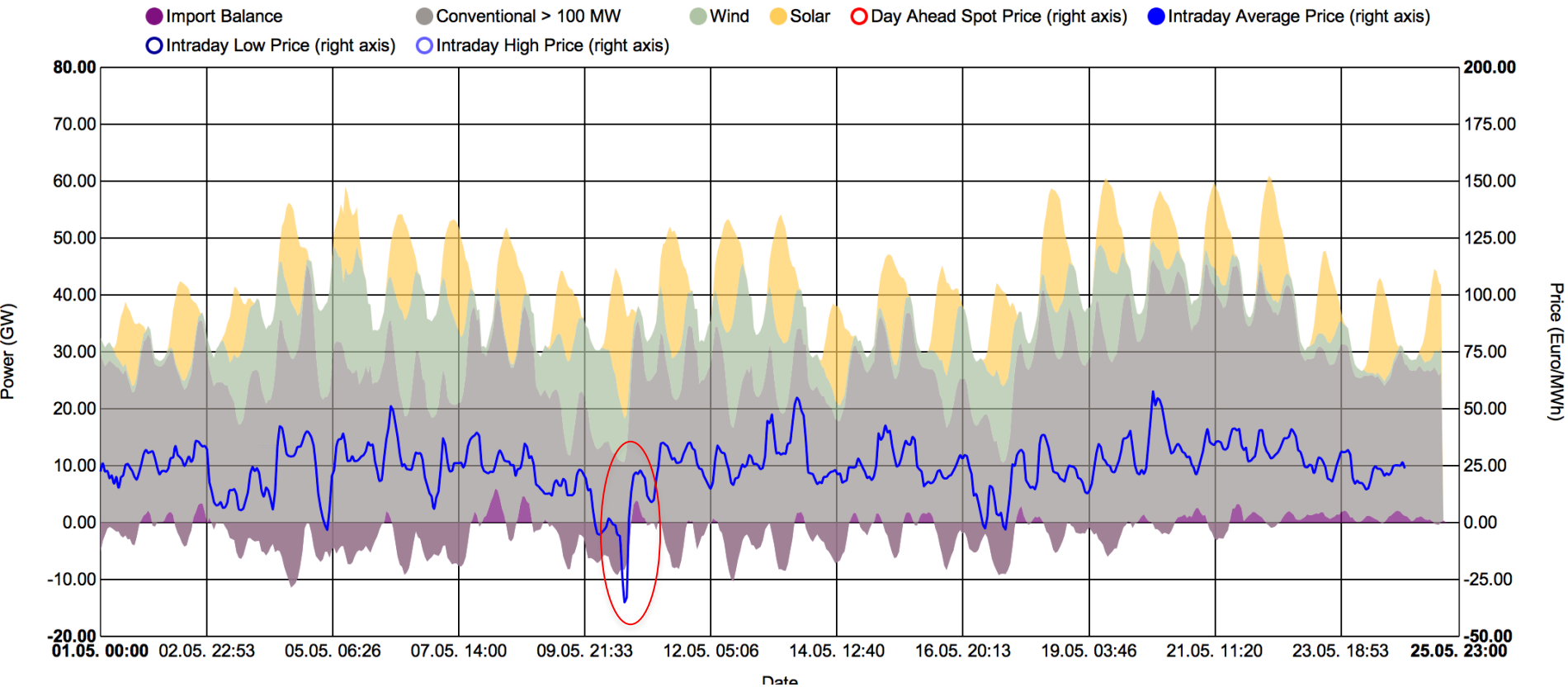
On May 11th, power prices were negative for several hours in Germany. (Source: EPEX)

Electricity production and spot prices in Germany, January 2015



Source: https://www.energy-charts.de/power.htm

Electricity production and spot prices in Germany, May 2015



Source: https://www.energy-charts.de/power.htm

How will this affect the electricity system in the long run?

The model

- Equilibrium model (parallel work with an agent based model).
- Maximizes consumer and produced surplus over each year

The model

Price: $p(q) = p_0 \left(\frac{q}{q_0} \right)^{\frac{1}{\varepsilon}}$

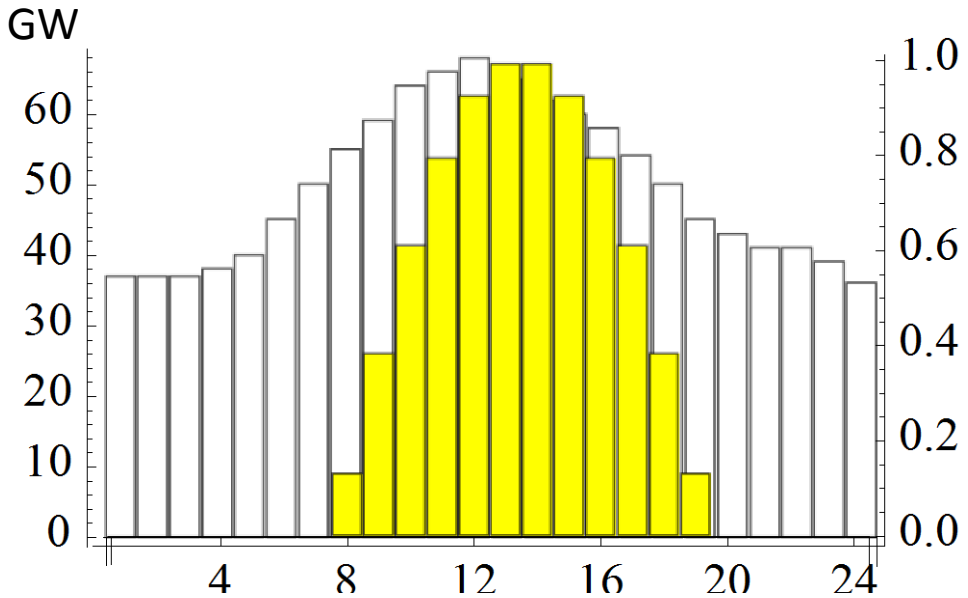
Electricity produced: $q_i = q_0 \left(\frac{r_{c,i}}{p_0} \right)^{\epsilon} - Q$

