Renewables in electricity generation

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Outline

I. RES-E backing

II. Electricity markets

III. RES in wholesale E-markets

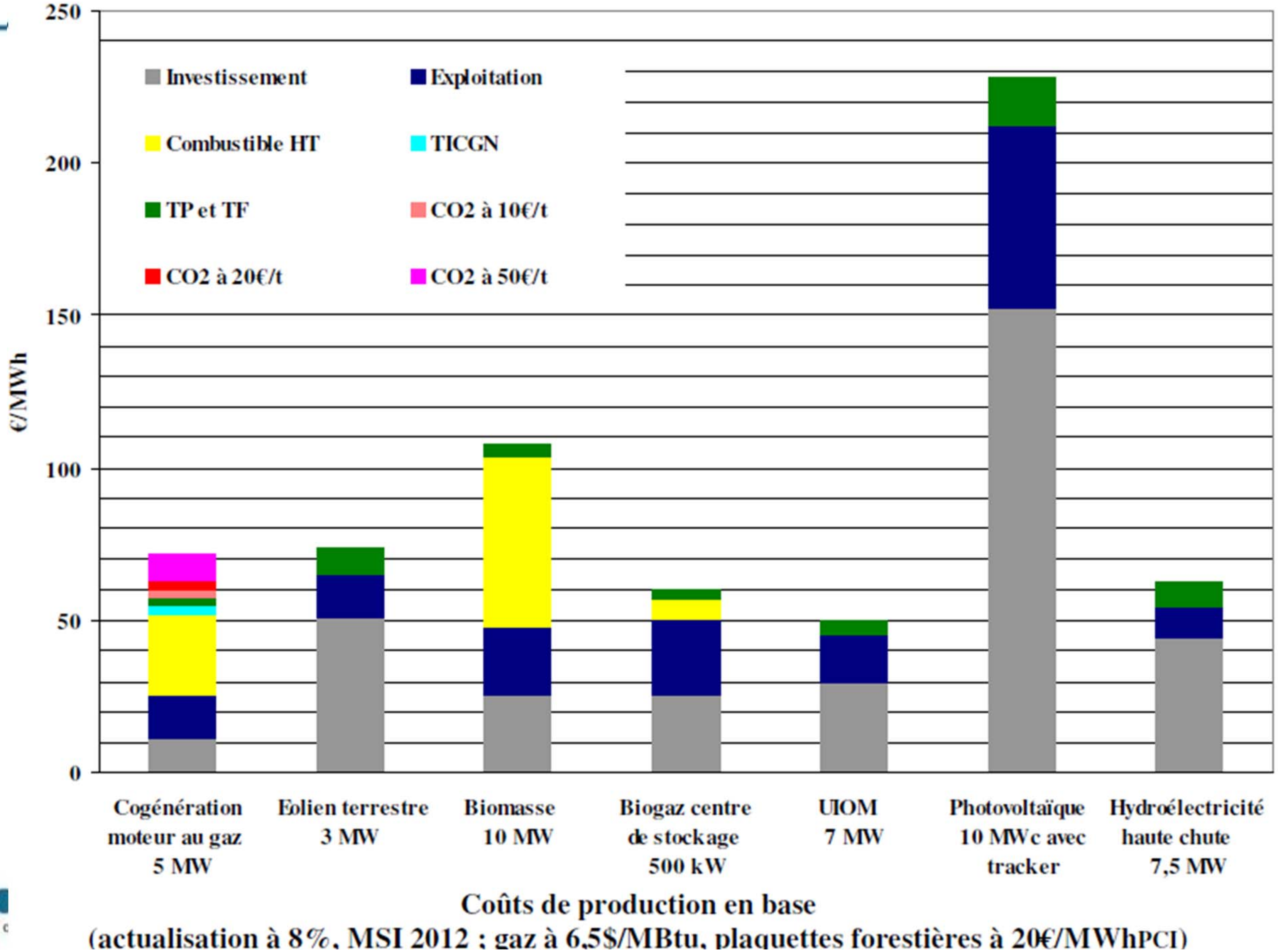
I. RES-E backing

Energy and Climate Policy in Europe

- for 2020, "*Energy and Climate Change Package*" and "*Energy Efficiency Package*" (*2007-2008-2009*)
  - to reduce greenhouse-gas emissions by 20% below 1990 levels
  - to boost the share of renewables in the total energy mix to 20%
  - to save 20% energy
- March 2011: "*Roadmap for moving to a competitive low-carbon economy in 2050*"

First hurdle for renewables: costs

source: "Synthèse publique de l'étude des coûts de référence de la production électrique", Ministère du développement durable



Second hurdle for renewables: intermittency

Wind power in 2009	Germany	Spain	UK	France
Production (GWh)	37500	37773	9304	7819
Installed capacity (MW)	25777	19148	4424	4626
Average duration at full capacity (hours)	1454	1972	2103	1690

