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Modelling the New Model: The electricity wholesale market after the Helm Review

Richard Green

BIEE Seminar, 7 February 2018

This is a tidied-up, slightly edited, version of the slides presented at the seminar, with thanks to attendees for helpful suggestions. Use the mouse on the printed bubbles to see my comments

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The Helm Review

A brief, selective, summary

- Complexity and winner-picking have increased costs
- Capacity auction (based on Equivalent Firm Power) is the most efficient way to meet security of supply
- Carbon tax (economy-wide, with border adjustment) is the most efficient way to meet carbon targets
  - Alternatively, add a carbon-constrained second stage to the capacity auction
- Network regulation should be reformed
  - System Operators would tender for many functions
- Suppliers should compete on a published supply margin and pass through all other costs transparently

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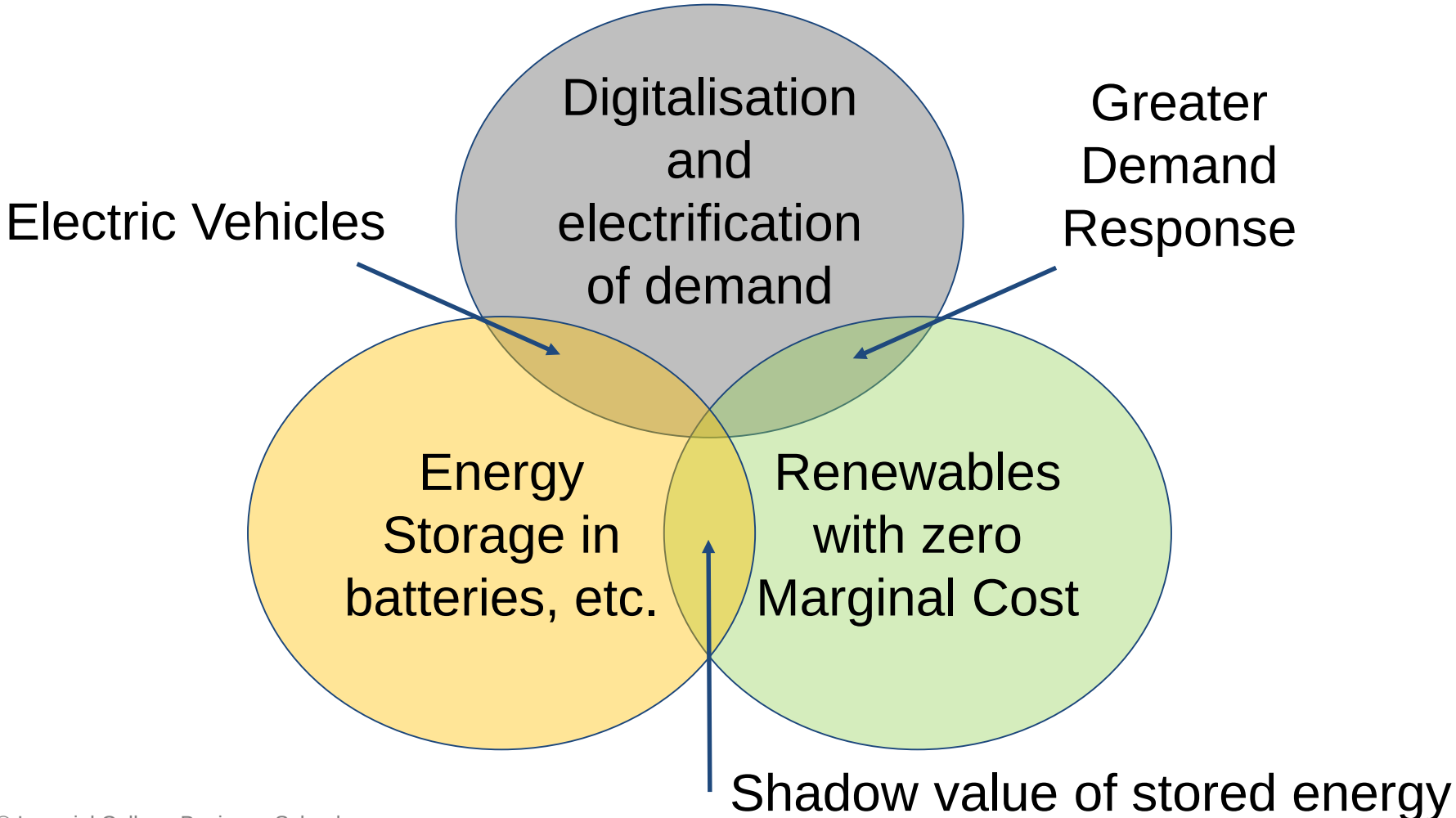
Three technological trends

(mostly) Chapter 6 of the Review



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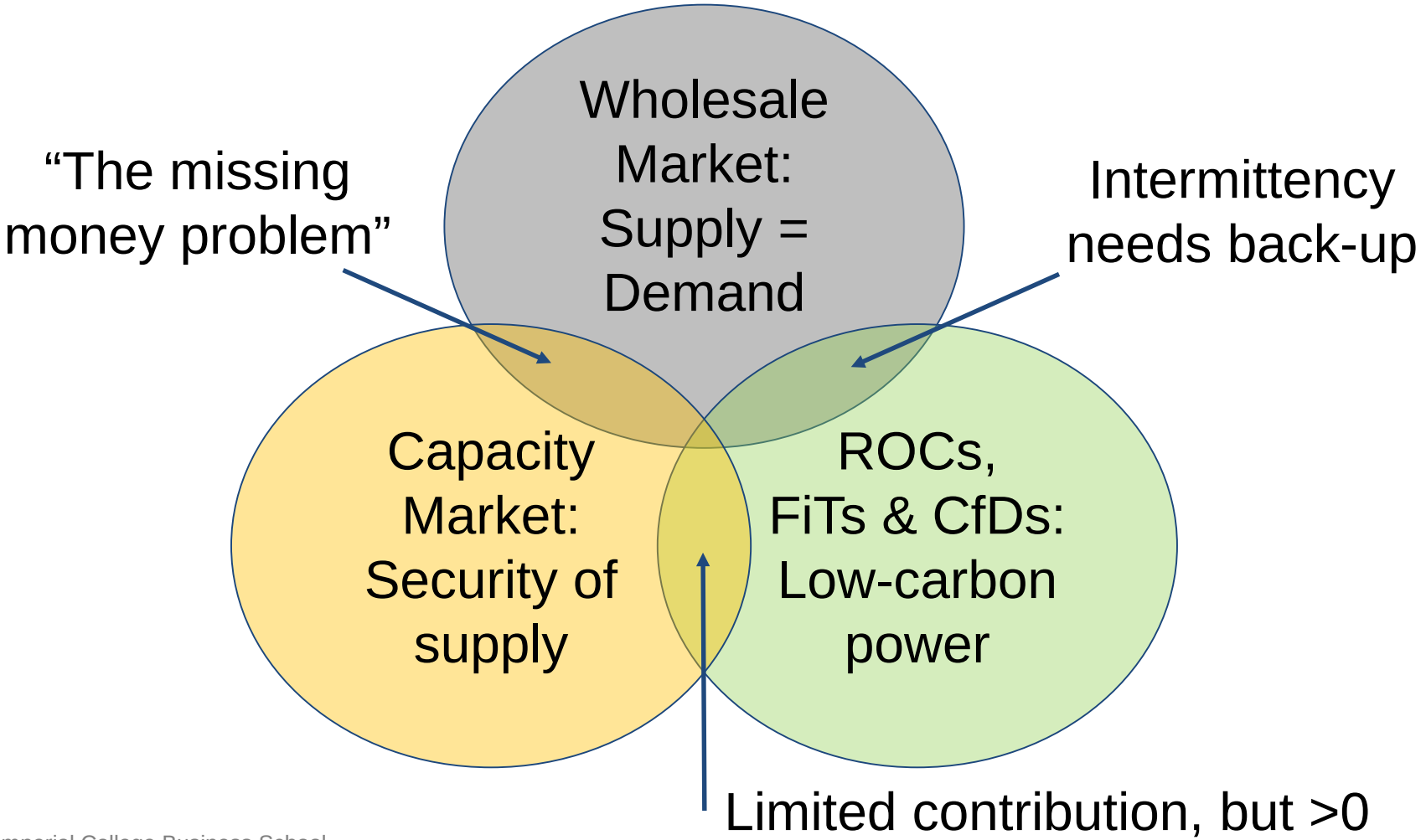
Electricity Generation

Chapter 7 of the Review



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The wholesale market

Chapter 7 of the Review

- Capacity costs will rise relative to running costs

- Much low-carbon output is effectively must-run
- Surplus output leads to zero or negative prices

- Intermittent wind and solar plant needs back-up

- Gas plants will see falling load factors

- Can costs be recovered in the energy market?

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The EFP Auction

- Government / System Operator sets capacity target
- Generators offer Equivalent Firm Power

How do you define “EFP”?	“Central balancing”	“Self-balancing”
Generators sell:	De-rated capacity	Firm capacity
Back-up is contracted by:	System Operator	Generators

What could we expect in the wholesale market?

Principles of supply and demand

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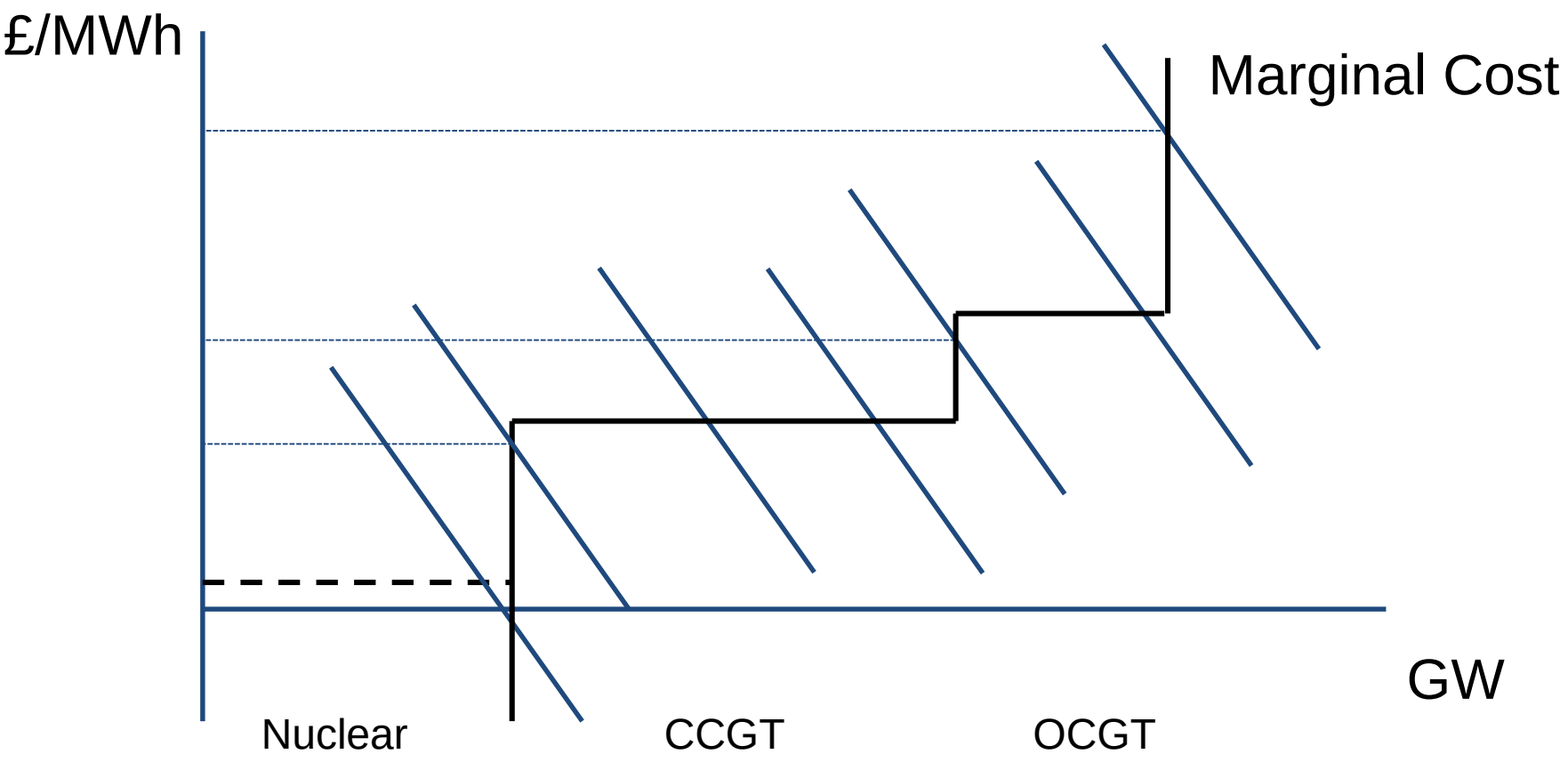
Demand and Supply