Capacities of gas and coal are chosen so that consumer and producer surplus is maximized.

$$\Pi(C) = \sum_{t=1}^{24*6} S_{c,t}(C) + \sum_{t=1}^{24*6} \sum_{i=1}^{N} (p_t(C) - r_{c,i}) q_{i,t}(C) - I_a C$$

The model

Demand and solar profile over 24 hours



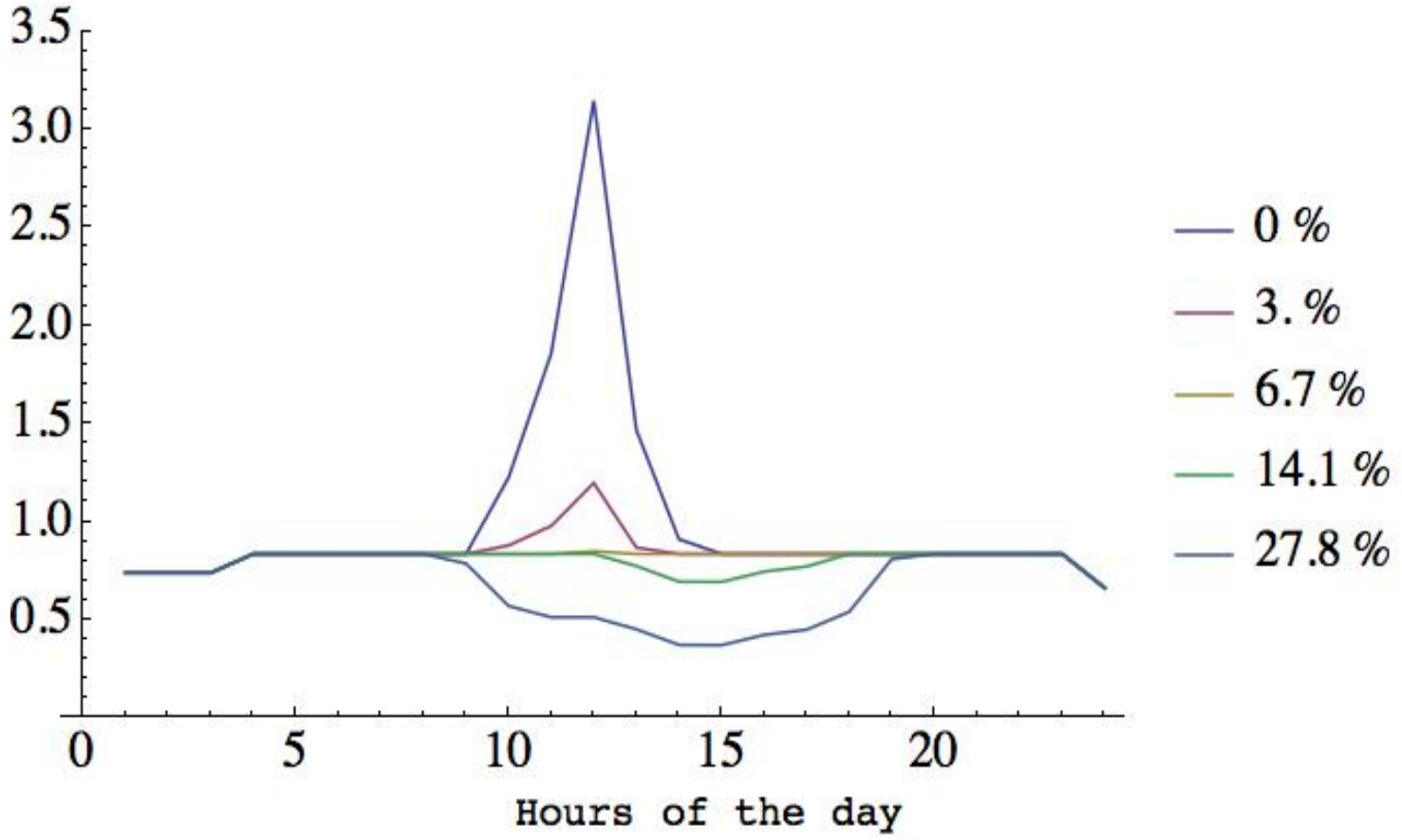
Data for demand from: http://www.ise.fraunhofer.de/en/downloads-englisch/pdf-files-englisch/data-nivc-/electricity-production-from-solar-and-wind-in-germany-2014.pdf