Source: **EurObserv'ER ,** February 2011, www.eurobserv-er.org/pdf/baro201.pdf

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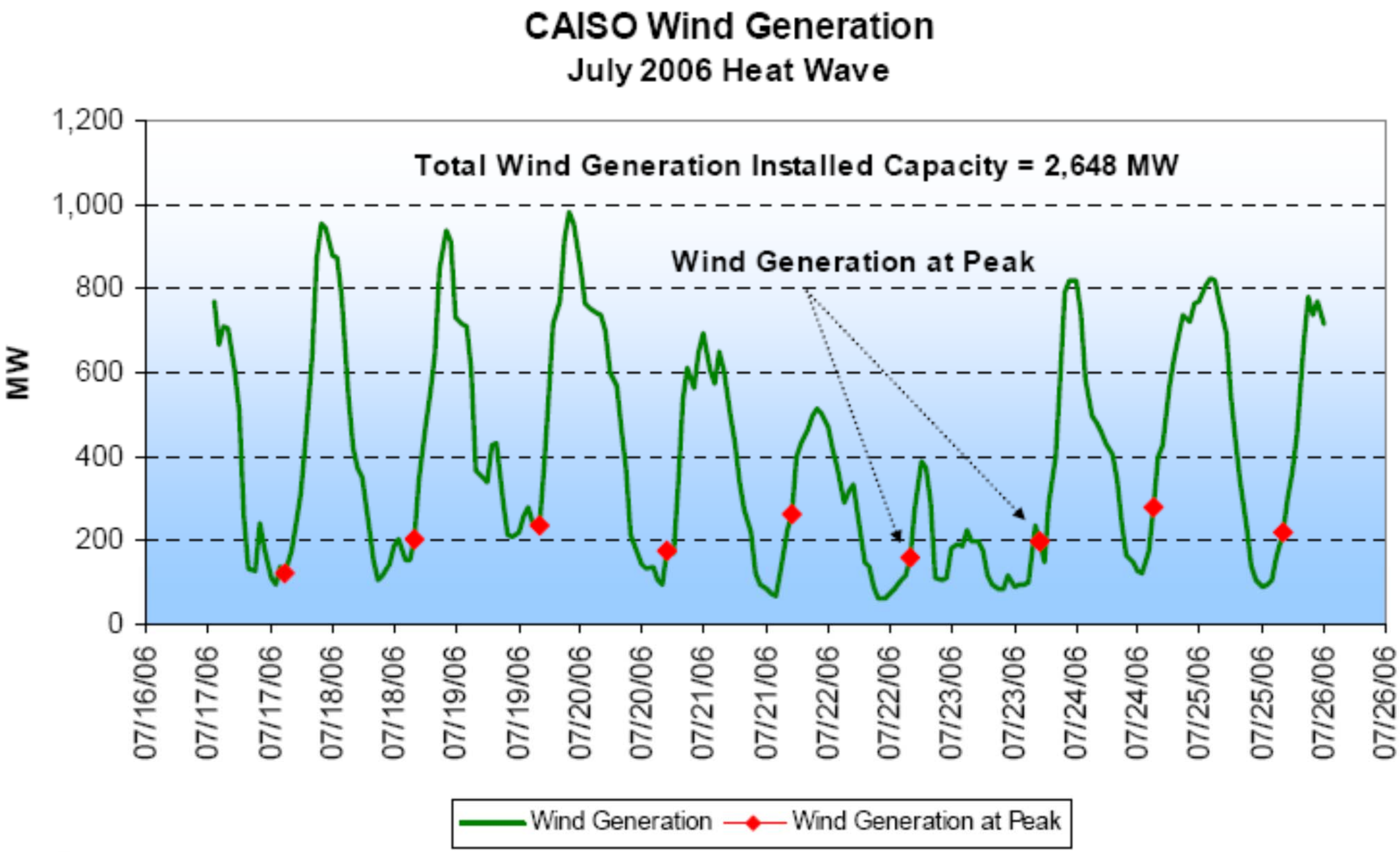
Intermittency (continued)



Source: NERC (2009)

Third hurdle: geographical dispersion

- Large scale development of renewable creates significant network expansion and management issues
- Grid upgrade during the next decade:
  - USA: $b50-100; UK: £b20
- Huge investment remains to be done
- Distributors face new challenge
  - Connection
  - Balancing
  - Metering

Incentives for renewable resources only address the cost issue

		Direct		Indirect
		Price-driven	Quantity-driven	
Regulatory	Investment focussed	• Investment incentives • Tax incentives	• Tendering system	• Environmental taxes
	Generation based	• Feed-in tariffs • Rate-based incentives	• Tendering system • Quota obligation based on TGCs	
Voluntary	Investment focussed	• Shareholder programmes • Contribution programmes		• Voluntary agreements
	Generation based	• Green tariffs		