Prices reflect Marginal Costs



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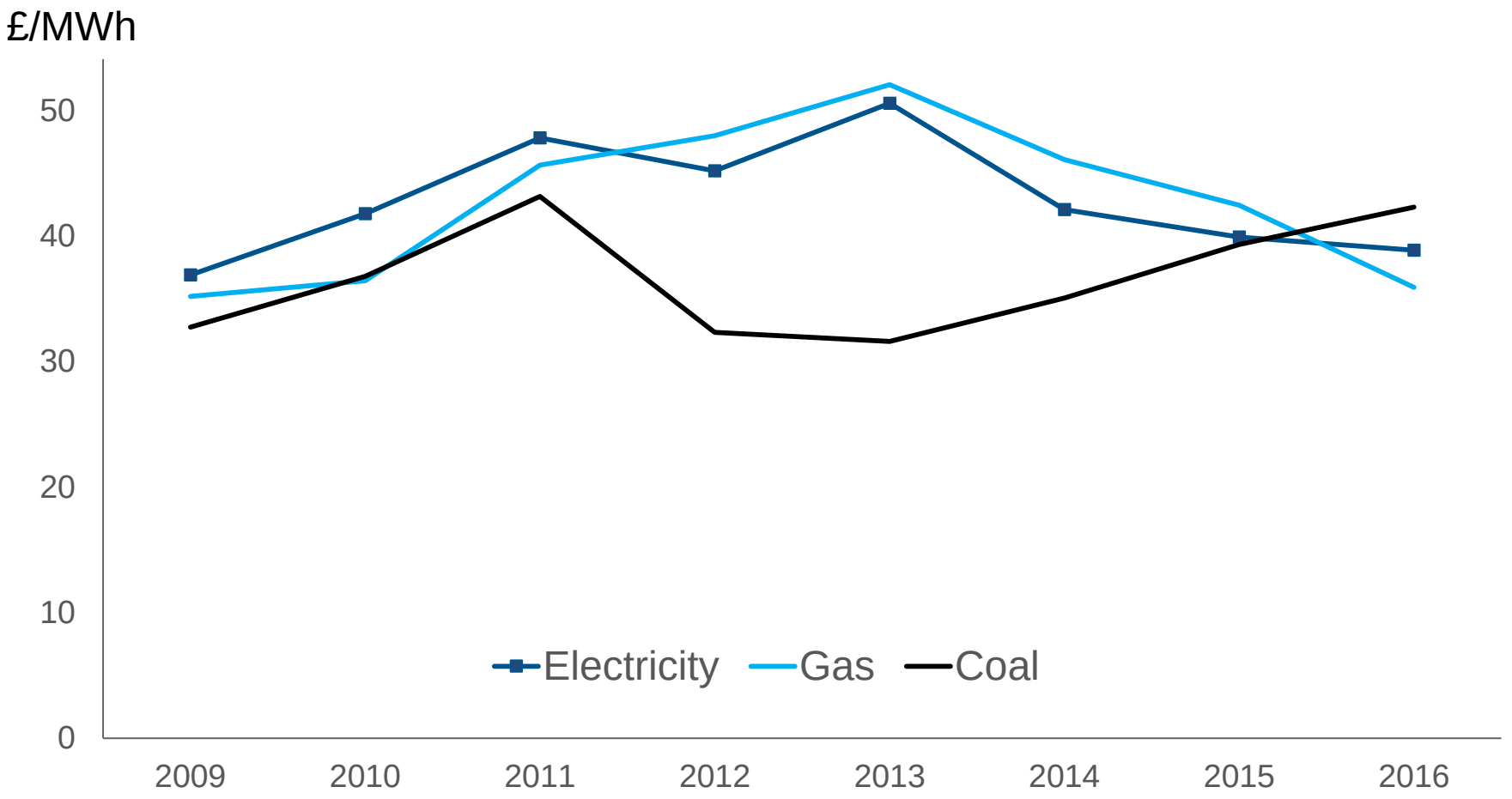
British Energy Prices

per MWh of electricity



Source: ElectricInsights.co.uk

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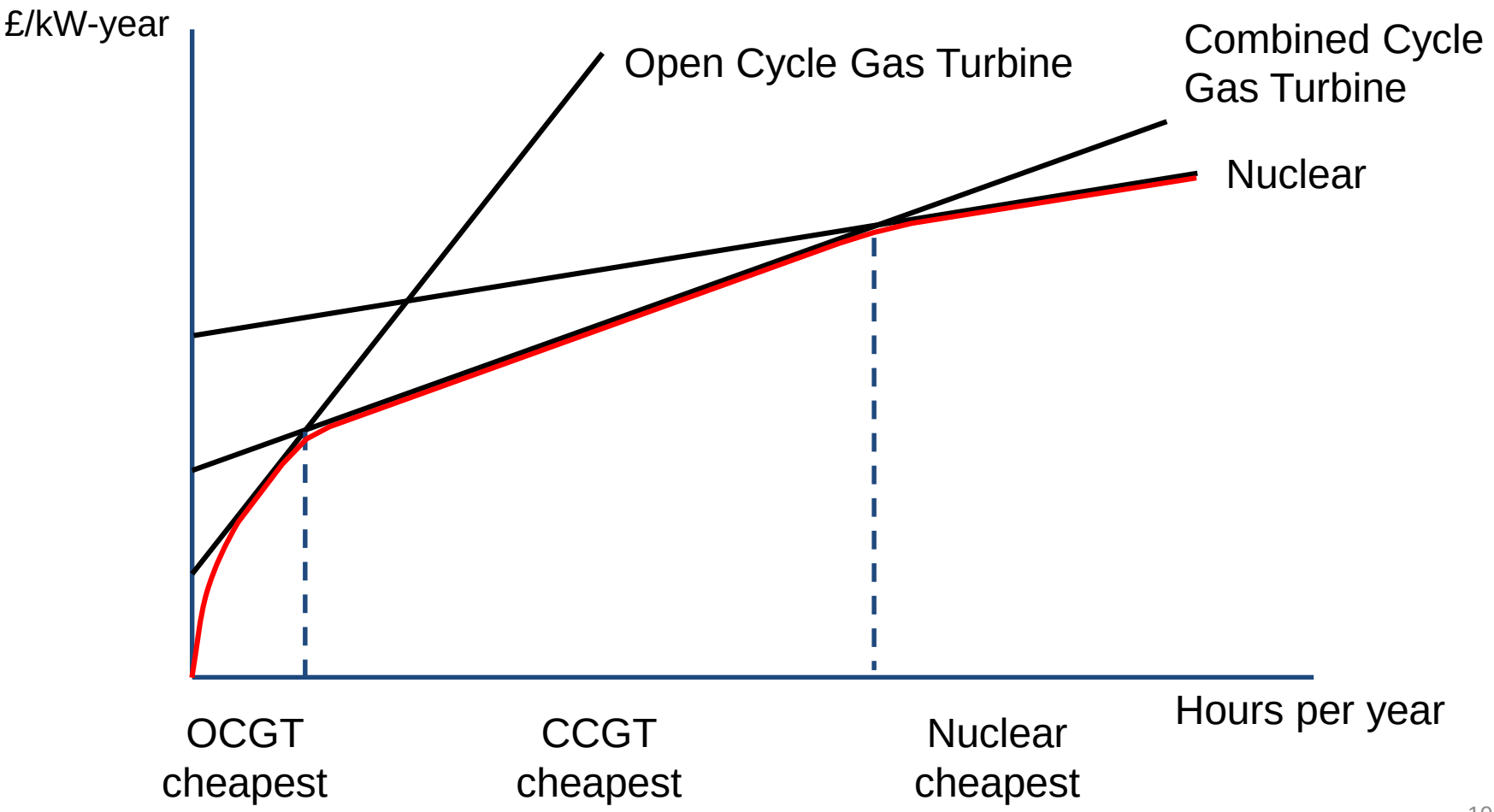
Generator Costs & Revenues



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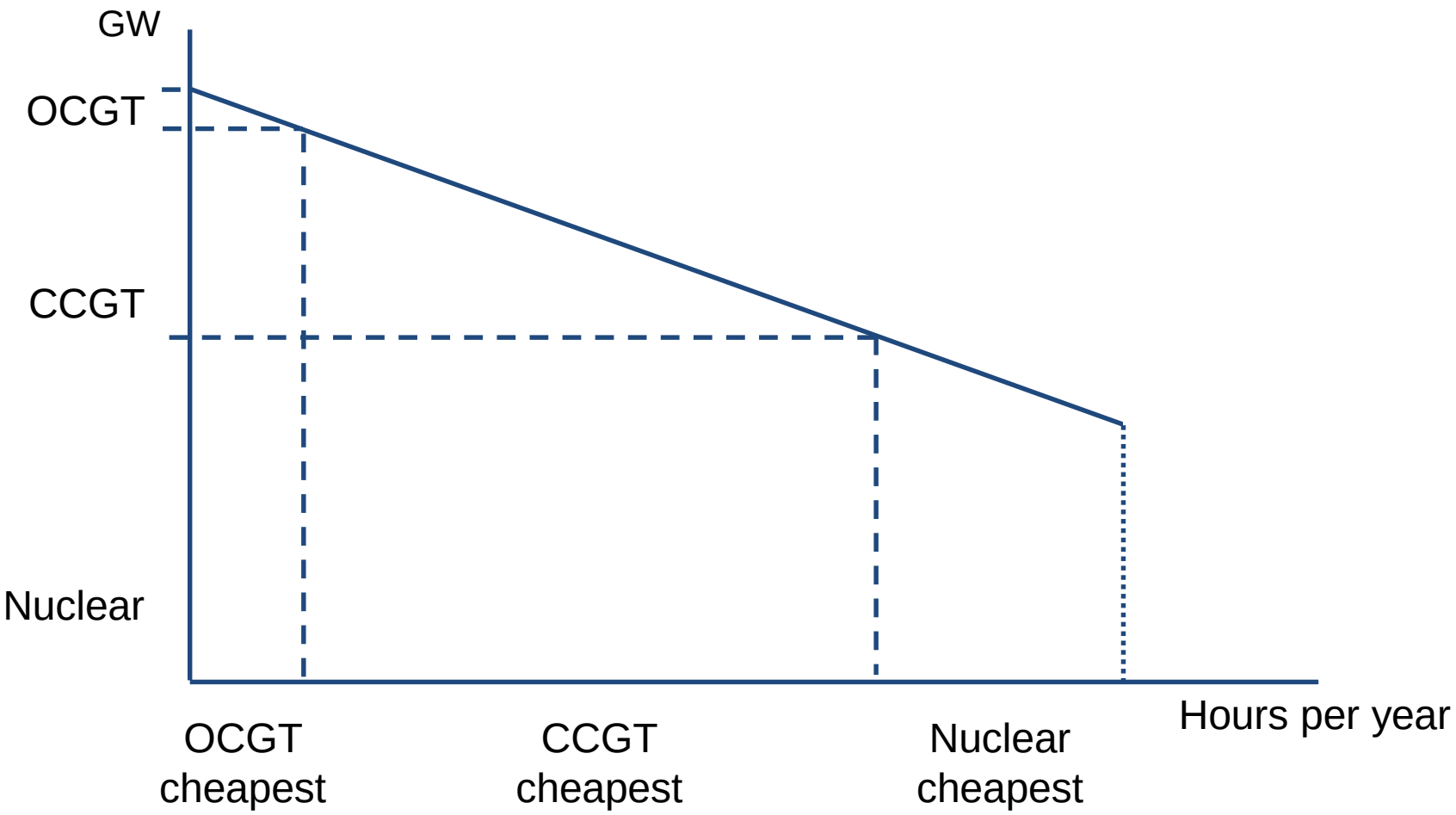
Load-duration and Capacity



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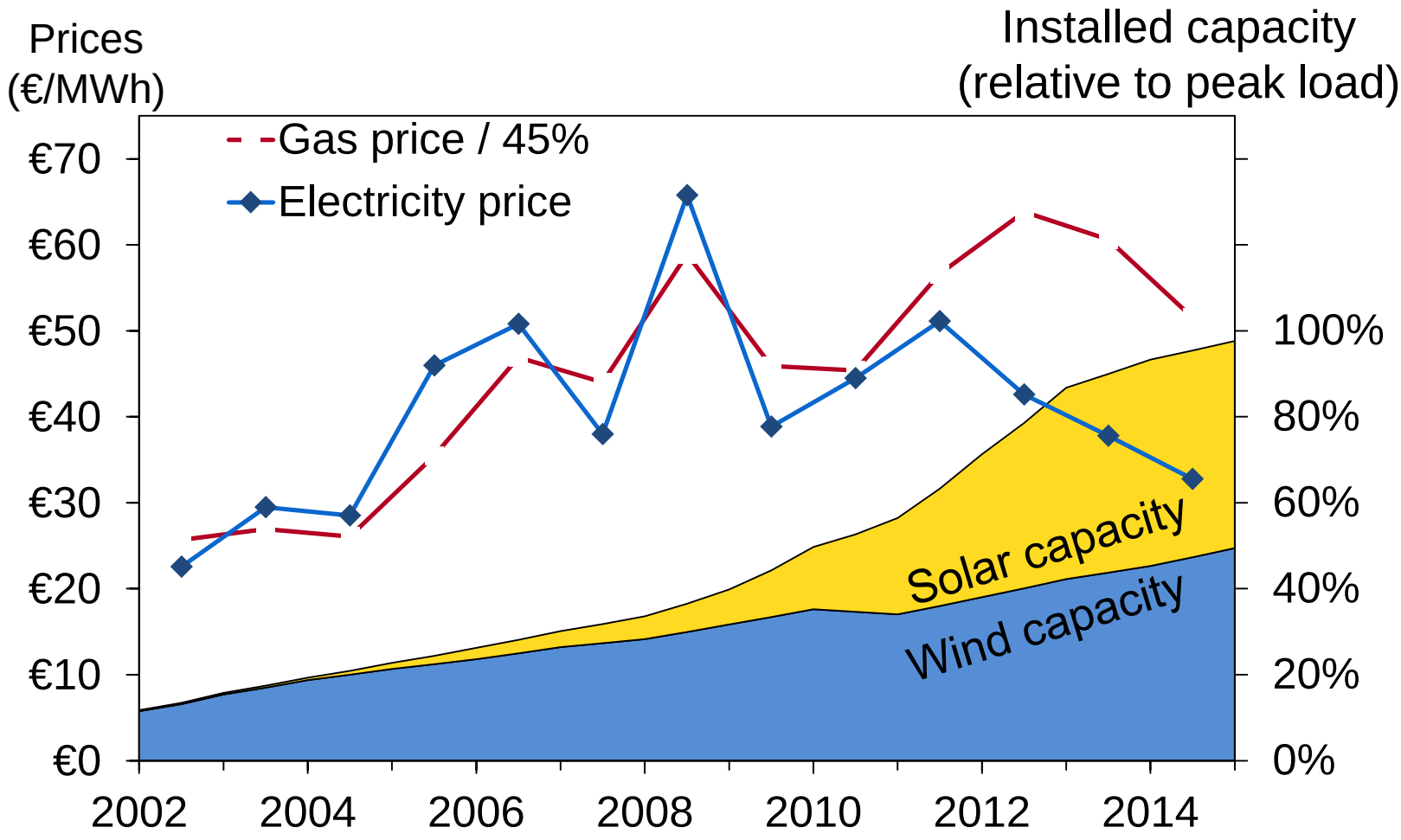
German Energy Prices: The Merit Order Effect