Sustained fossil capacity

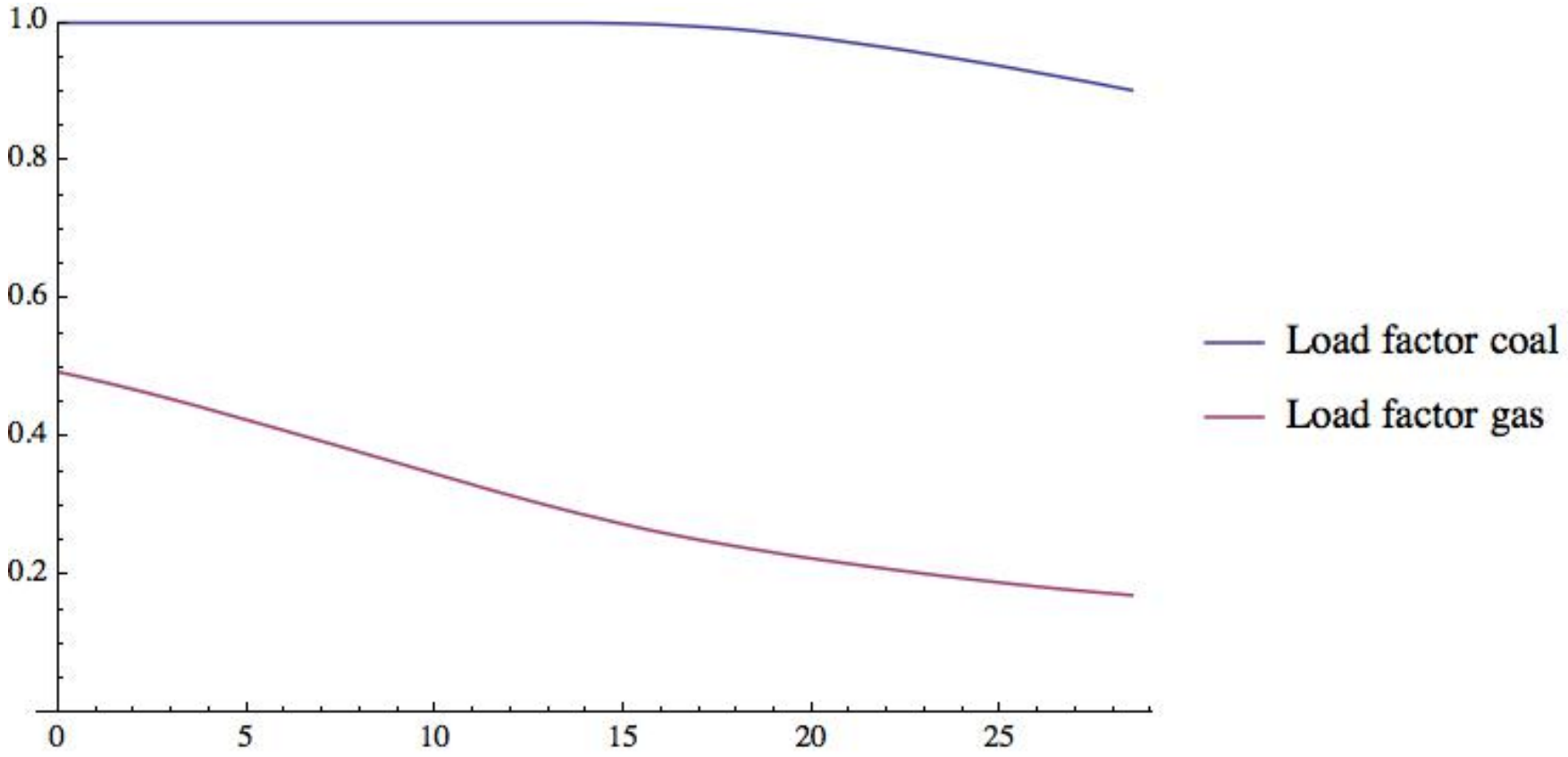
- It takes time for old power plants to shut down
- What happens when the fossil capacity is kept in the system while solar and wind power is increased drastically?