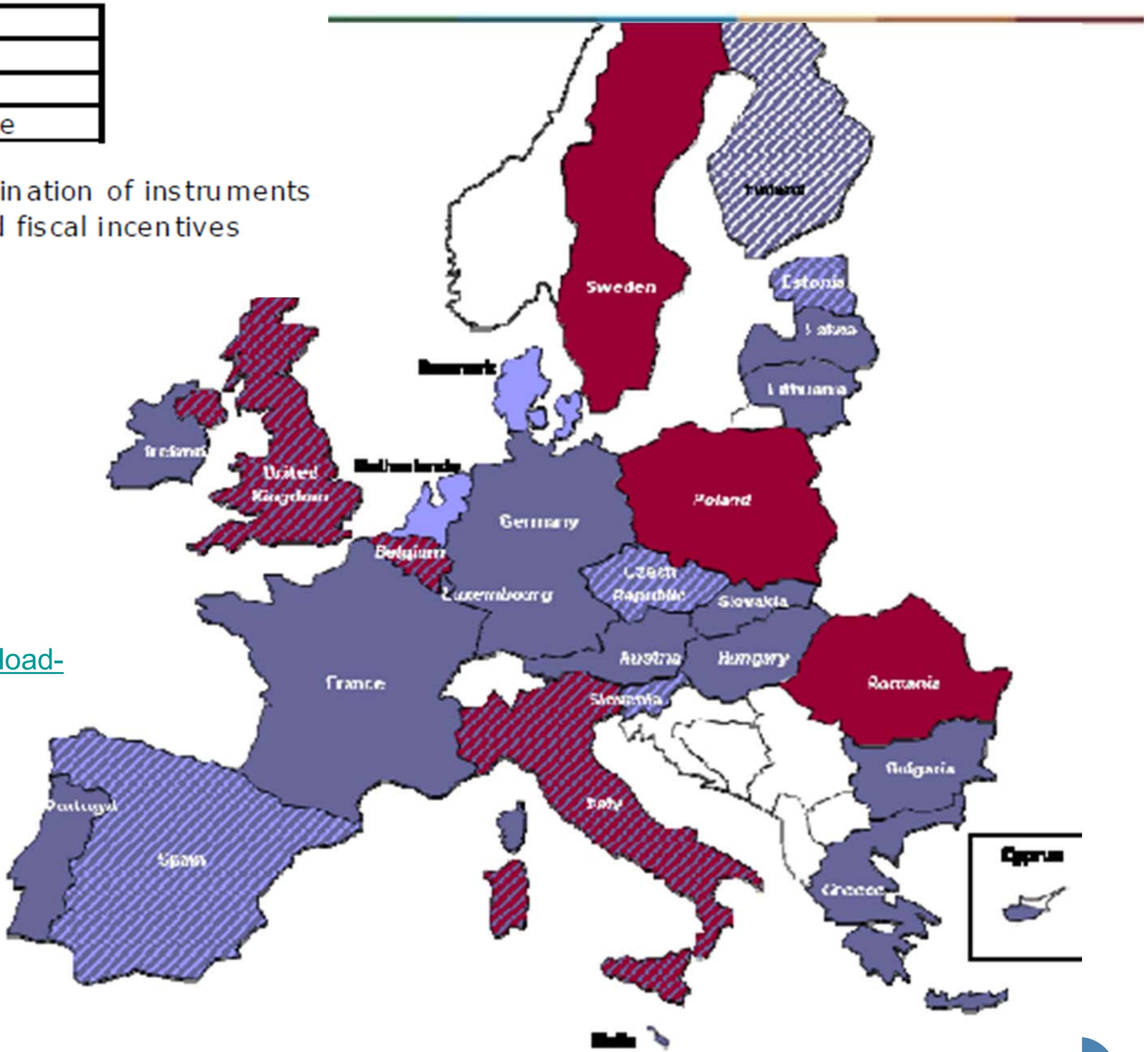
Source: Held *et al*. (2006)

EU countries according to their support mechanisms for RES-E

	Quota obligation
	Feed-in tariff
	Feed-in premium
	Other instruments than the above

Notes:

1) The patterned colours represent a combination of instruments
2) Investments grants, tax exemptions and fiscal incentives are not included in this picture.



Source: "Recent experiences with feed-in tariff systems in the EU – A research paper for the International Feed-In Cooperation" November 2010
www.feed-in-cooperation.org/wDefault_7/download-files/8th-workshop/IFIC_feed-in_evaluation_Nov_2010.pdf

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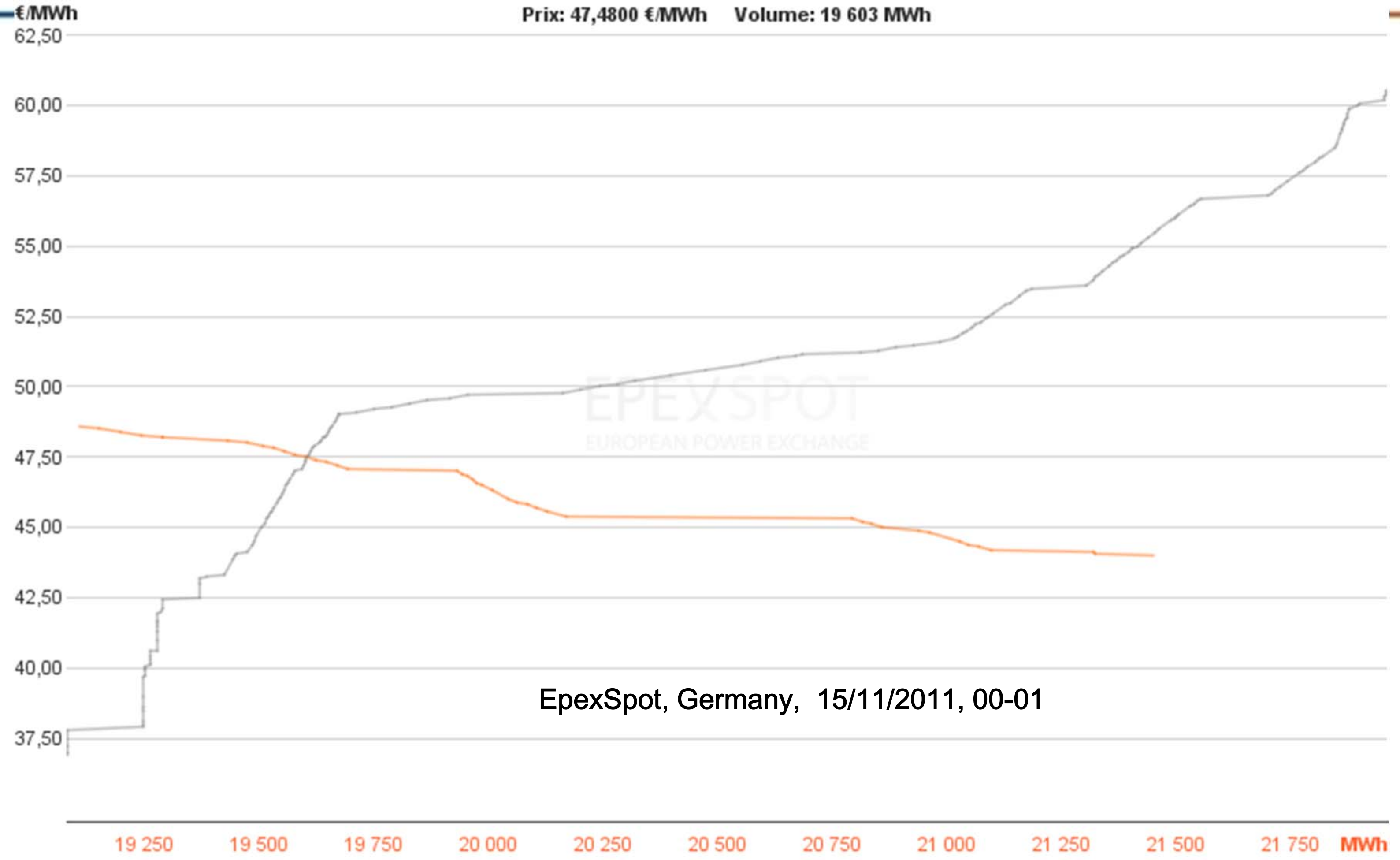
II. Electricity markets