Source: Green and Staffell, Oxrep, 2016

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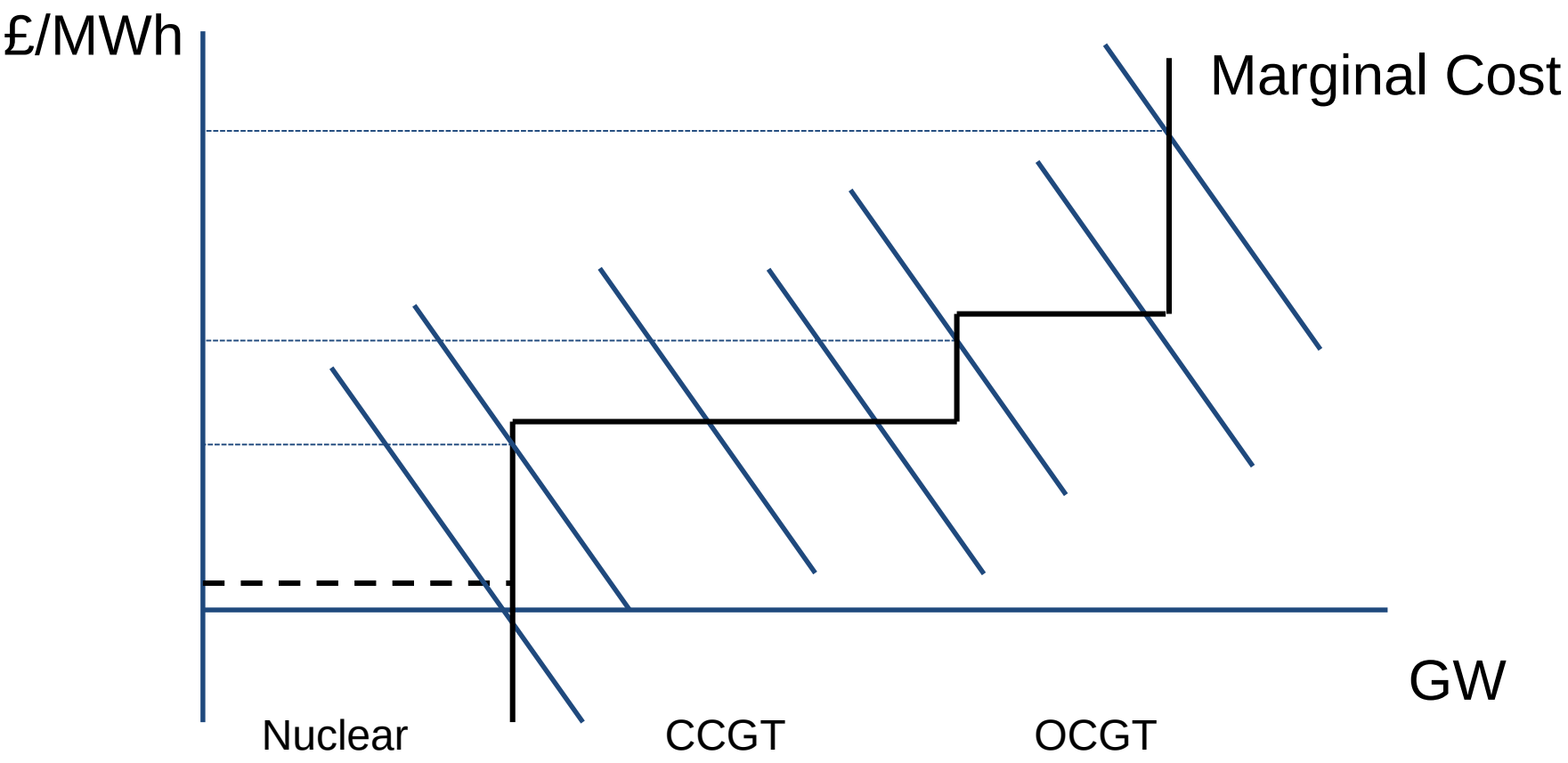
Demand and Supply

The merit order effect



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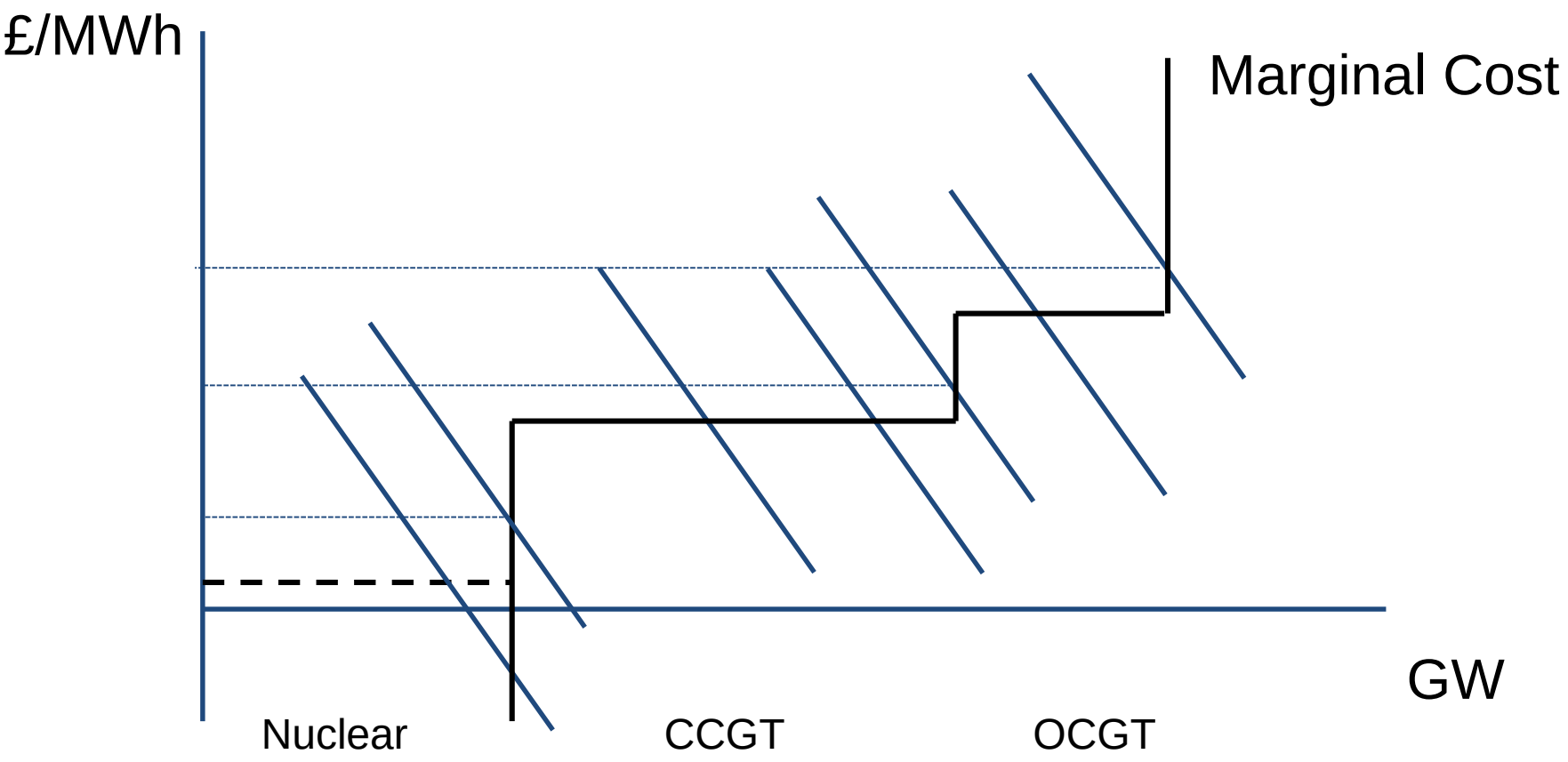
Demand and Supply

The merit order effect



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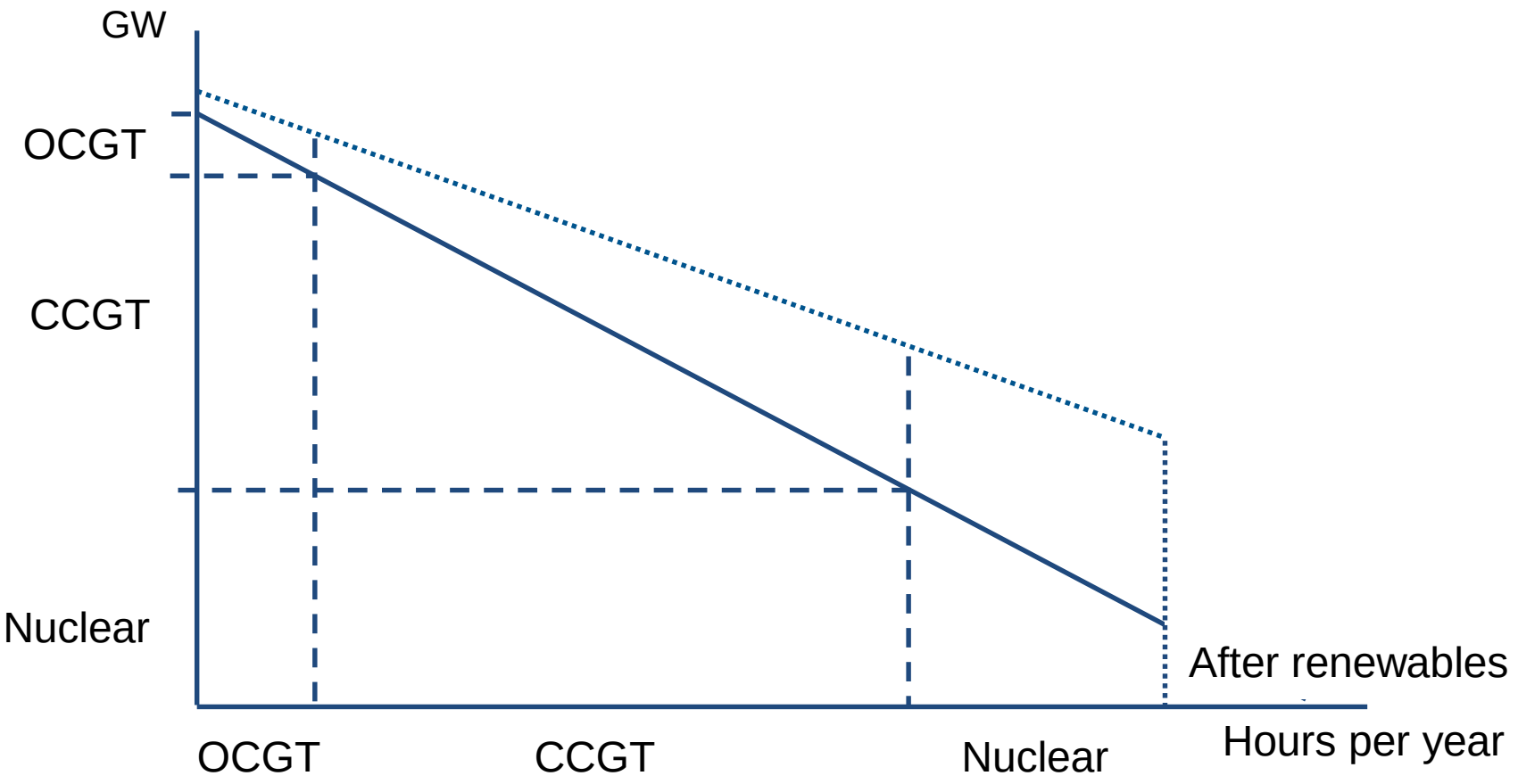
Capacity and Load



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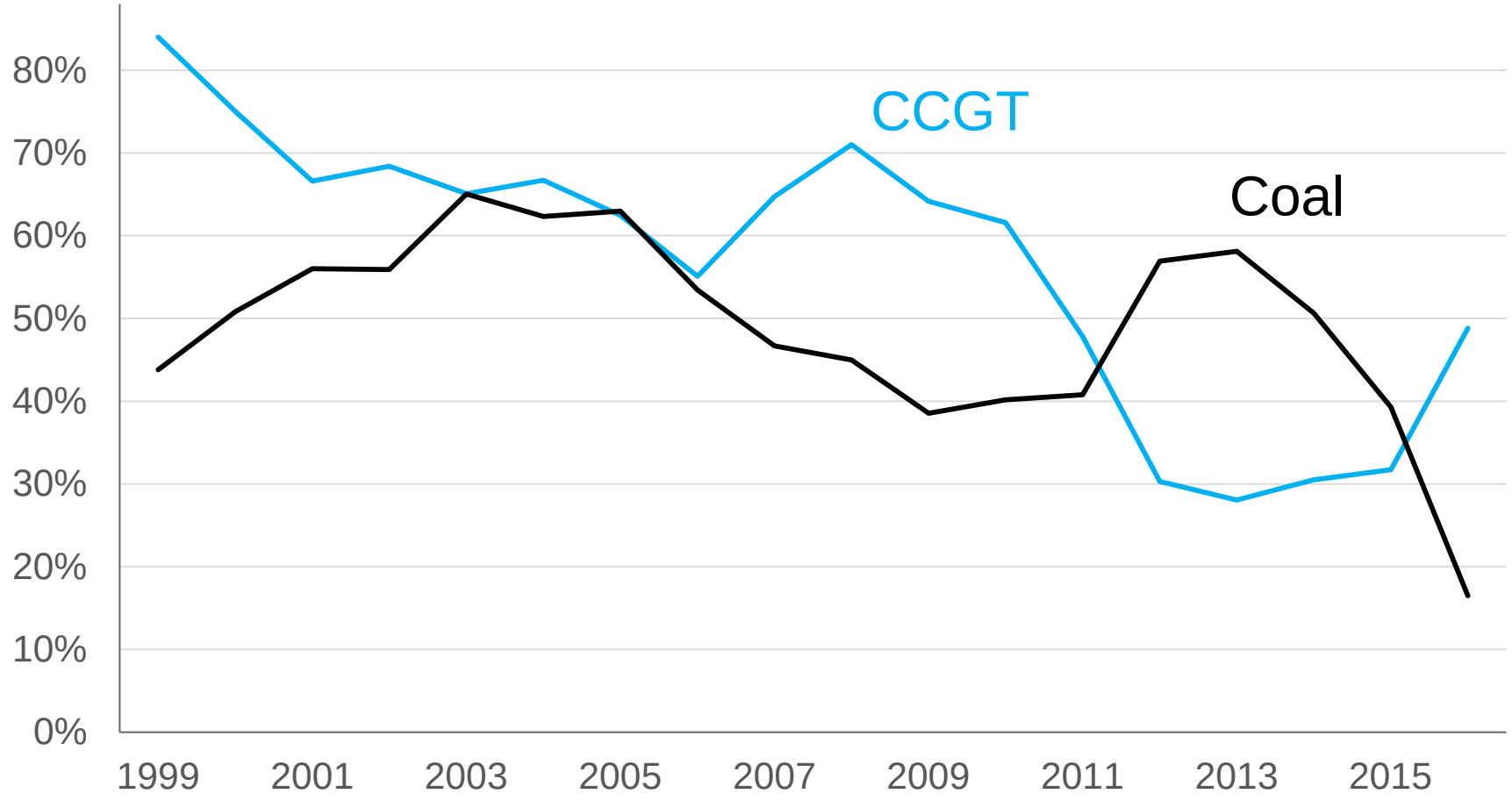
Generators' Load Factors