Results –sustained fossil capacity

Hourly prices over an average day, with increasing shares of solar



Results –sustained fossil capacity

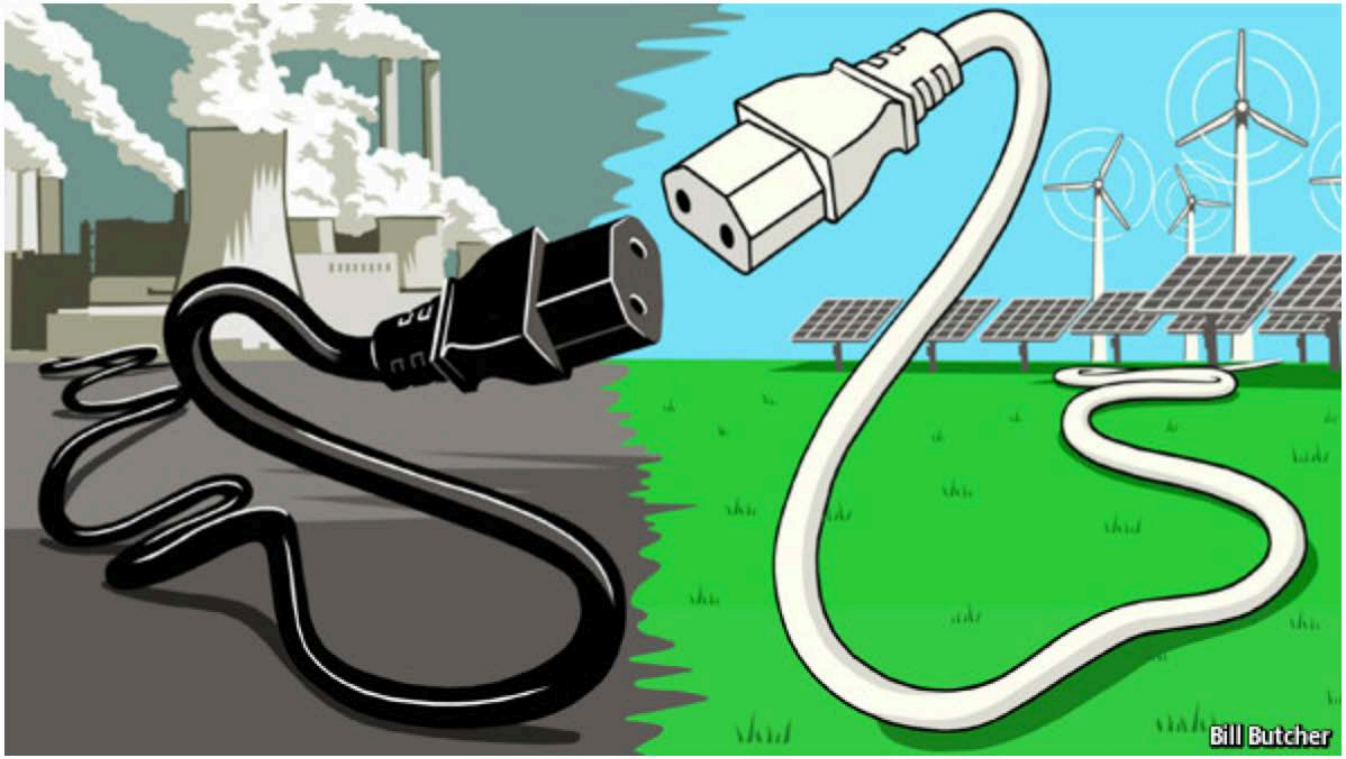


European utilities

How to lose half a trillion euros

Europe's electricity providers face an existential threat

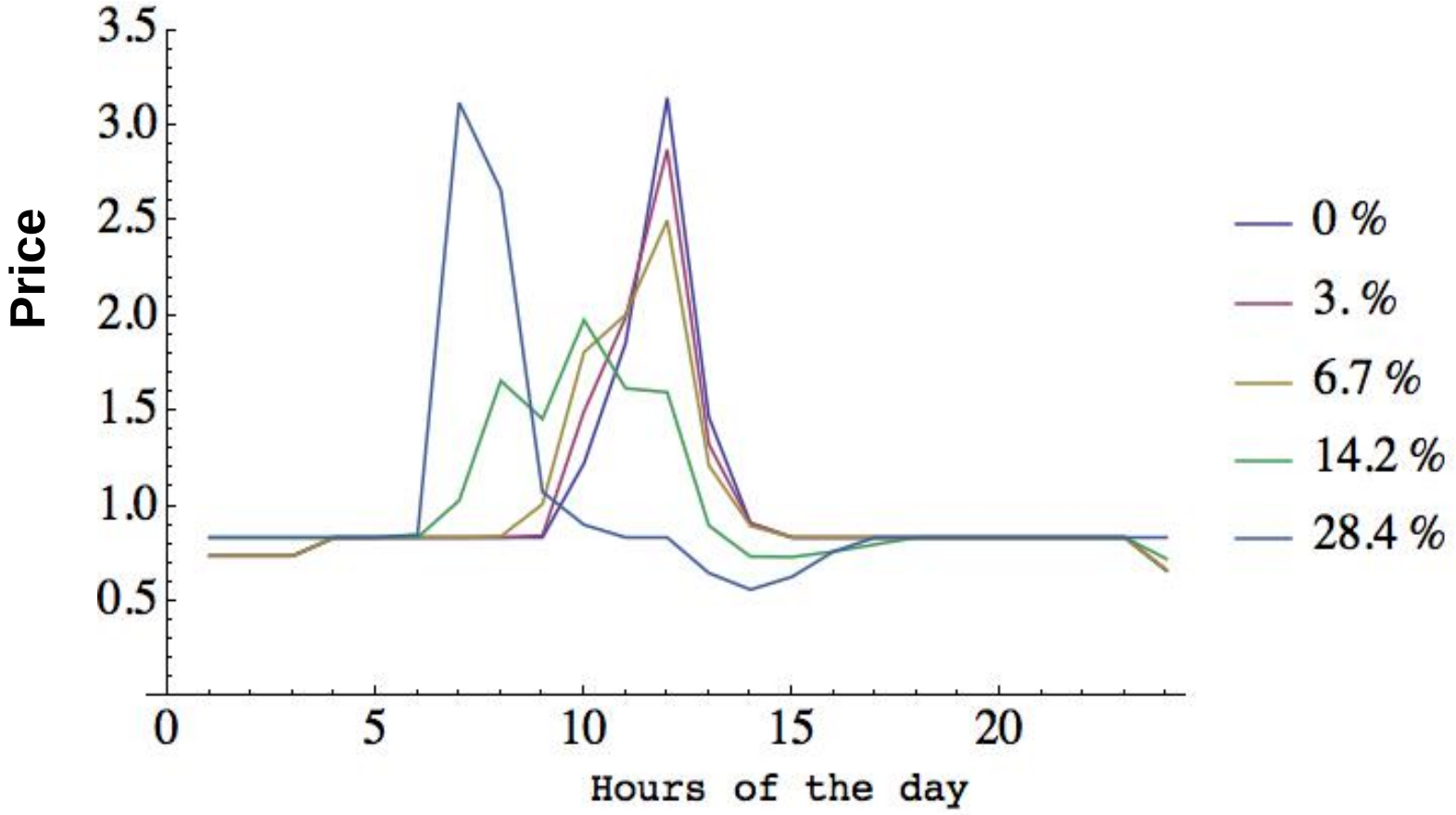
Oct 12th 2013 | From the print edition



Source: http://www.economist.com/news/briefing/21587782-europes-electricity-providers-face-existential-threat-how-lose-half-trillion-euros