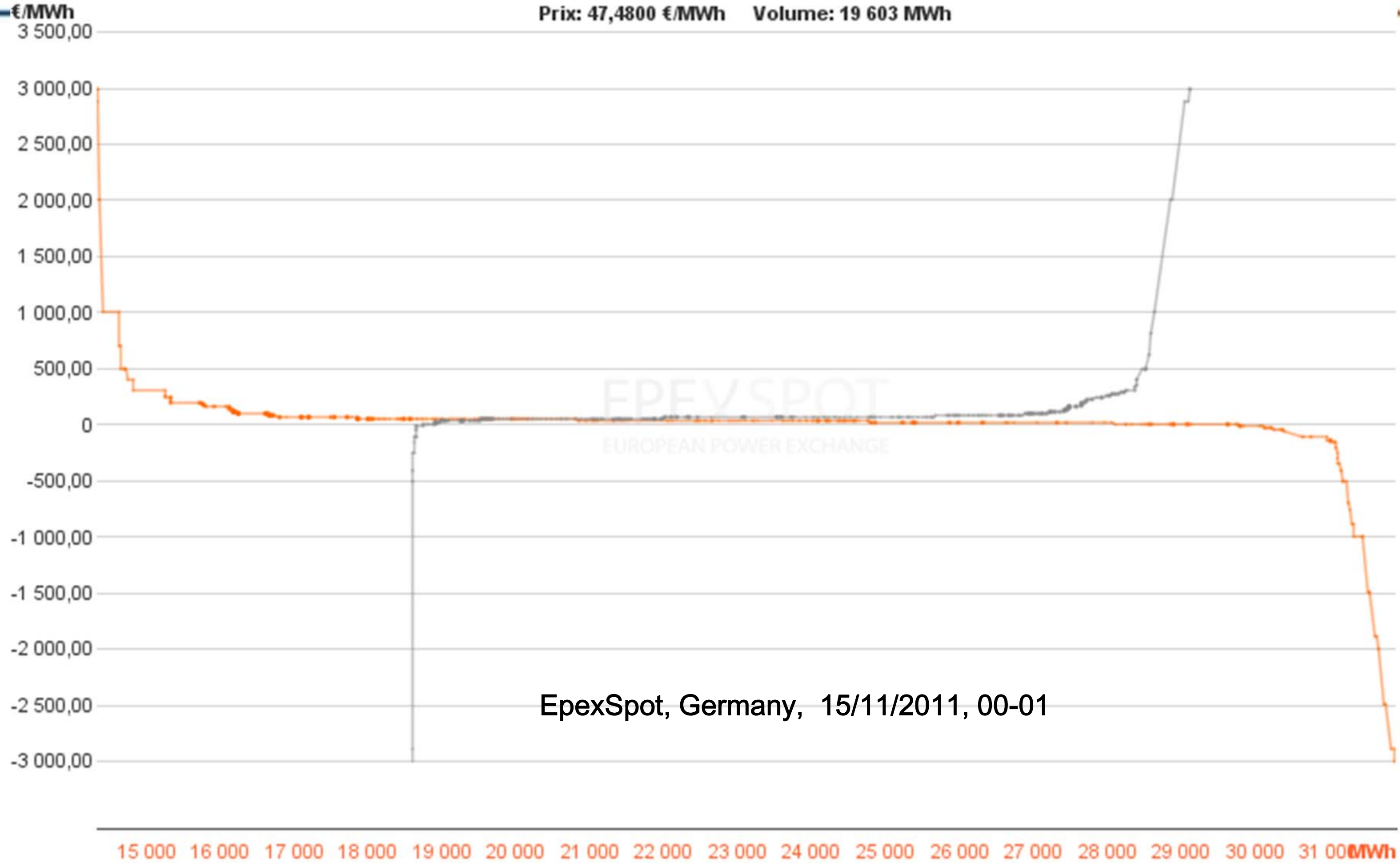
Energy exchange

- In the EU: APX, EPEX, IPEX, Nord Pool, OMEL, …
- Spot market :
  - Day-Ahead Market where producers, wholesalers and eligible final customers may sell/purchase electricity for the next day;
  - Intra-Day Market (MI), where producers, wholesalers and final customers may modify the injection/withdrawal schedules of the Day-Ahead;
  - Ancillary Services Market where TSOs procure the dispatching services needed to manage, operate, monitor and control the power system.
- Forward Market with delivery taking/making obligation, where participants may sell/purchase future electricity supplies.
- What is the impact of RES-E on wholesale markets?