UK-wide, including Northern Ireland



Source: Digest of UK Energy Statistics

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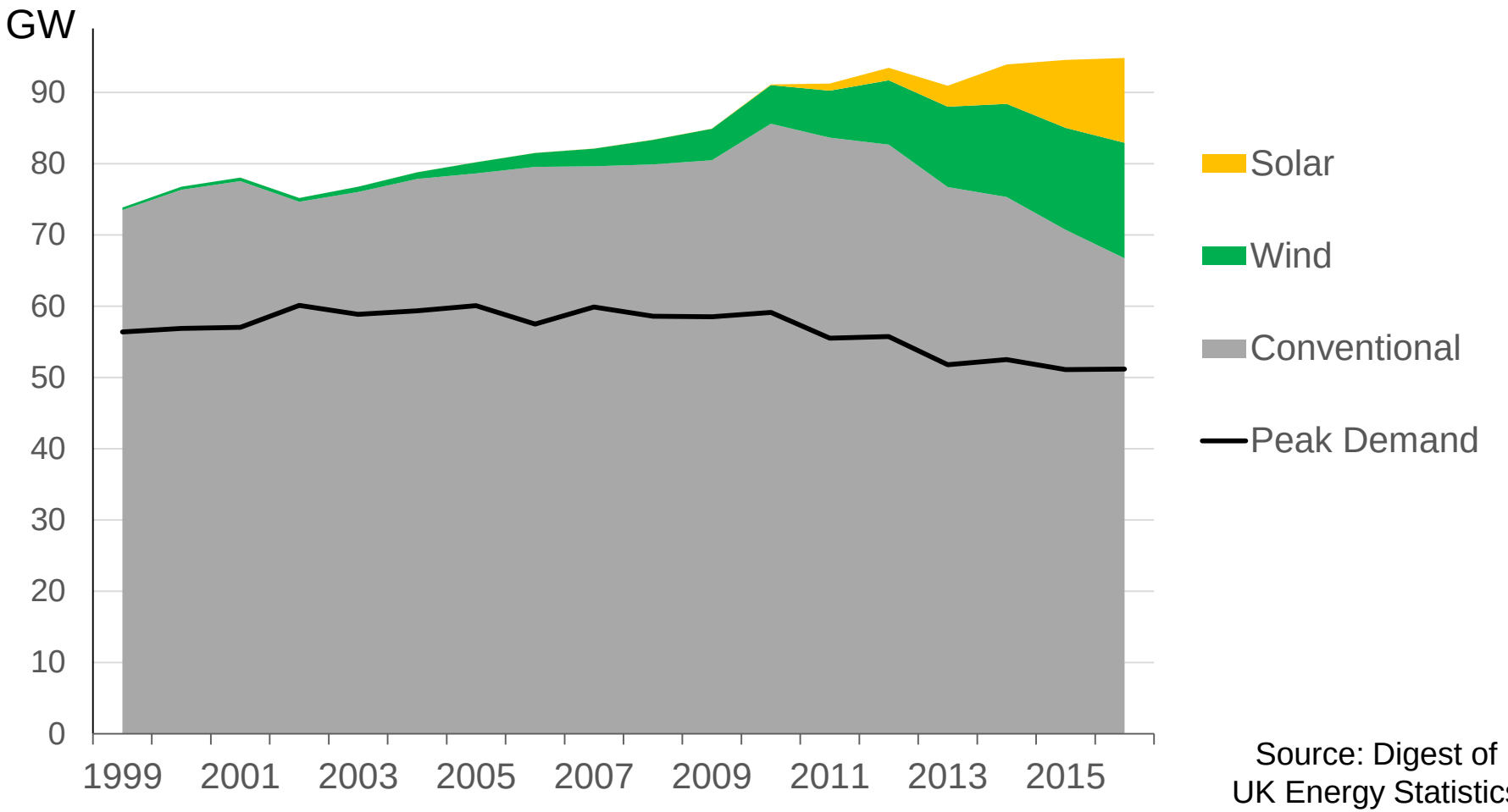
Capacity and Peak Demand

Great Britain



Source: Digest of UK Energy Statistics

Modelling the future

The energy market is here for the long term…

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A simple model

- Merit order stack with nuclear, biomass, CCGT, OCGT, diesel, load-shedding
- Costs based on 2016 BEIS Generation Cost Report and central fuel price projections for 2025
- Weather pattern of 2011 for demand and renewable output
- Autarkic GB system, with daily storage cycle
- Adjust capacity for (approximate) break-even and low amounts of load-shedding with a VOLL-linked price
- Cap the energy price at a lower level, and assume EFC auction revenues will fill the gap

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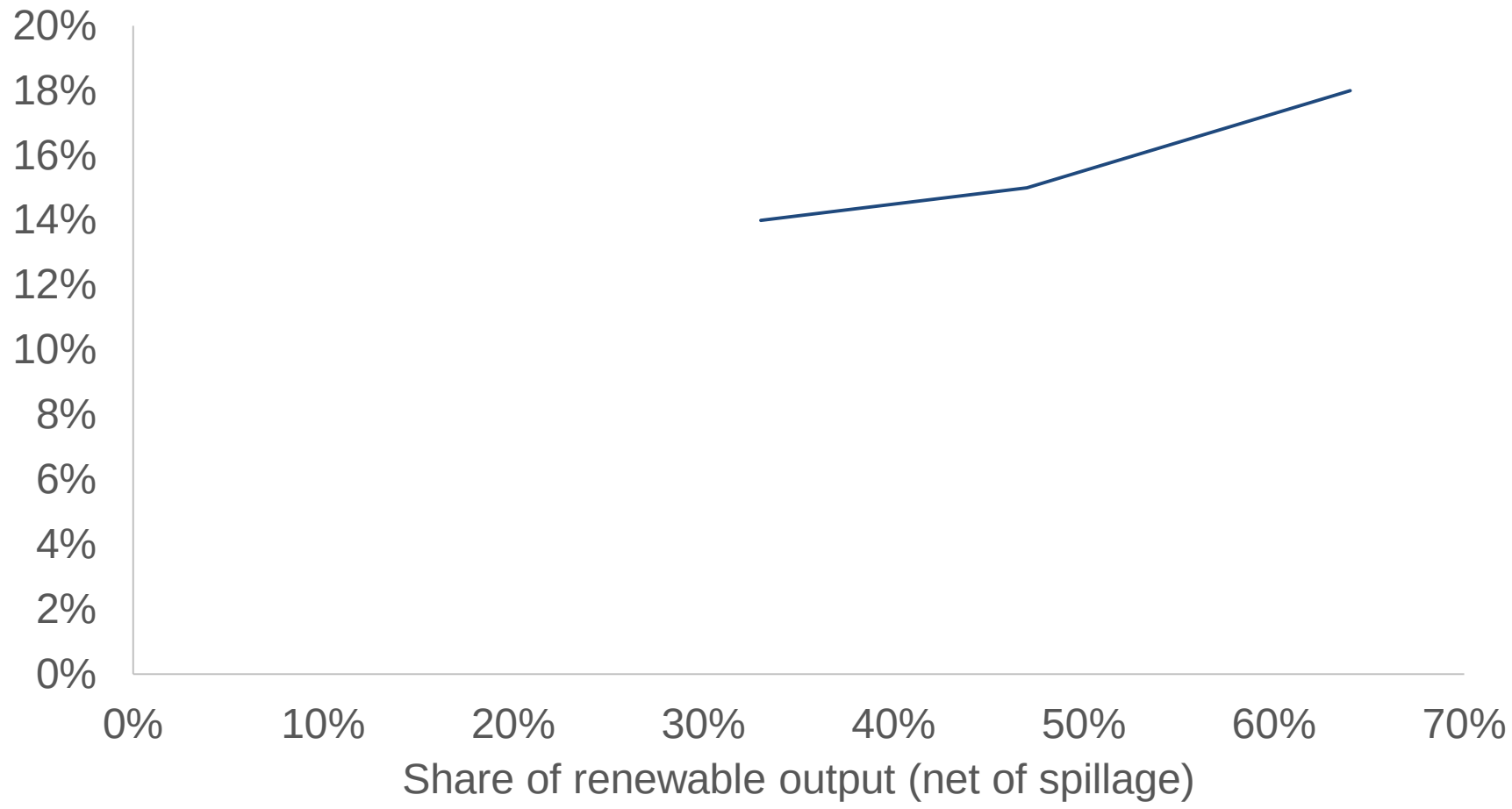
Buying Capacity or Energy?

Share of equilibrium revenues from capacity auction



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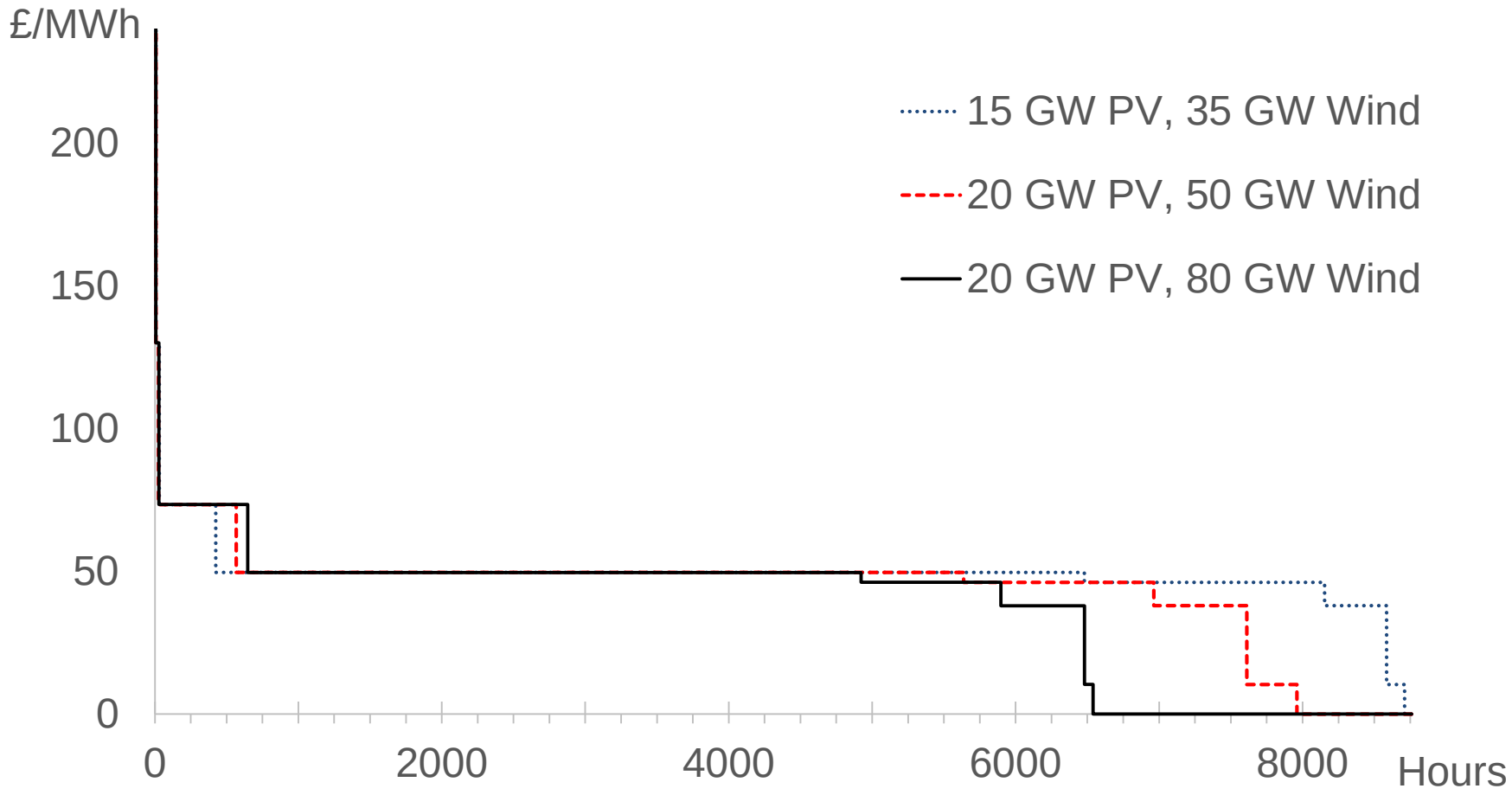
The shape of future prices?

Price-duration curve, given model assumptions



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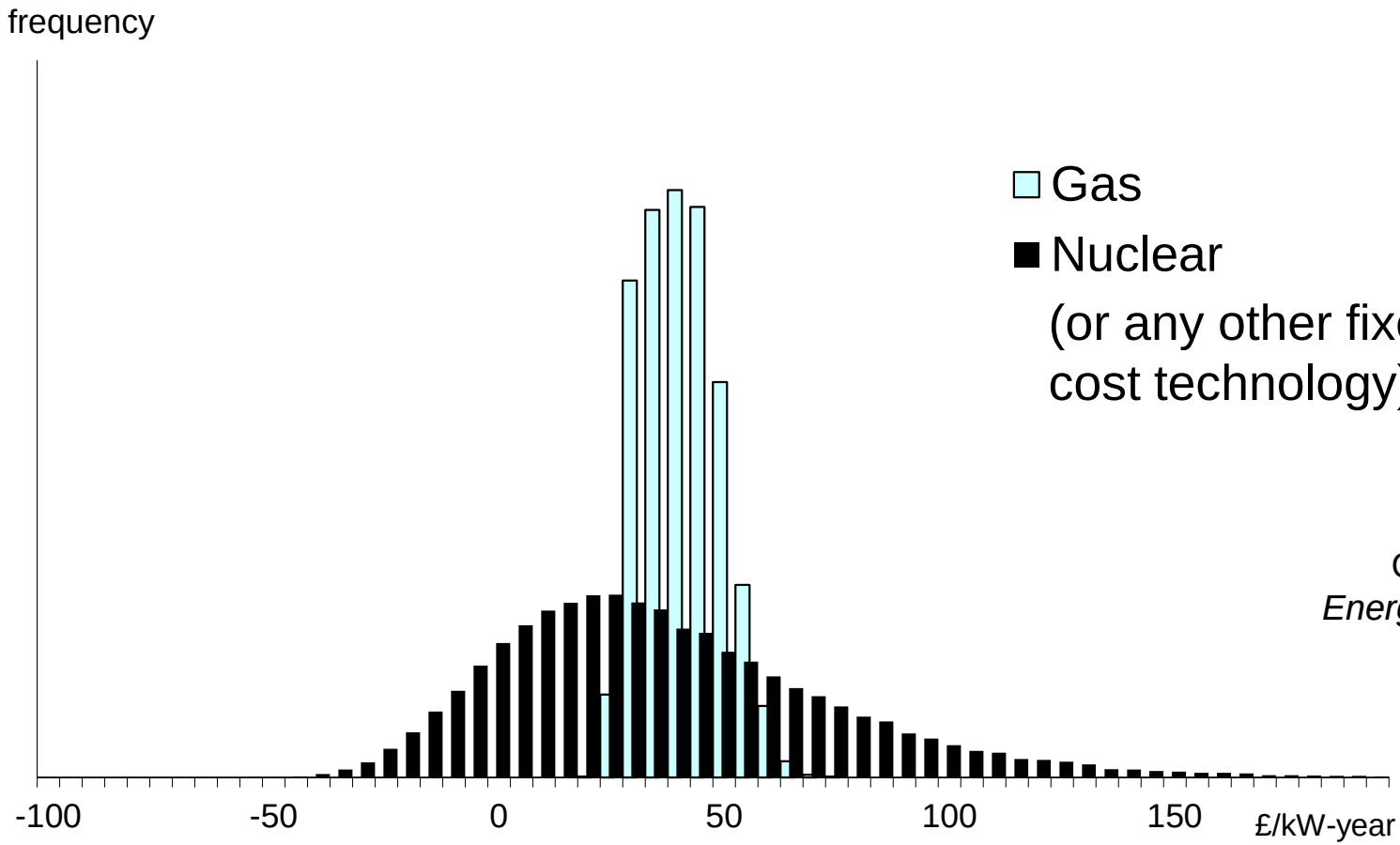
Generators' profit risk