Results –optimized fossil capacity

Hourly prices over an average day, with increasing shares of solar



Results-optimized fossil capacity

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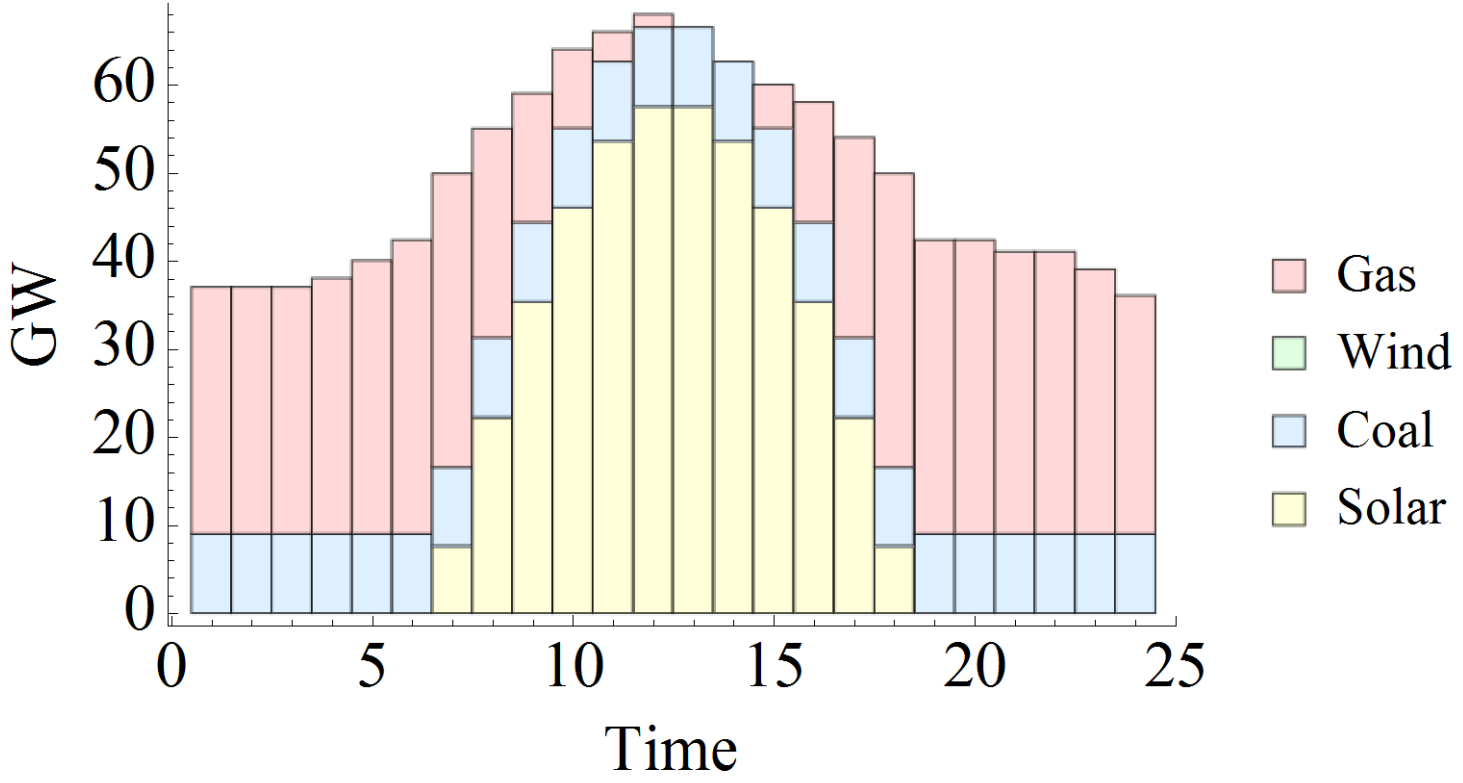
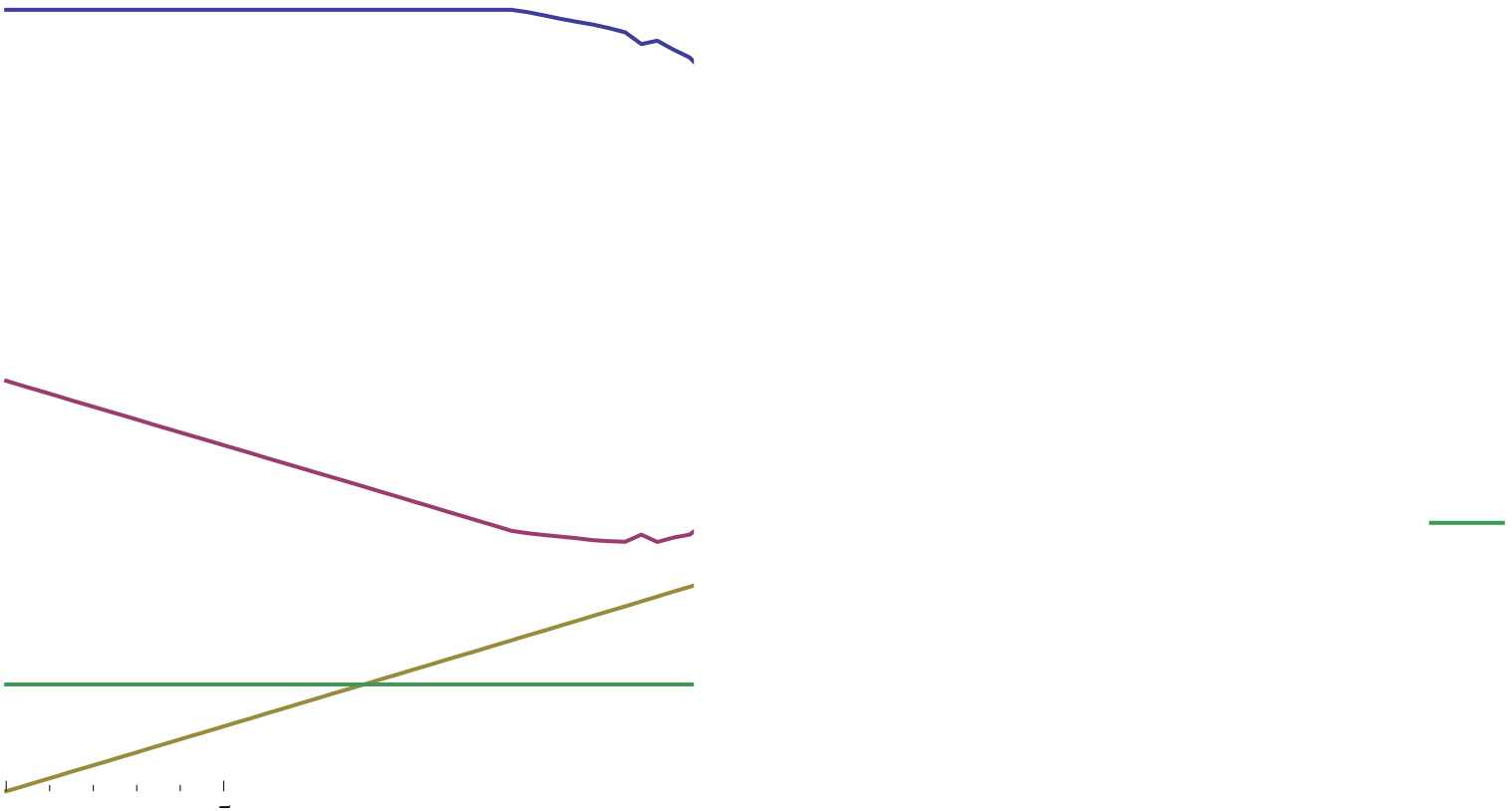
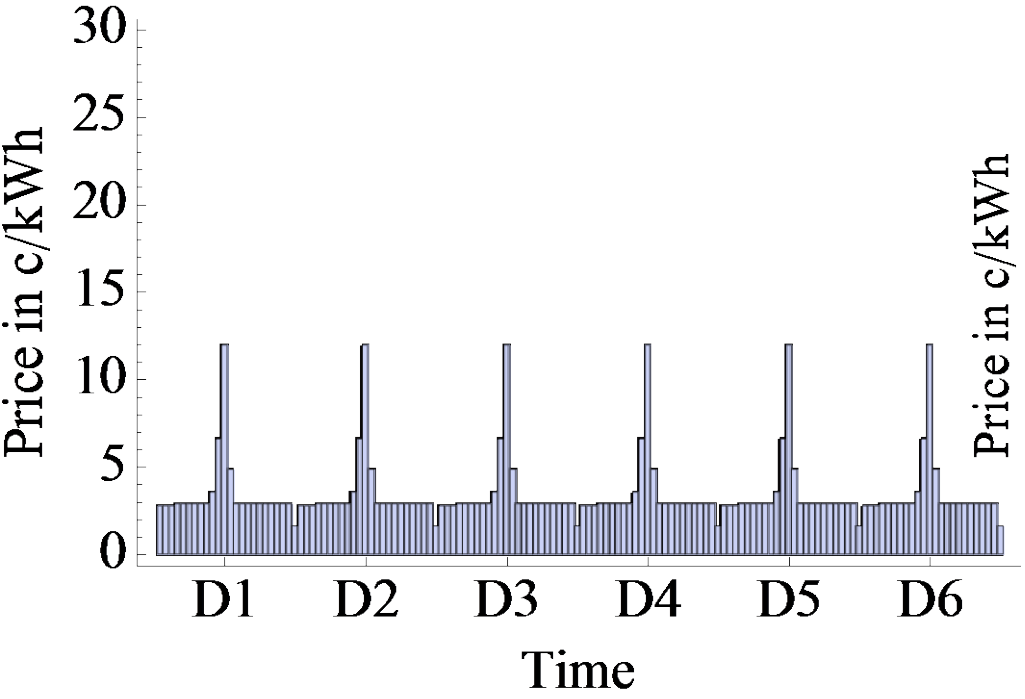


