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# The Future of Electricity: A Market with Marginal Costs of Zero?



Richard Green, IAEE European Conference, 2017

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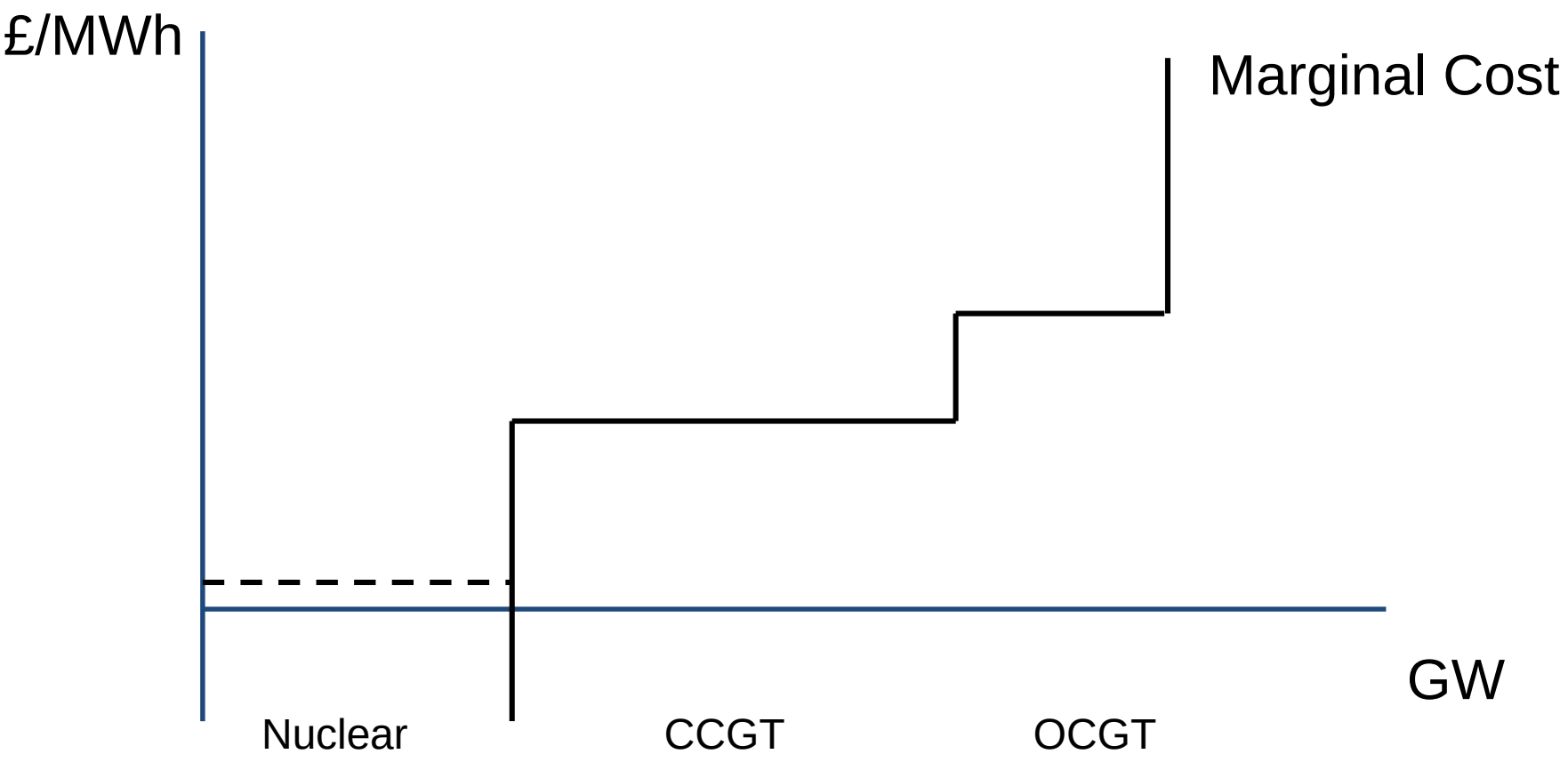
# Supply