Earlier work varying fuel prices



Green, *Energy Journal*, 2008

(the *positions* depend on particular cost assumptions; the *shapes* do not)

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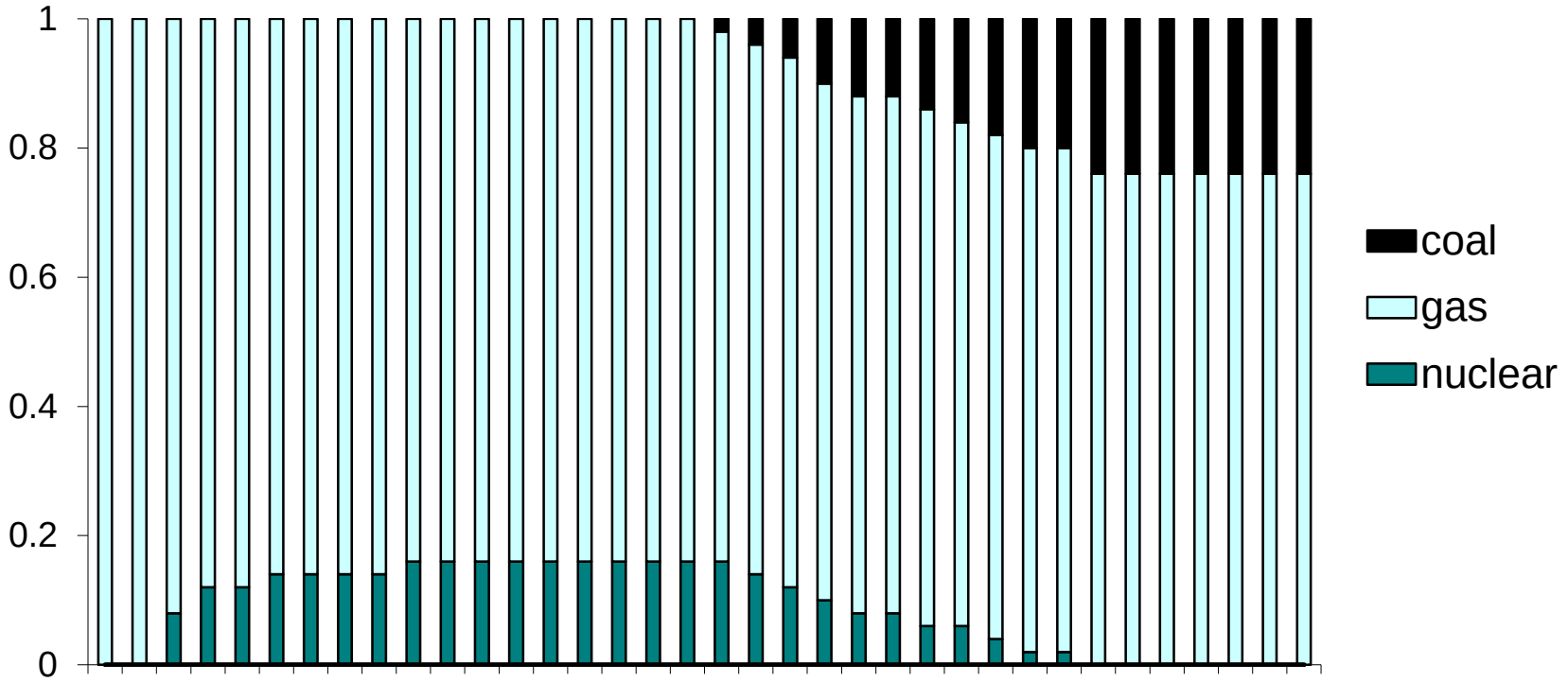
Optimal Portfolios

Given the previous risk profiles



Level of risk aversion (increasing to the right)

Green, *Energy Journal*, 2008

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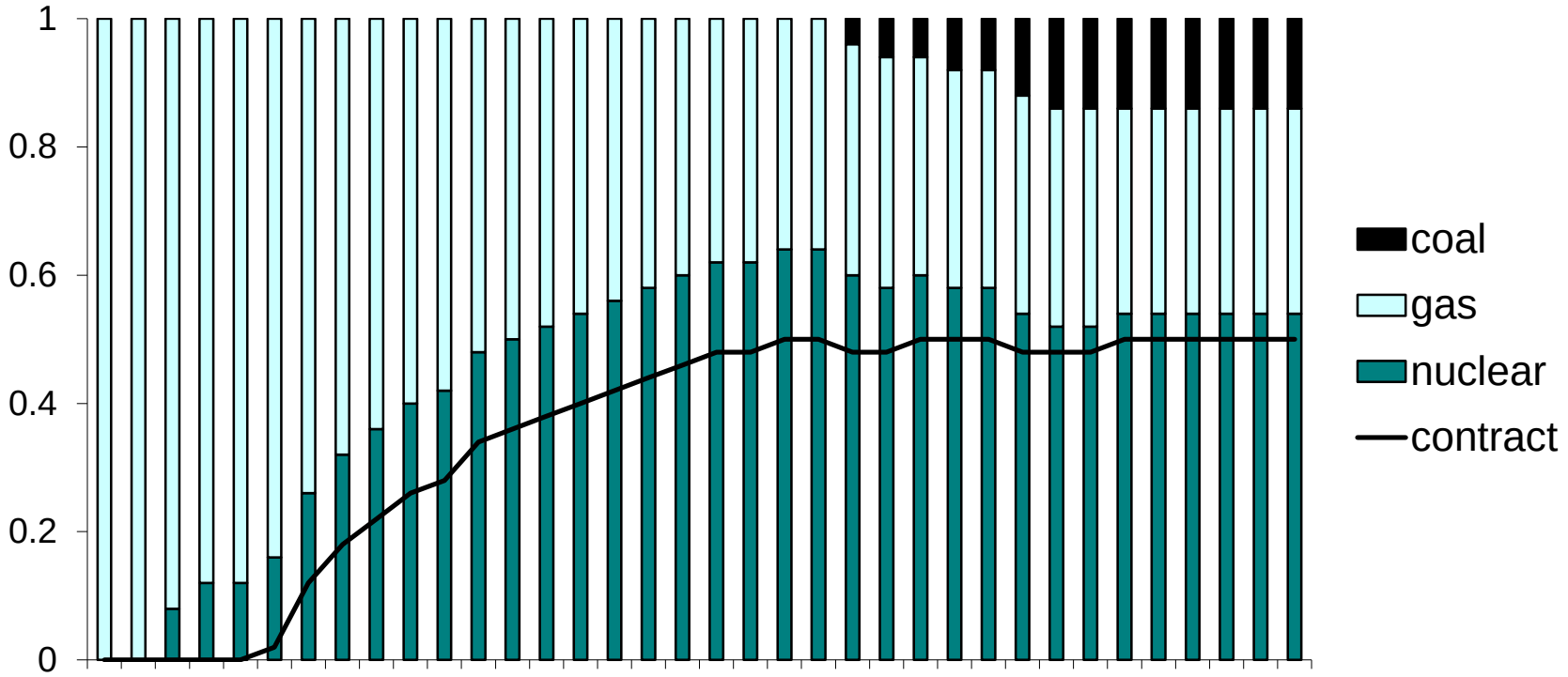
Optimal Portfolios

Optional Fixed-price, Long-term, Contracts



Level of risk aversion (increasing to the right)

Green, *Energy Journal*, 2008

What is electricity worth?

Some power stations are more equal than others

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Dimensions of power

- Hirth *et al.* (*Renewable Energy,* 2015) doi:10.1016/j.renene.2014.08.065 have differentiated electricity in terms of:
  - Time
  - Location
  - Lead Time
- The most valuable power is typically produced:
  - When demand is high compared to supply
  - Geographically* close to consumption
  - With little or no notice

* In fact, electrically close, which may not be quite the same

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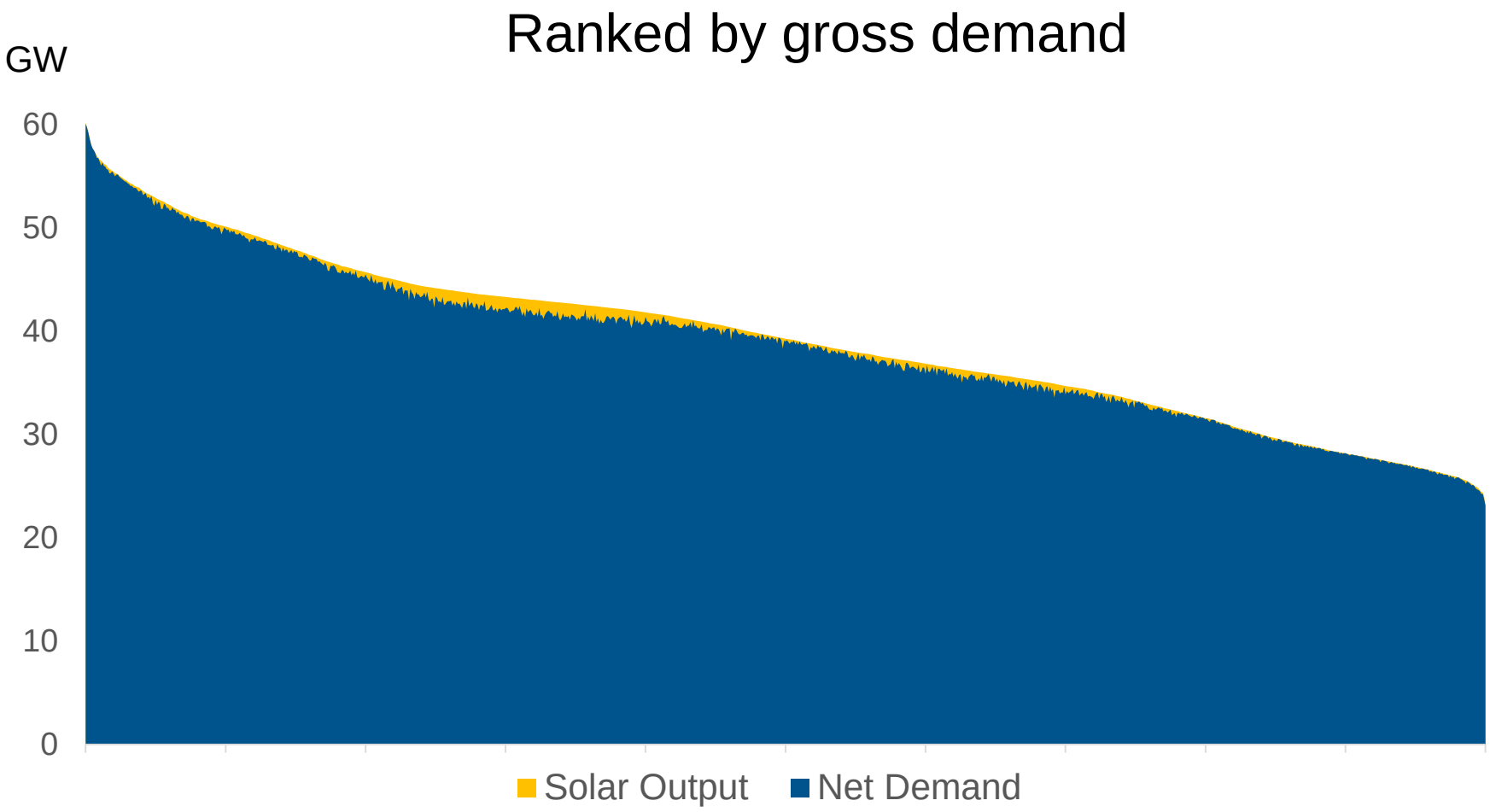
Load duration curve for GB

2011 demand and weather with 5 GW solar PV



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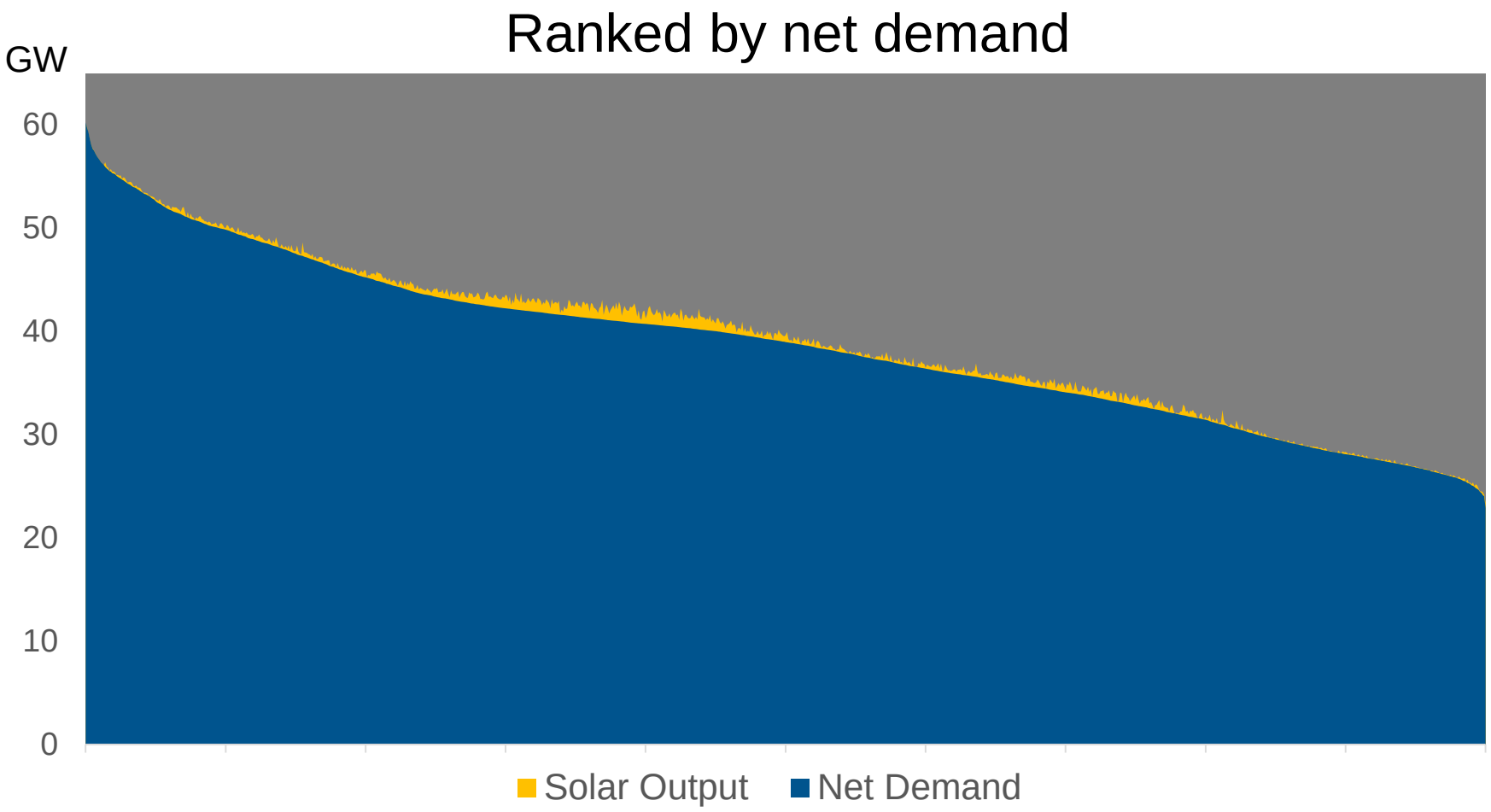