Results -optimized fossil capacity

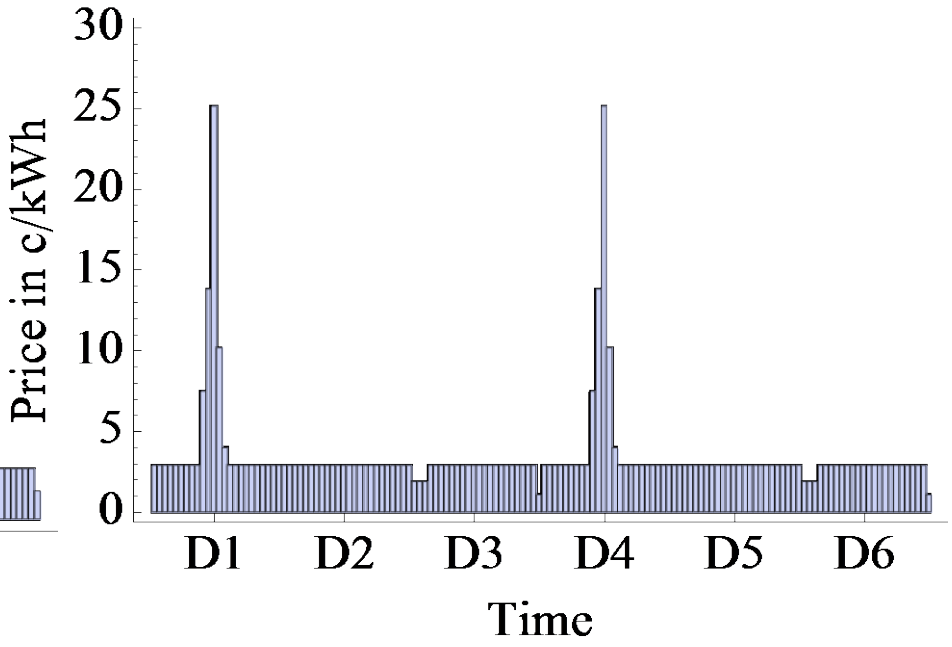
Yearly electricity production, by technology, as a function of solar electricity share



Results -optimized fossil capacity



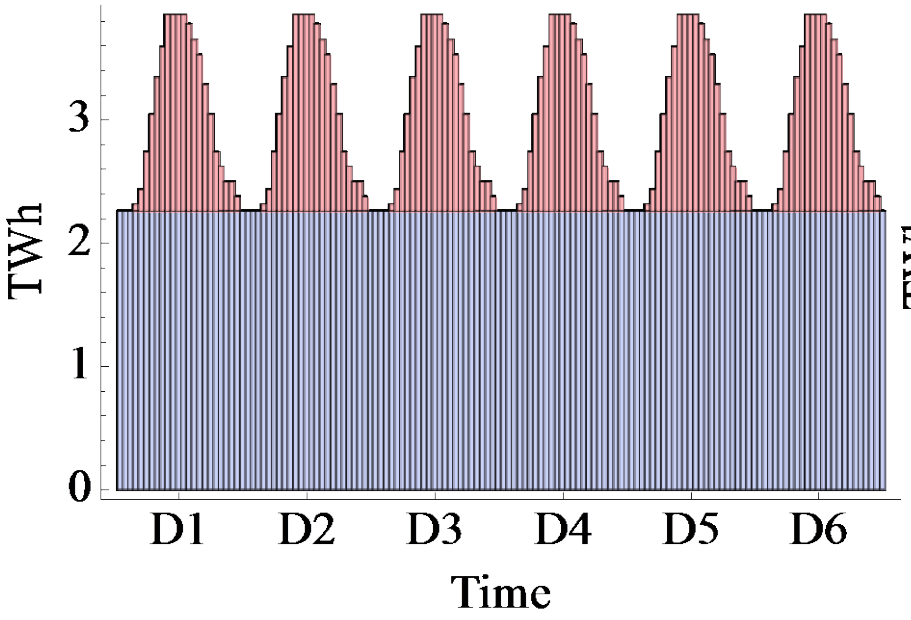
0% electricity production from wind power