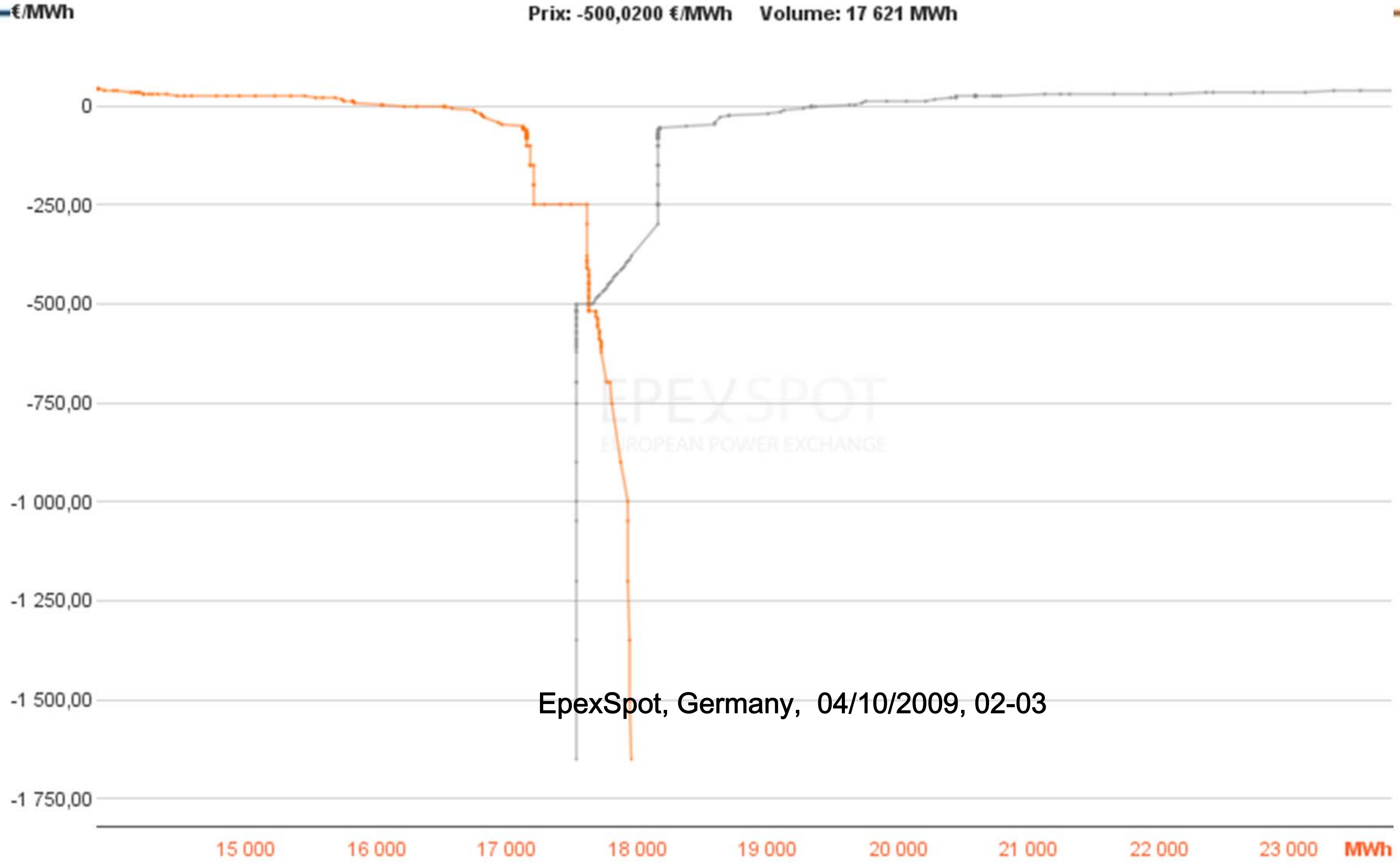
A “normal” hourly market …



… where some bids are surprising …



… resulting in the possibility of non-standard equilibrium.



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III. RES in wholesale E-markets

The economic rationale for negative prices

- Proposition:
  - Negative prices are due to wind-powered plants using opportunistically a market rule designed for thermal plants

- Analysis in three steps
  - Why are negative bids allowed?
  - Why do some buyers and sellers bid negative prices?
  - Why does the market clear at negative price?

Why are negative bids allowed?

- Assumption:
  - Authorities design markets with the objective of welfare maximization

- Consequence:
  - It must be true that, under some circumstances, electricity has an optimal negative value, which means <u>both negative marginal surplus and negative marginal cost</u>

Negative marginal surplus

- $\max\limits_{q^g, q^c} \quad S(q^c) - C(q^g)$

- Negative marginal surplus can be explained by saturation: $S'(q^c) < 0 \text{ if } q^c > \tilde{q} = arg\{S'(q^c) = 0\}$

- Nevertheless, why should q^c be pushed beyond $\tilde{q}$?

- Because the disposal cost of excess electricity is larger than the disutility of $(q^g - \tilde{q})$. Recall: electricity is not storable at large scale.