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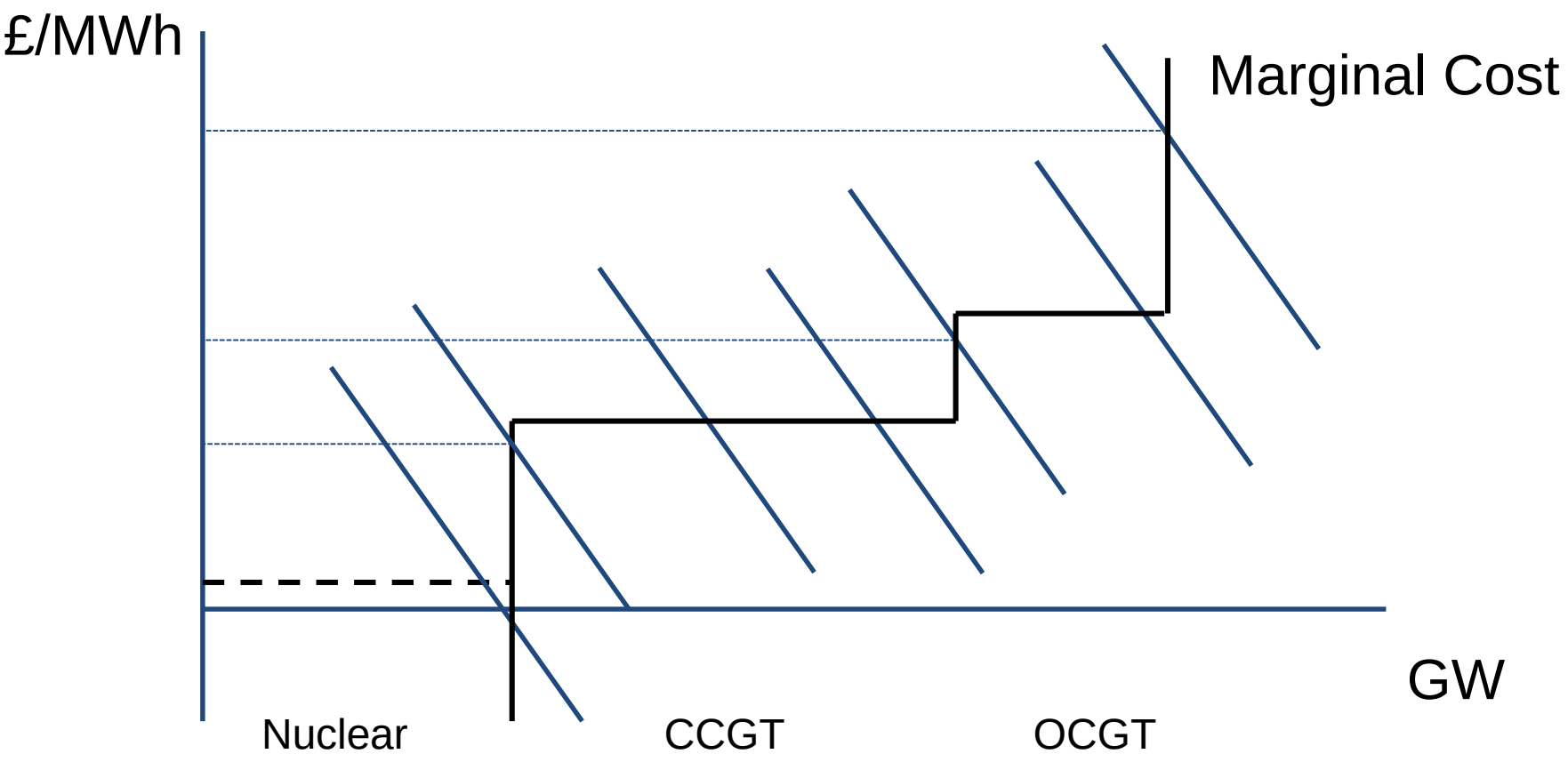
# Demand and Supply