30% electricity production from wind power

Results -optimized fossil capacity

Electricity production on the six typical days



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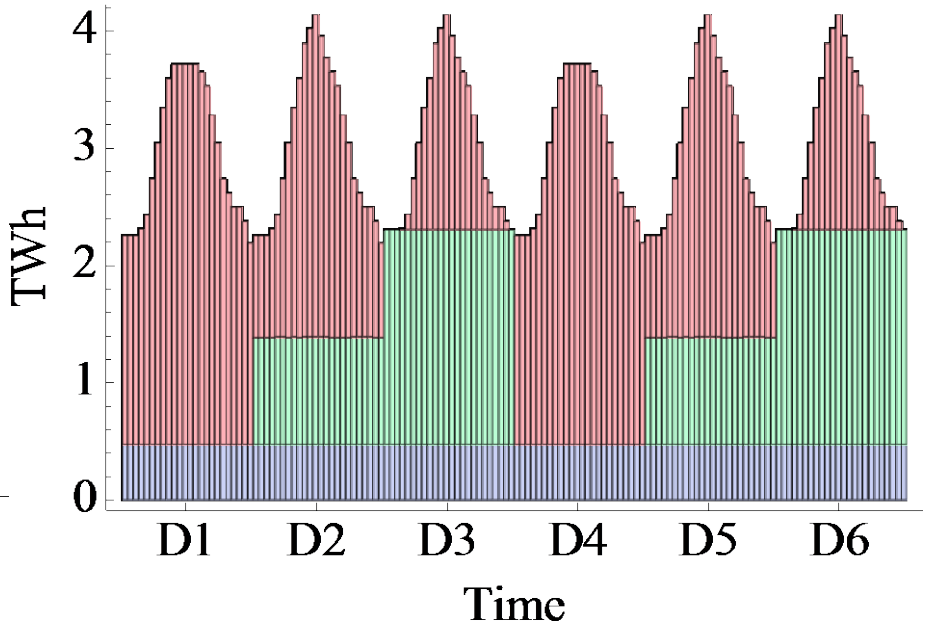

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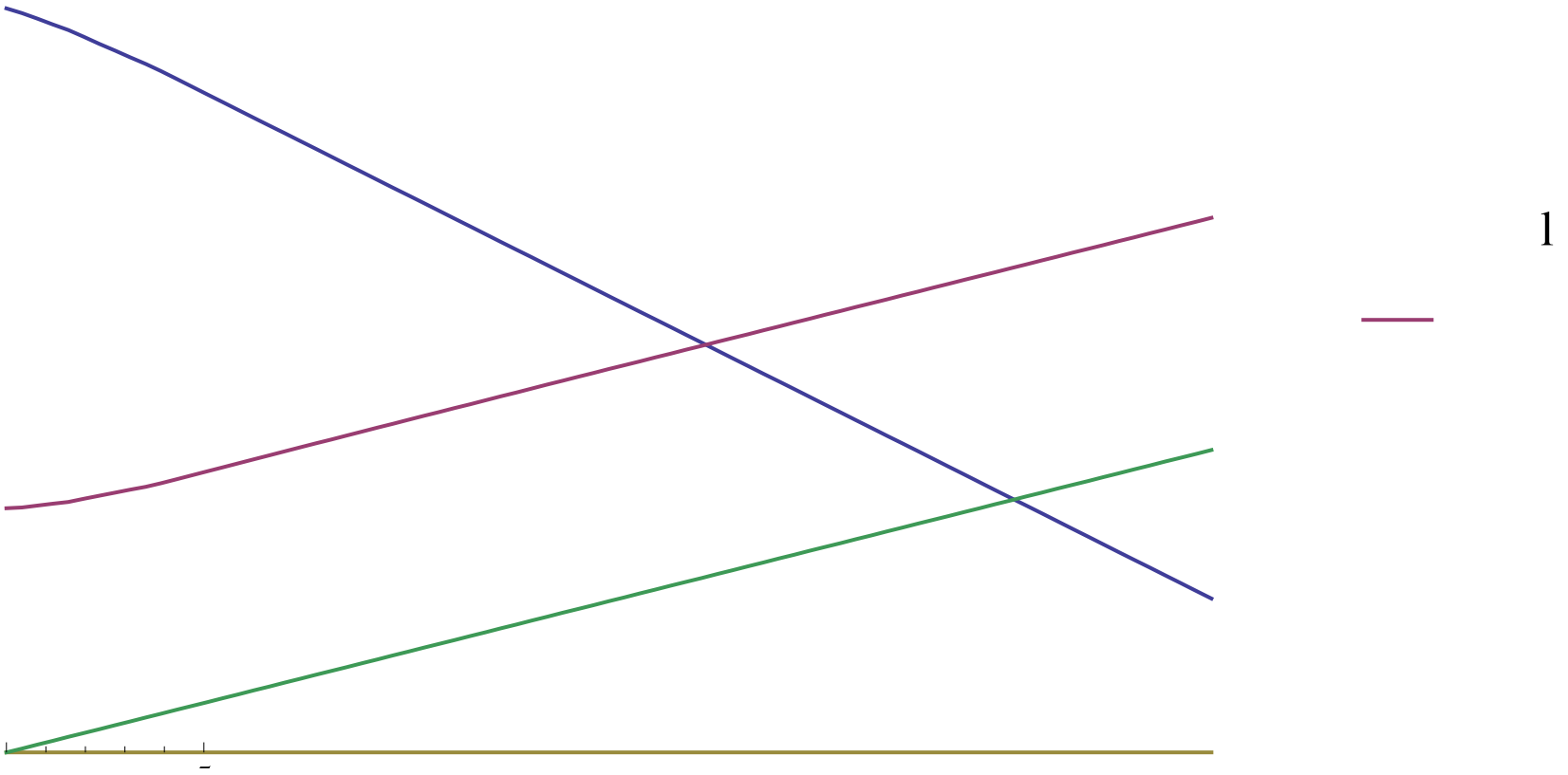
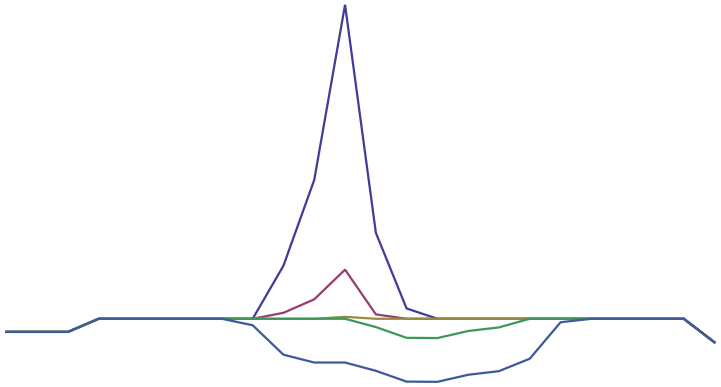
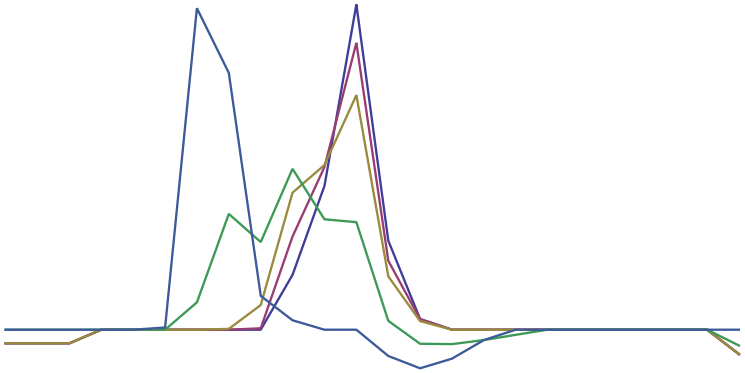