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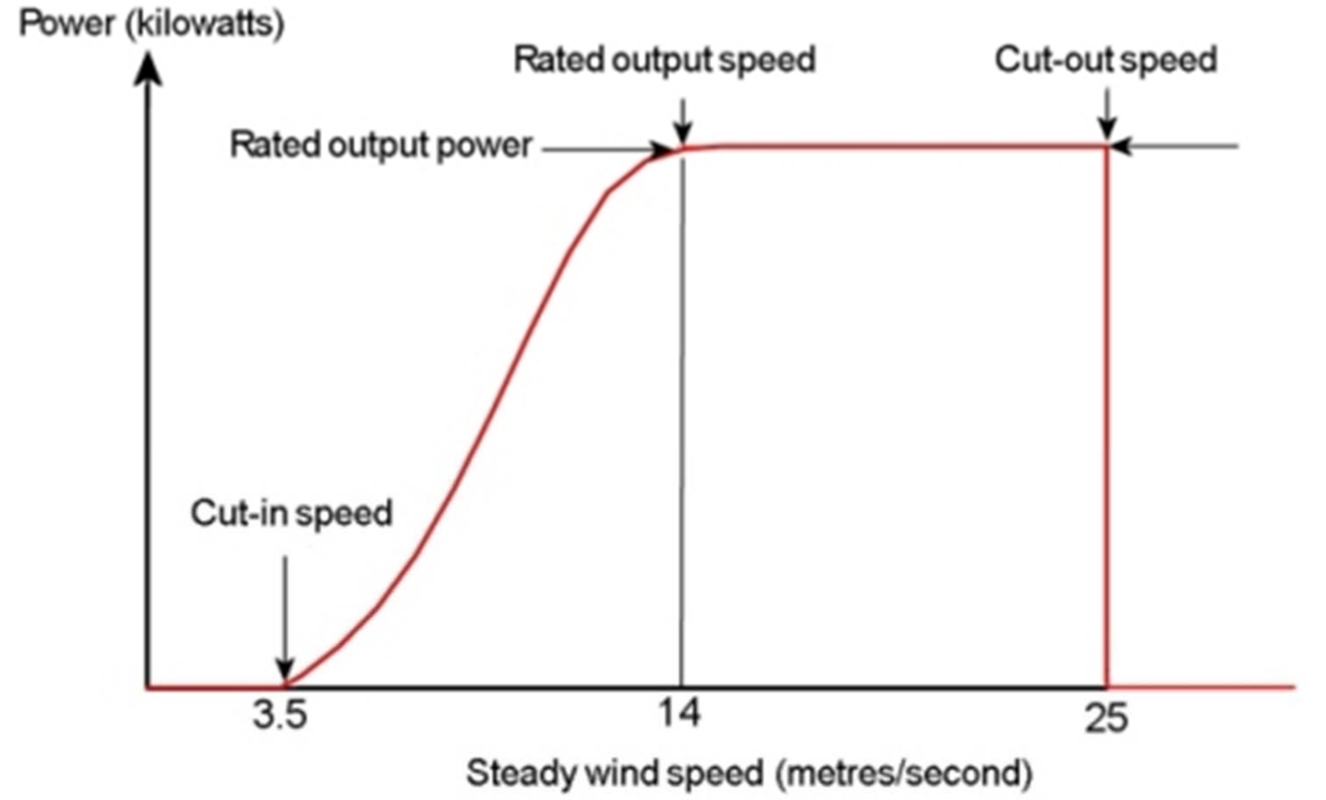
Negative marginal cost

- Negative marginal cost can be explained by output restrictions and intertemporal complementarity in thermal plants
  - Start-up, warm-up, shutdown delays and costs
  - Positive and negative ramp rate (ΔMW per minute)
- Example

  $C(q_n, q_d) = c(0)q_n + c(q_n)q_d$ where $c'(q_n) < 0$

  Then $\frac{\partial C(q_n,q_d)}{\partial q_n} = c(0) + c'(q_n)q_d < 0$ when expected q_d is large
- By contrast, wind turbines can be shutdown at no cost