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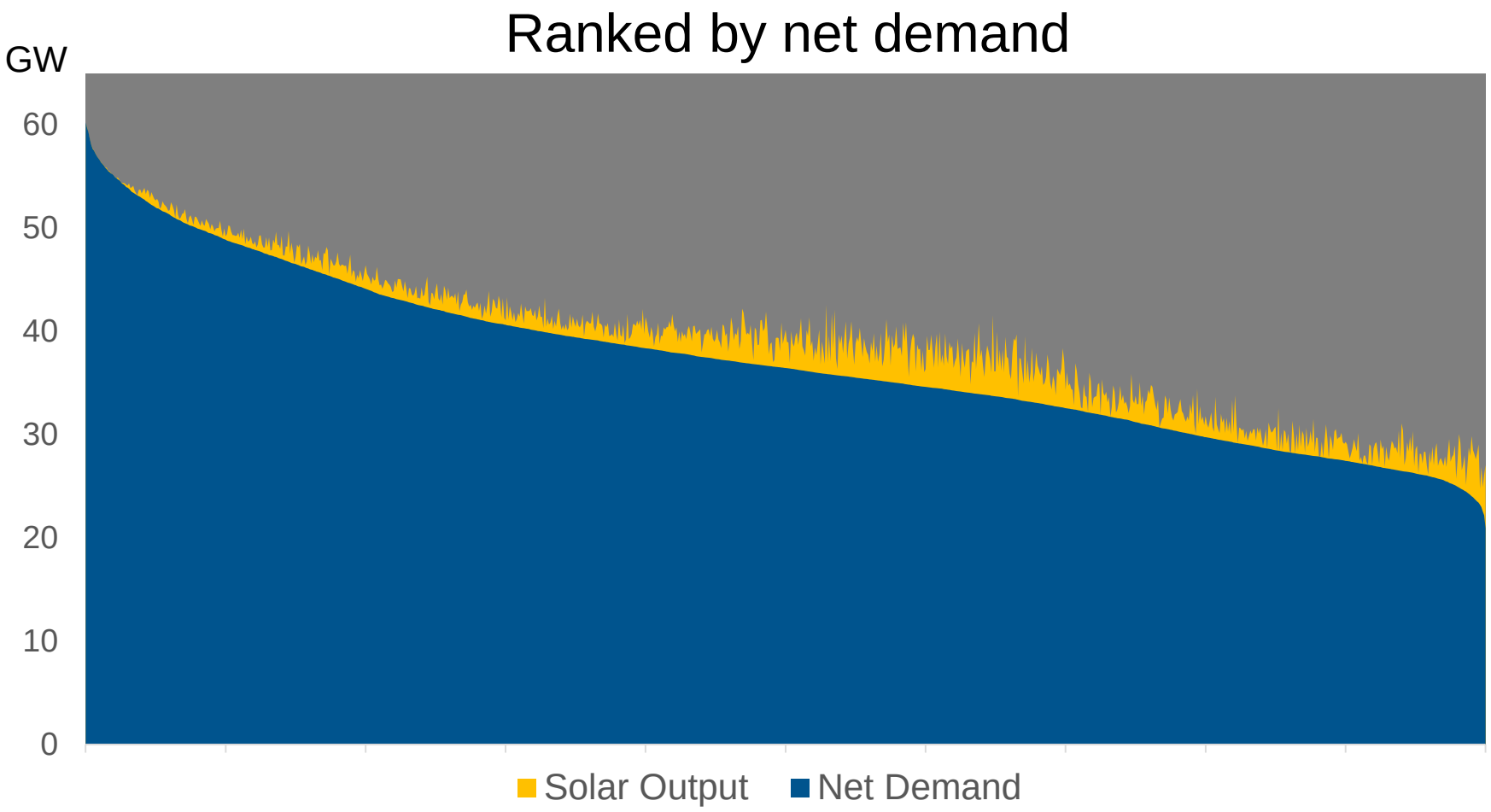
Load duration curve for GB

2011 demand and weather with 20 GW solar PV



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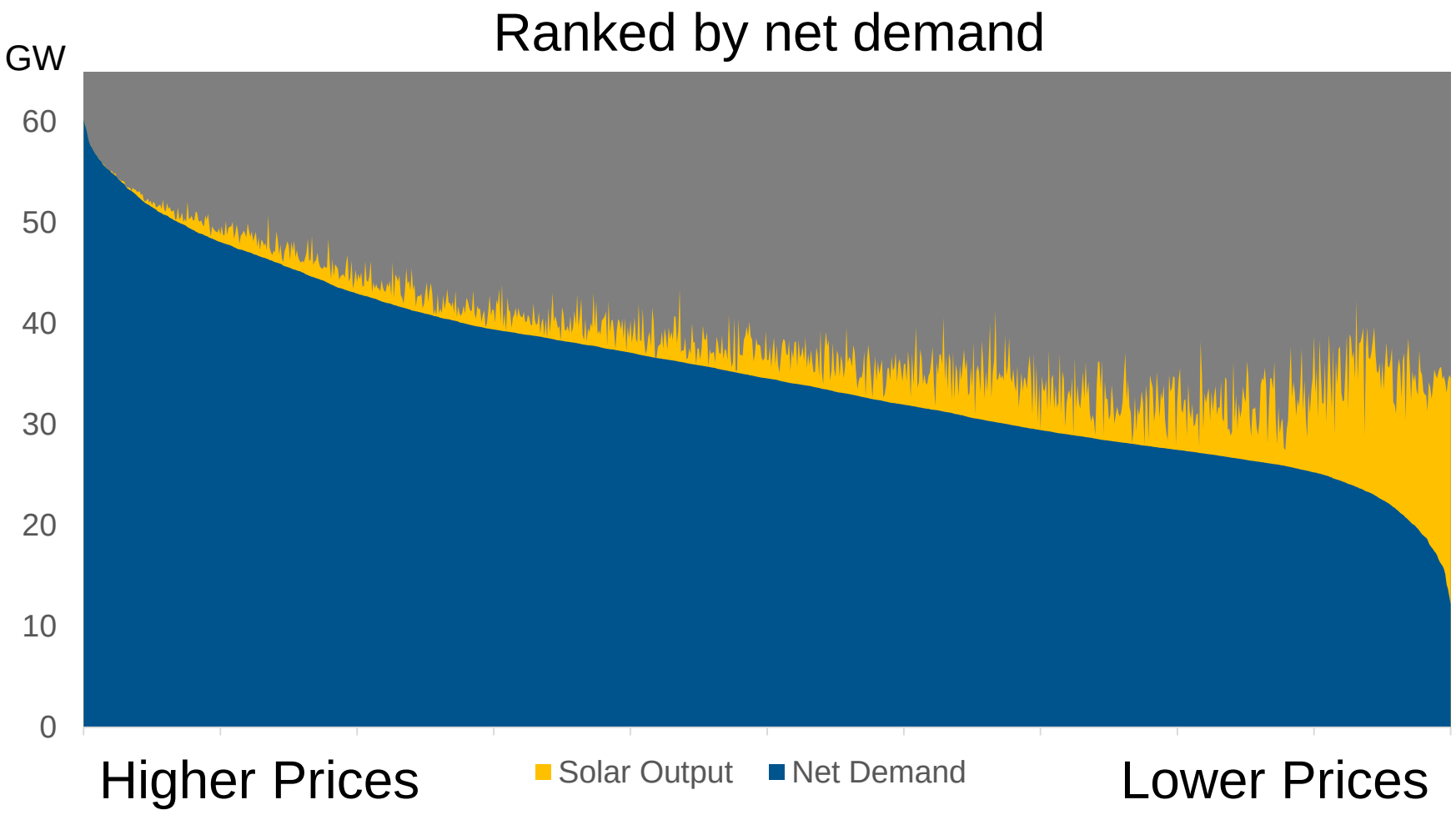
Load duration curve for GB

2011 demand and weather with 40 GW solar PV



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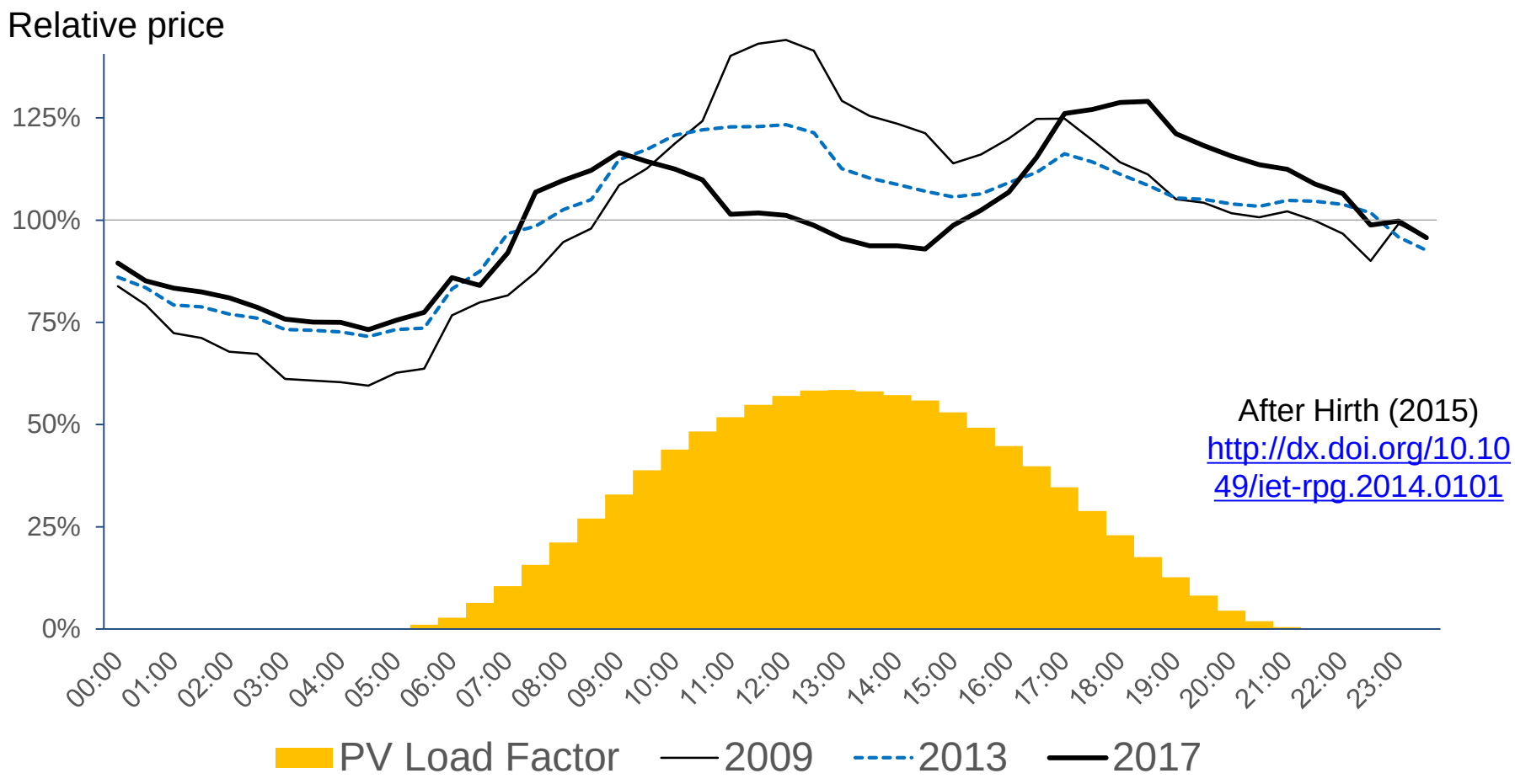
PV and Relative Prices

Great Britain, May-July



After Hirth (2015)
http://dx.doi.org/10.1049/iet-rpg.2014.0101

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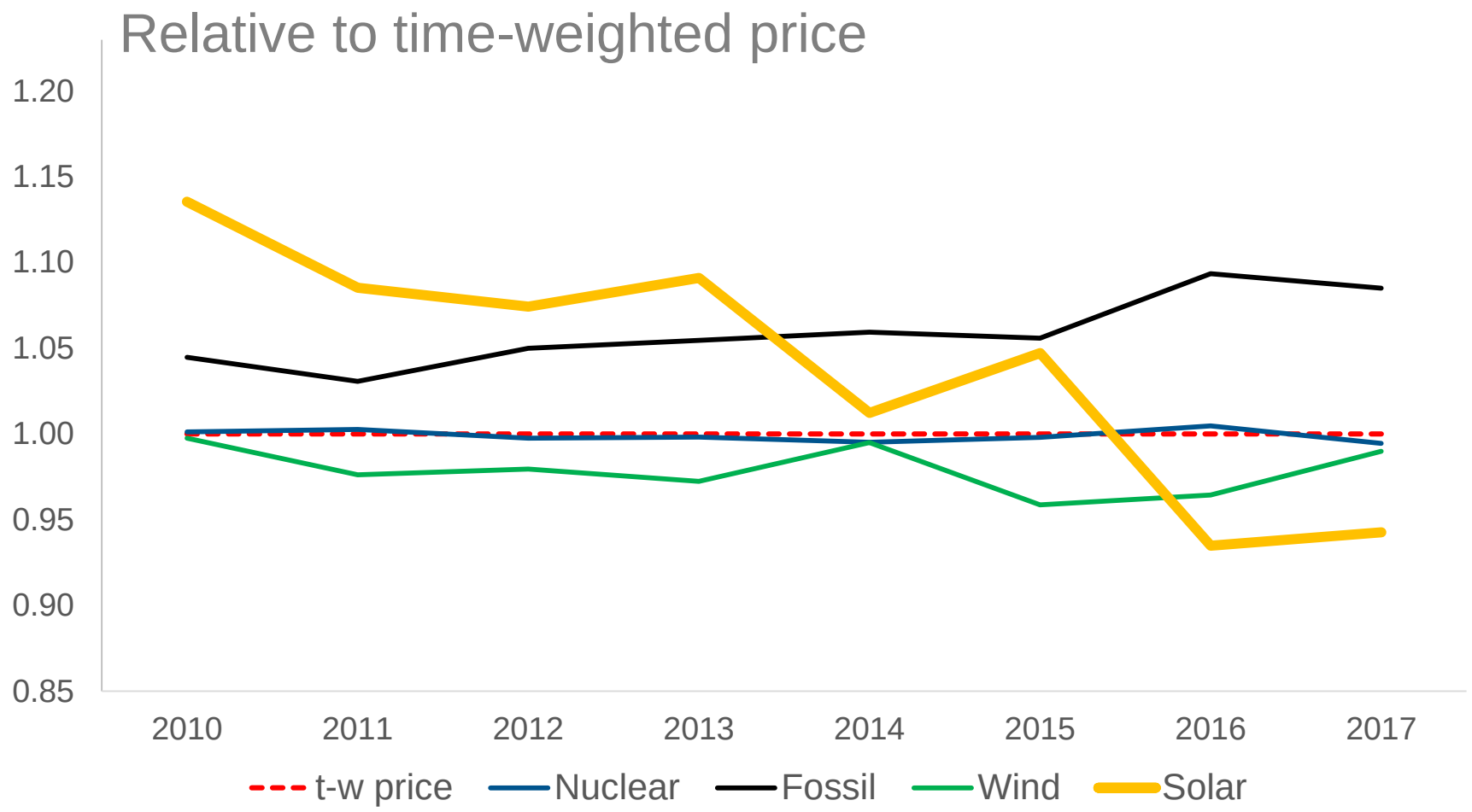
Output-weighted prices



Source: ElectricInsights.co.uk

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What *is* the Equivalent Firm Capacity of Renewables?