Results -comparison

Sustained fossil Capacity

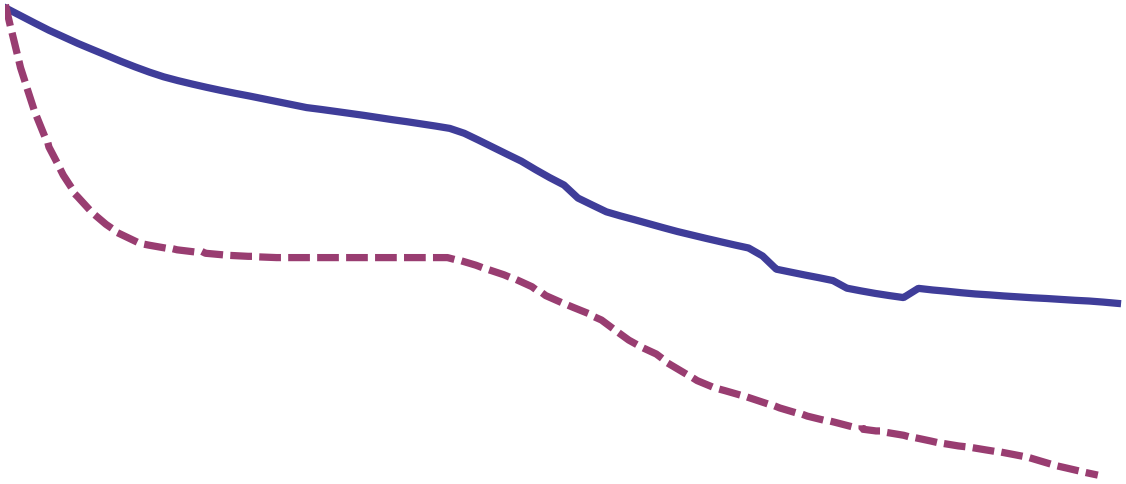


Optimized fossil capacity



Results -comparison

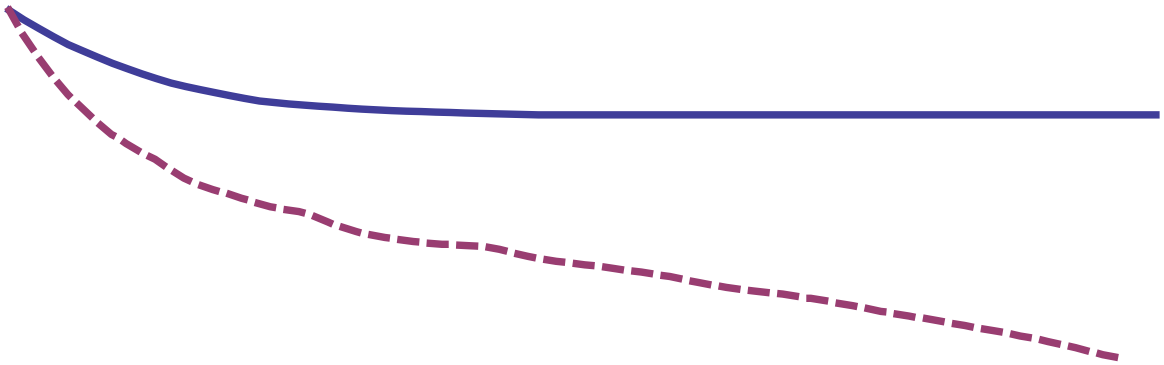
Profit for variable renewable energy



Optimized fossil capacity
Sustained fossil capacity

Results -comparison

Profit for variable renewable energy



Optimized fossil capacity

Sustained fossil capacity

Conclusions

- Variable Renewable Energy causes electricity prices to decrease, as long as fossil capacity is sustained
- Potentially higher price peaks in the long run if fossil capacity is “optimized”
- Profitability of the VRE’s themselves decreases as their share of the system increases.