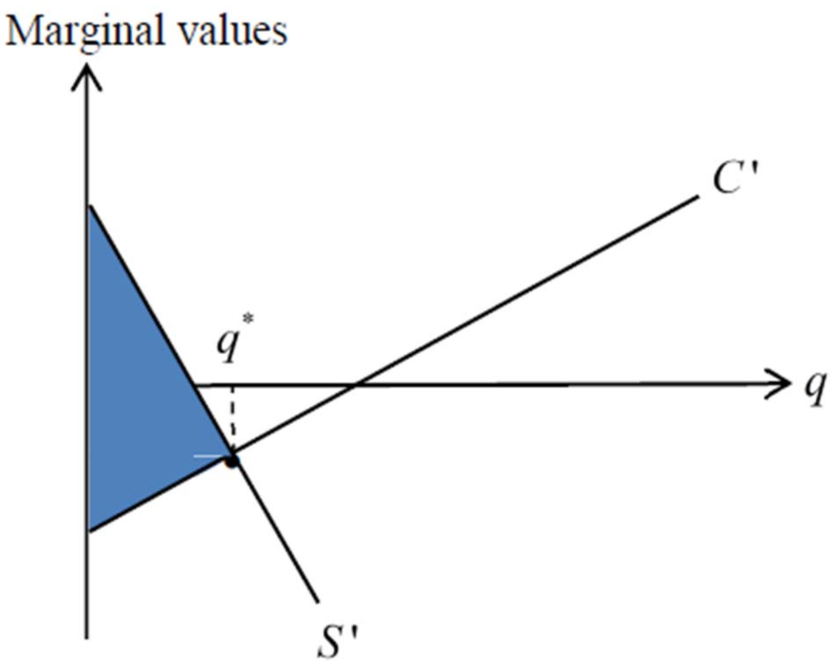
Power in the wind



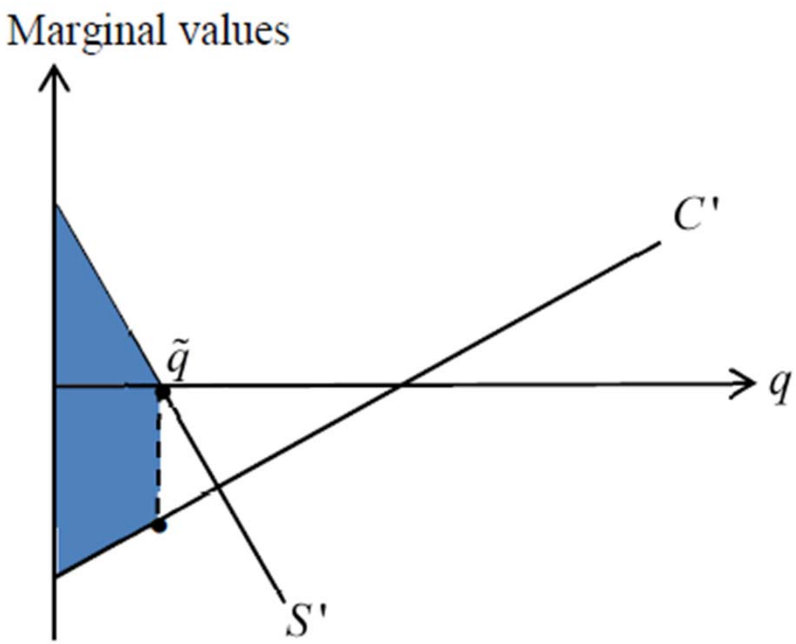
Typical wind turbine power output with steady wind speed.

source : www.wind-power-program.com/turbine_characteristics.htm

In a nutshell, non-negativity restrictions decrease welfare …

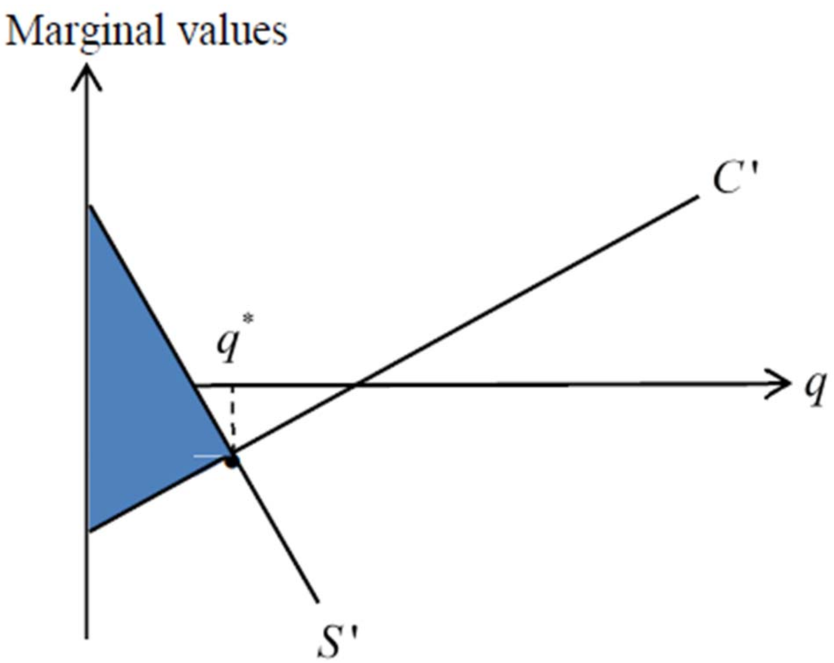


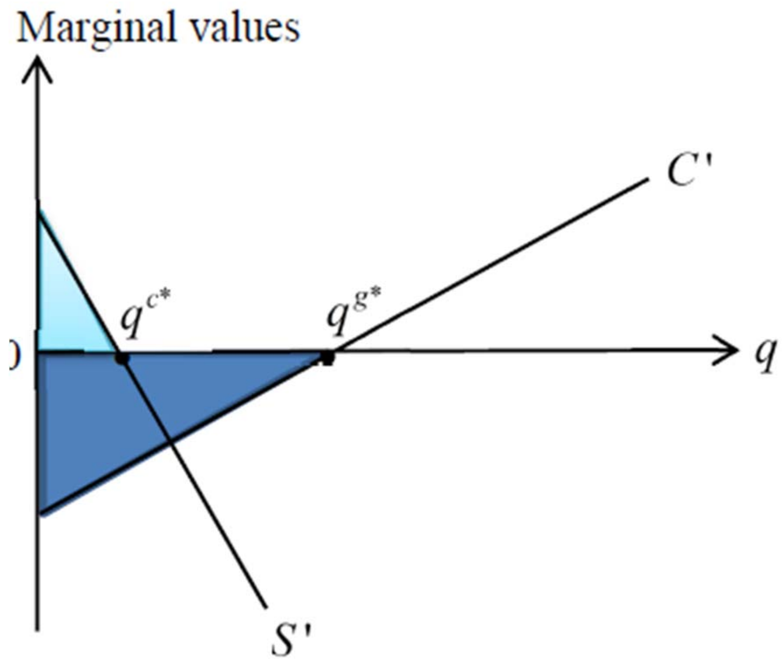
$$\underset{q^c, q^g}{Max} \; S(q^c) - C(q^g)$$
$$s.c. \quad q^c = q^g$$



$$\underset{q^c, q^g}{Max} \; S(q^c) - C(q^g)$$
$$s.c. \quad S'(.) \geq 0$$
$$\text{et} \quad q^c = q^g$$

… and deletion of excess energy do even better





$$\underset{q^c, q^g}{Max}\ S(q^c) - C(q^g)$$
$$s.c. \quad q^c = q^g$$

$$\underset{q^c, q^g}{Max}\ S(q^c) - C(q^g)$$

Why do some buyers and sellers bid negative prices?