2011 data only	Onshore Wind	Offshore Wind	PV
Annual Average Load Factor	27%	37%	10%
LF in top 1% of gross demands	27%	41%	1%
LF in top 1% of net demands	10%	13%	2%

What if we have an *Energy* Market?

How storage changes price-setting

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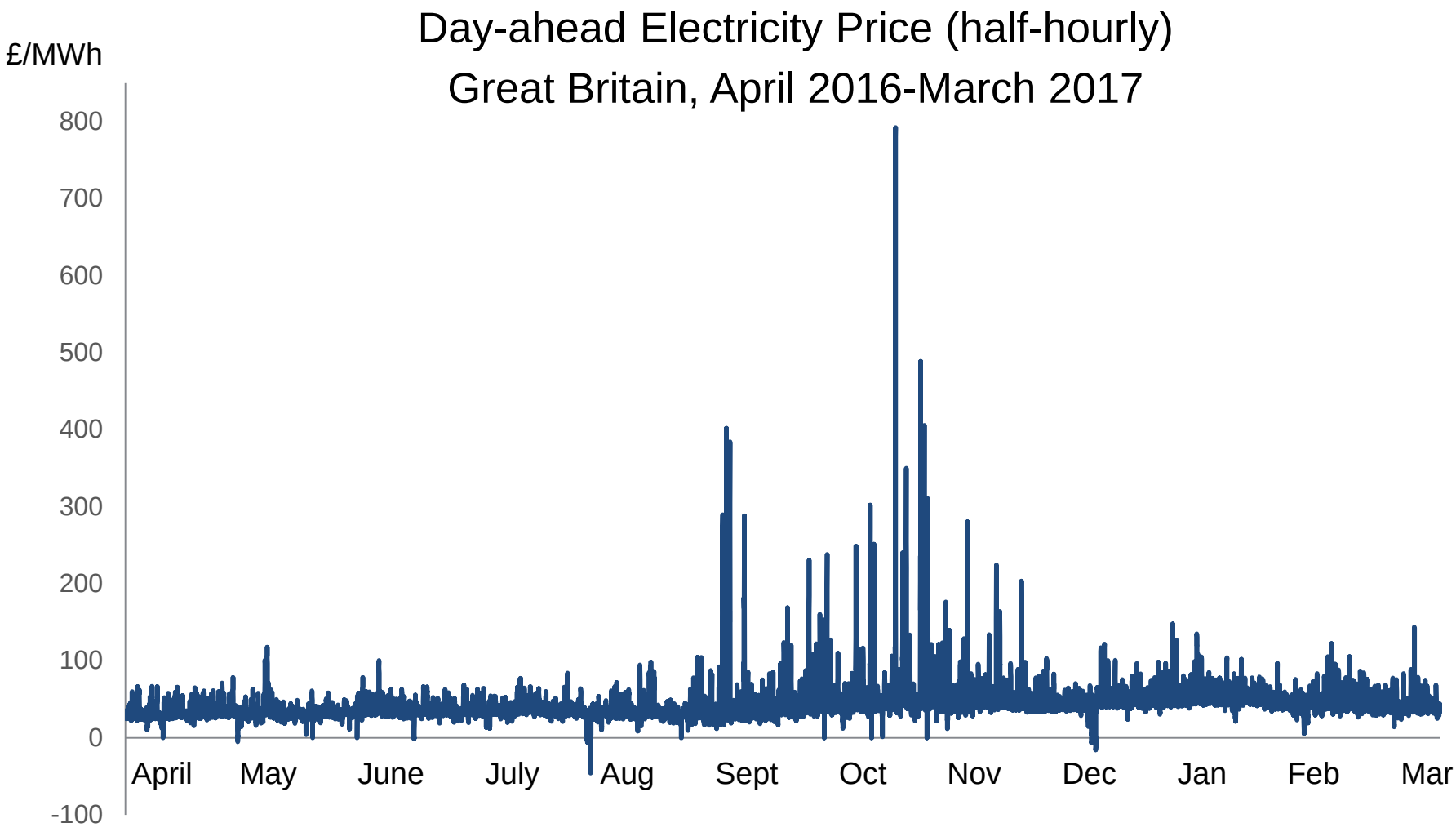
A volatile market



Source: ElectricInsights.co.uk

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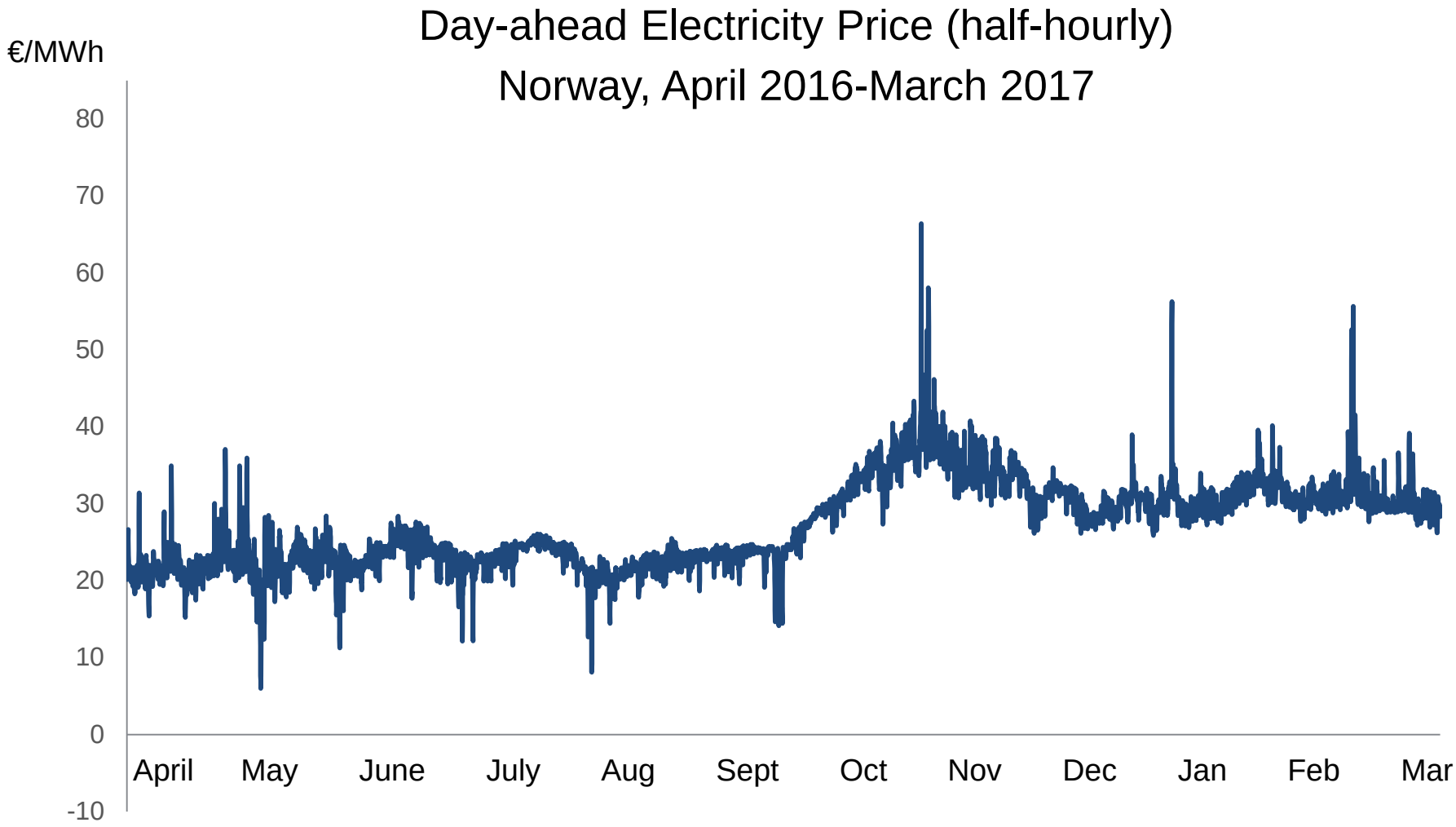
A less volatile market



Source: Energinet.dk

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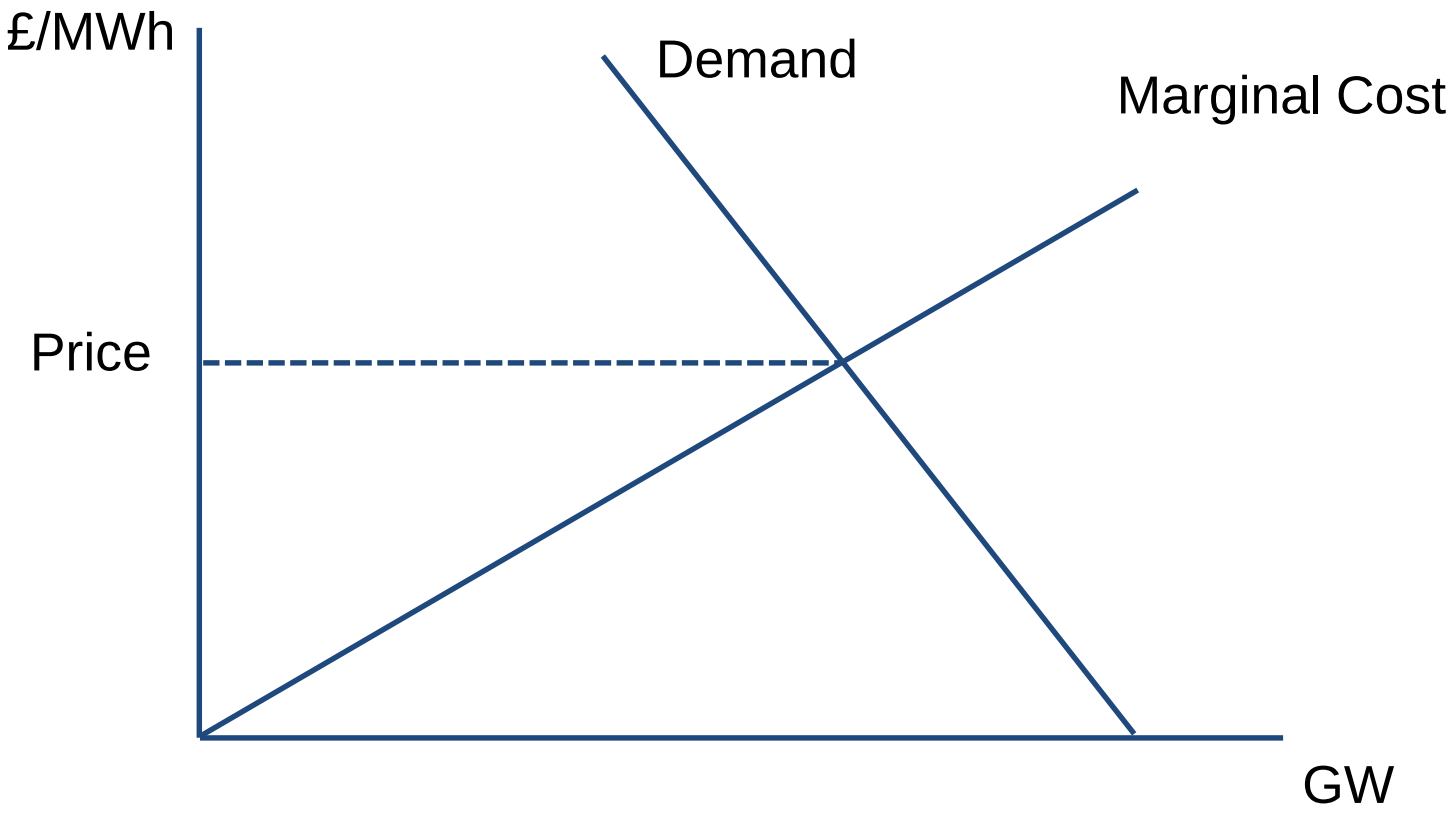
Supply and Demand