- Thermal plants
  - Are ready to pay to be included into the merit order because of the aforementioned restrictions and complementarities
  - Some thermal plants with well-filled order book are ready to make way to other producers; they want to buy energy at negative price

- TNO and DNO must compensate for thermal losses at any price; negative price is a windfall gain.

Windfarms

- Windfarms revenue is a tariff depending on the energy injected into the grid:
  - feed-in tariff
  - premium on top of the spot price
  - TGC
- Given that windfarms
  - receive a revenue per kWh equal to
    - the spot price p plus the administrative reward β when producing
    - nil otherwise,
  - Incur a zero operating cost,
- they want to inject electricity when

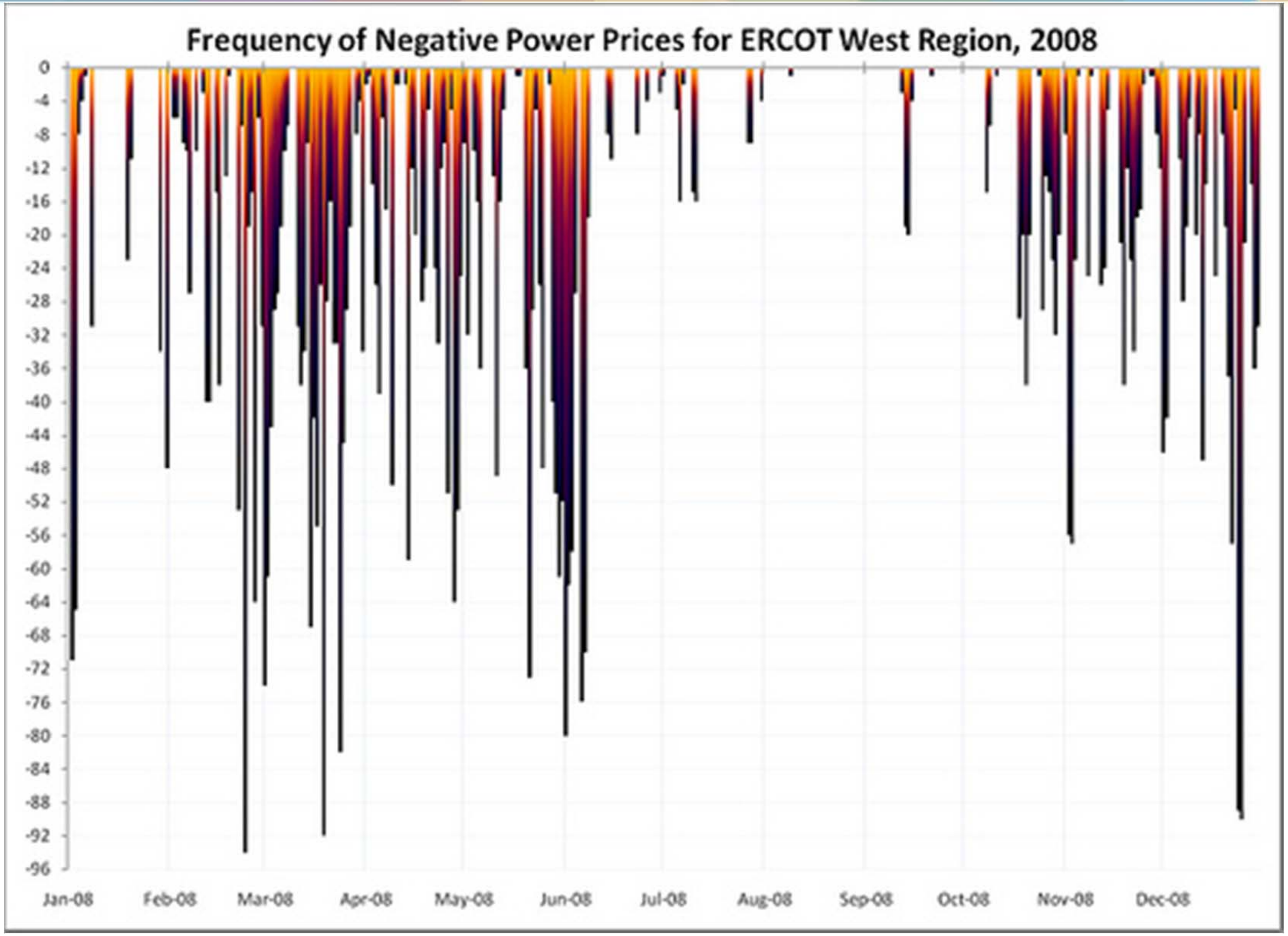
$$p + \beta \geq 0 \quad \Rightarrow p \geq -\beta$$

Why does the market clear at a negative price?

- Unsurprisingly, because there is production in excess of demand
  - It occurs at night when demand is low and thermal plants are preparing for day peak hours
  - It occurs in windy regions

- Not very frequent events, but the number will increase with the development of wind-powered plants.

ERCOT



In the first half of 2008, prices were below zero nearly 20 percent of the time. During March, when negative prices were most frequent, prices were below zero about 33 percent of the time. After mostly taking the summer off, negative power prices were back to near 10 percent in October

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Some conclusions

- Negative prices intrinsically efficient for thermal producers but wind farmers free-ride on the mechanism
- Thermal plants must bid lower than they would if they want to be dispatched
- Increase the volatility of prices
- Reallocate a share of production rents to consumers
- Strong incentive to install transmission lines and storage facilities (pump storage)