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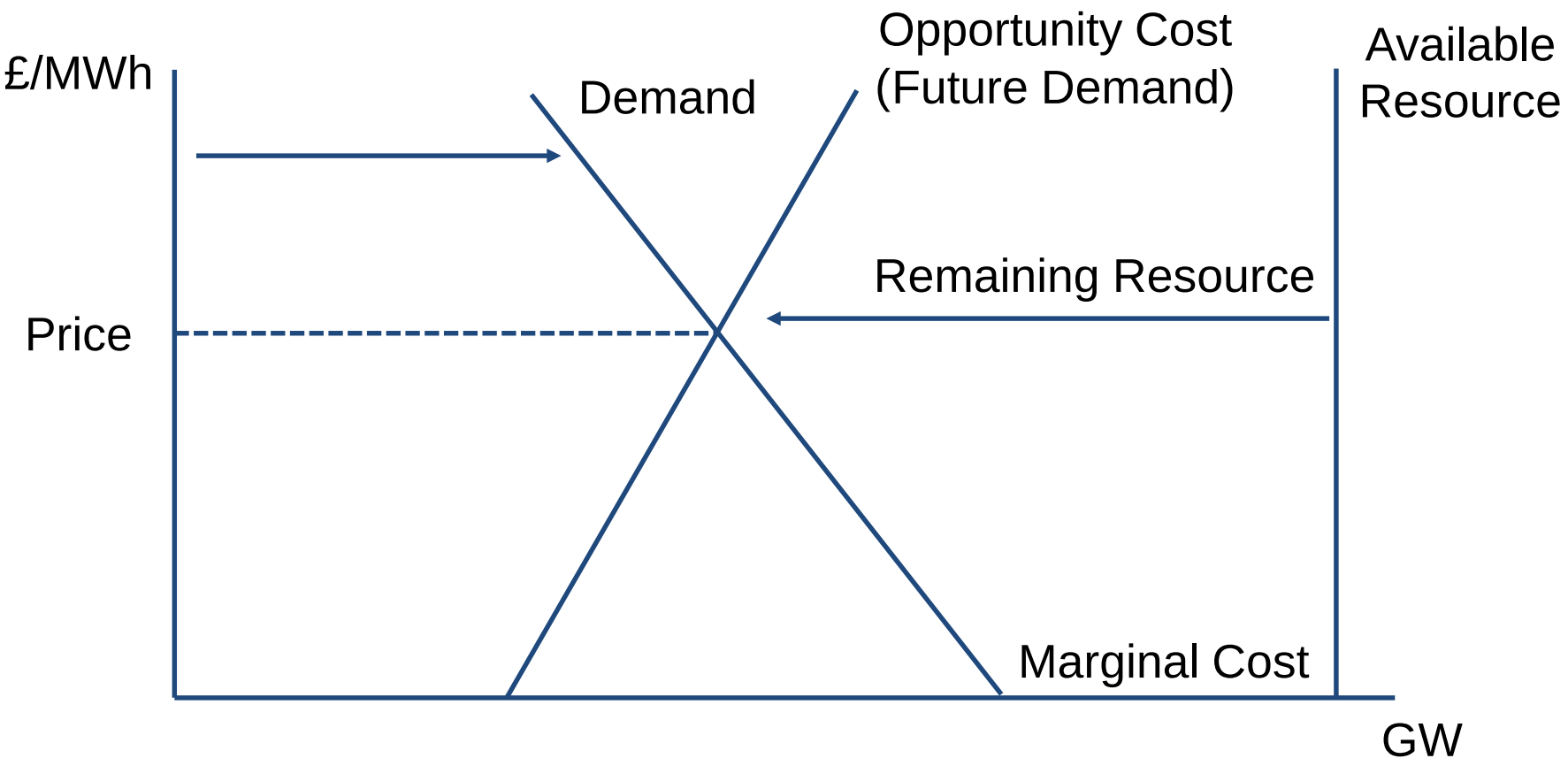
Supply and Demand



Finn's bathtub, from Forsund (2007) *Hydropower Economics,* Springer

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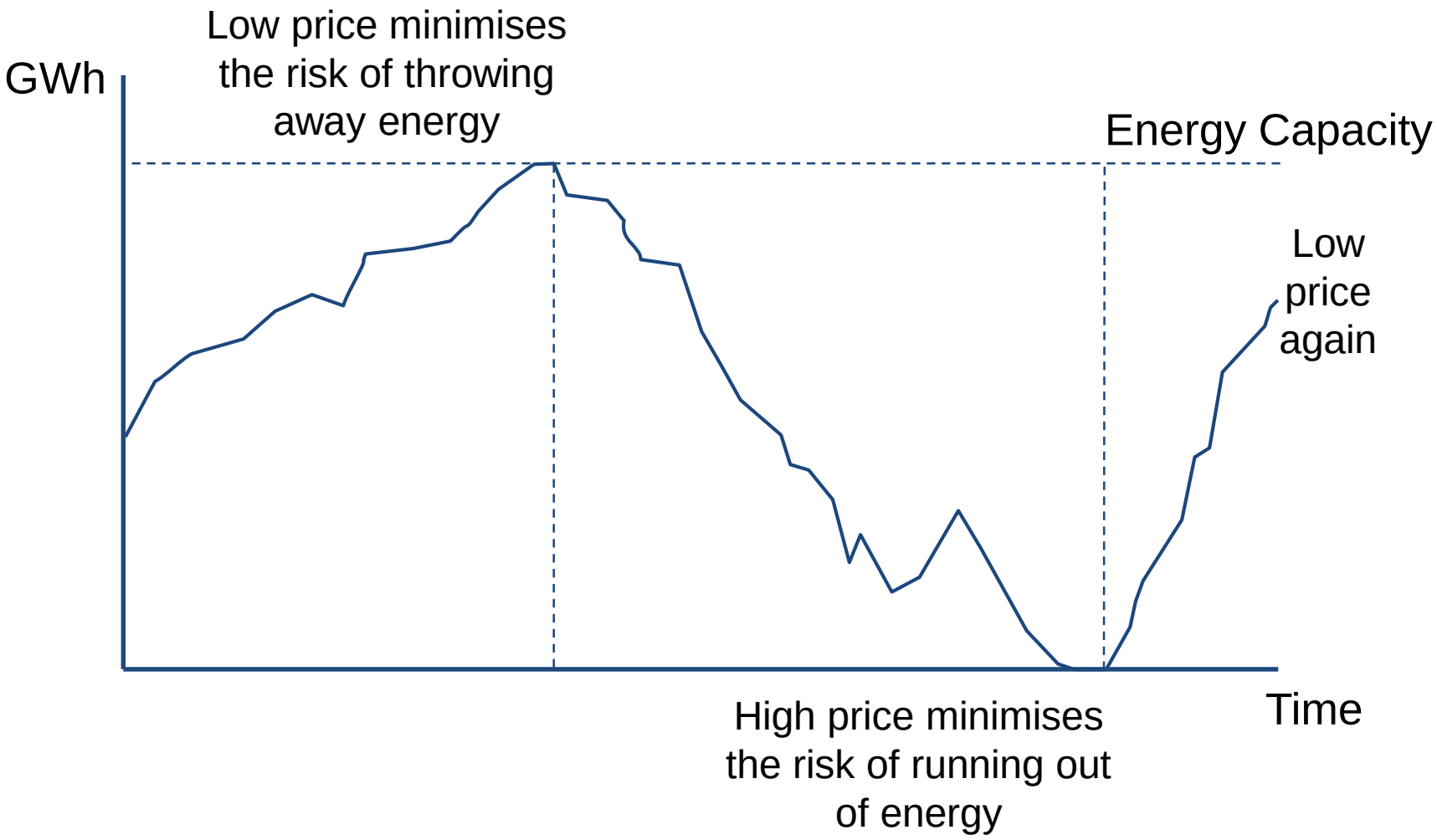
Reservoir Levels



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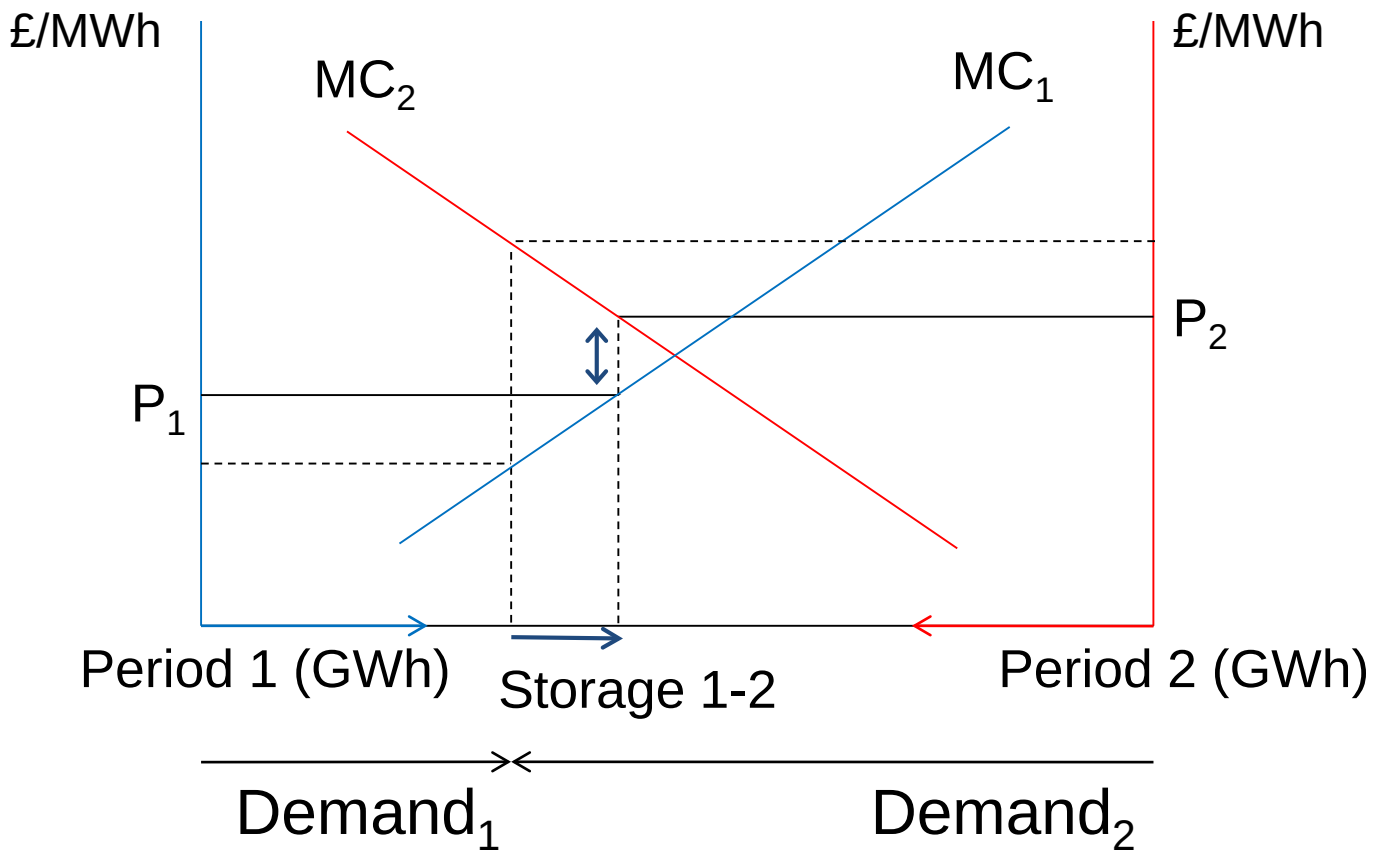
Richard's bath-tub

Storage with generation



The maximum amount of storage is limited by its energy capacity (horizontal arrow) or the minimum price ratio (P_2/ P_1 > efficiency)

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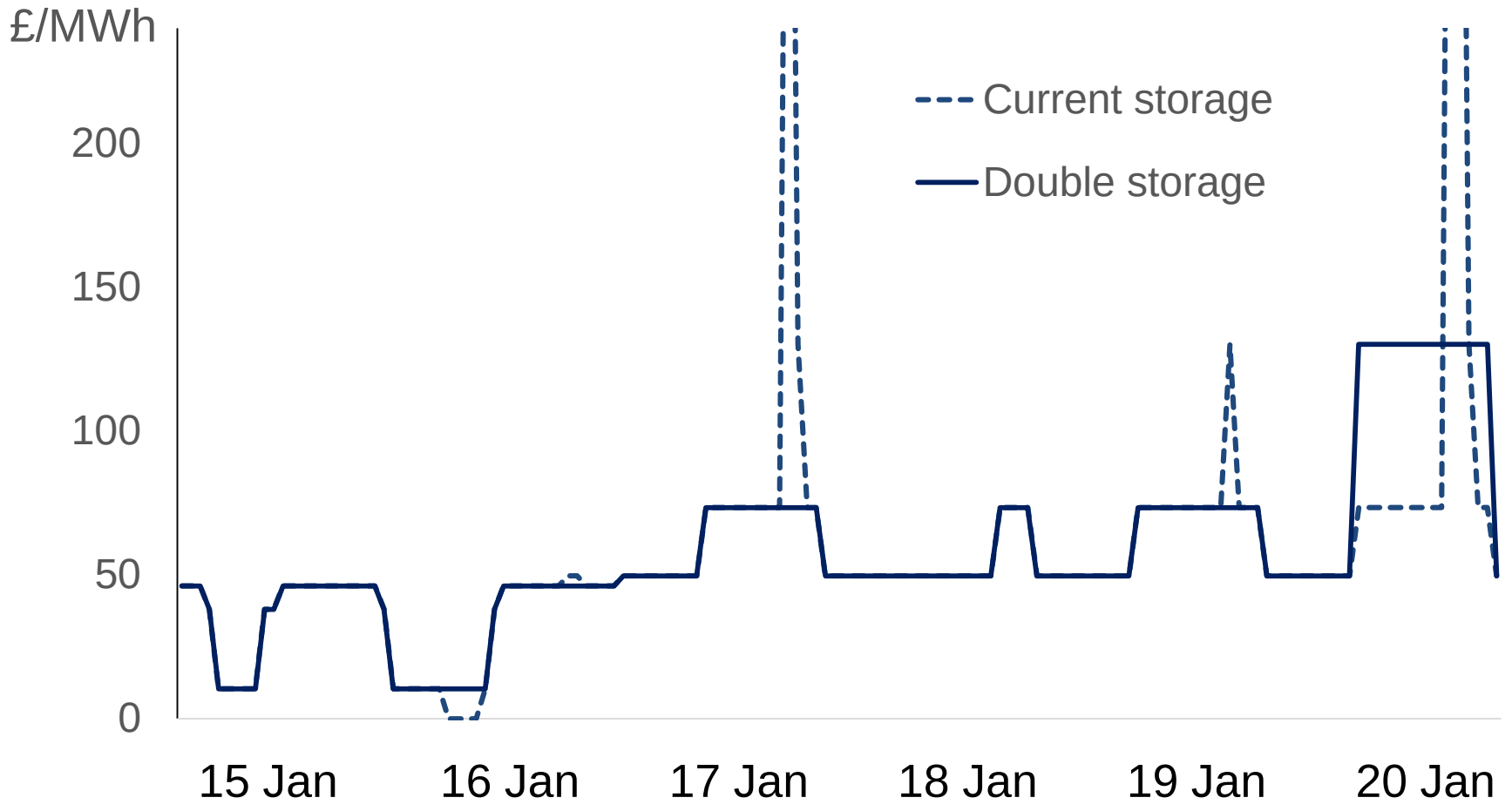
Storage and price patterns

Indicative only



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My reactions:

- Even with a lot of zero-MC plant, positive power prices will dominate returns to generators
- Power prices linked to gas are risky for renewables, and they won't get much more from an EFP auction
- Storage could start to affect price patterns, but you need high power *and* energy capacity relative to RES capacity

Over to you…

Thank you!