## Prices reflect Marginal Costs



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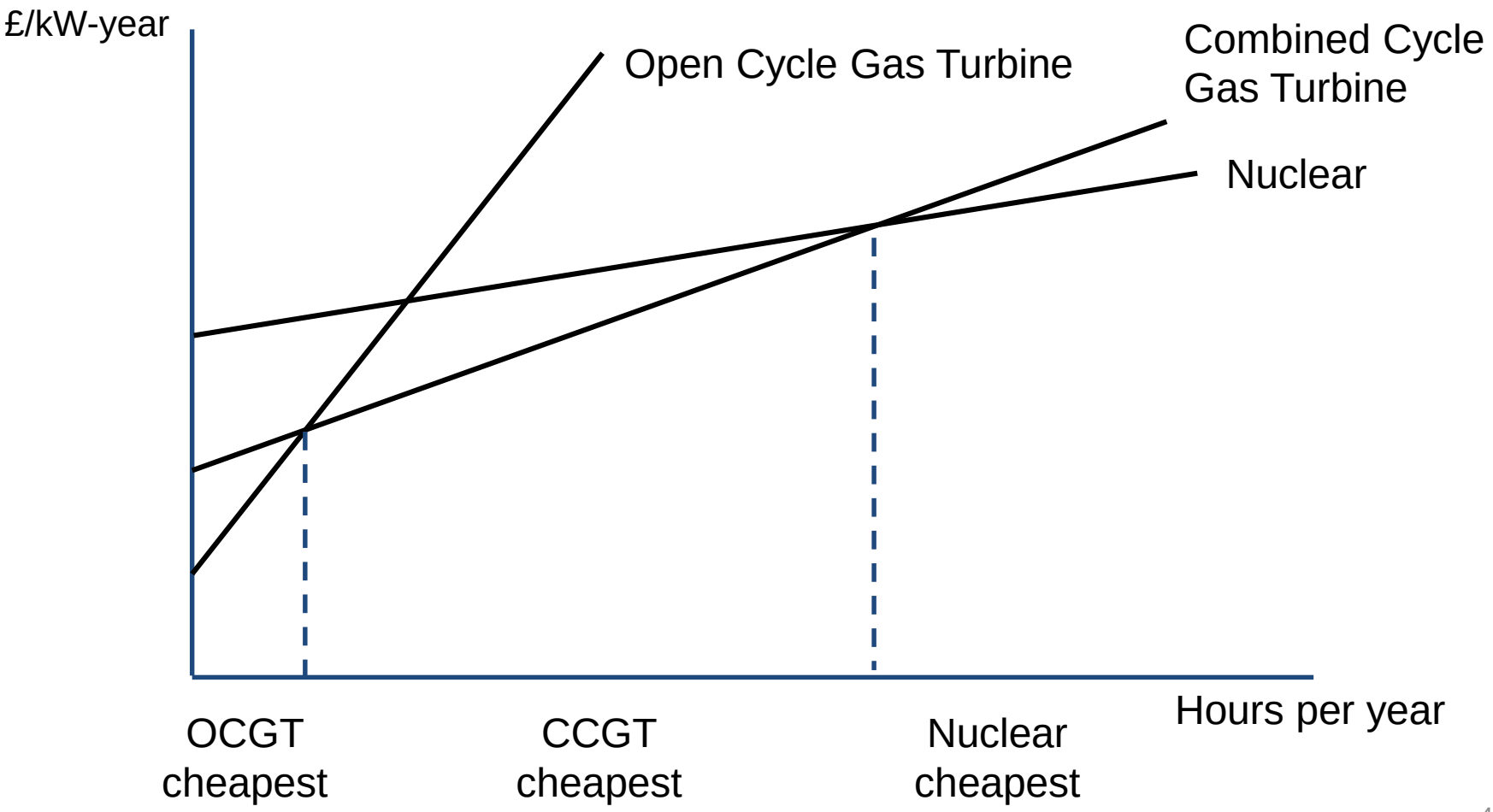
# Annual Generation Costs



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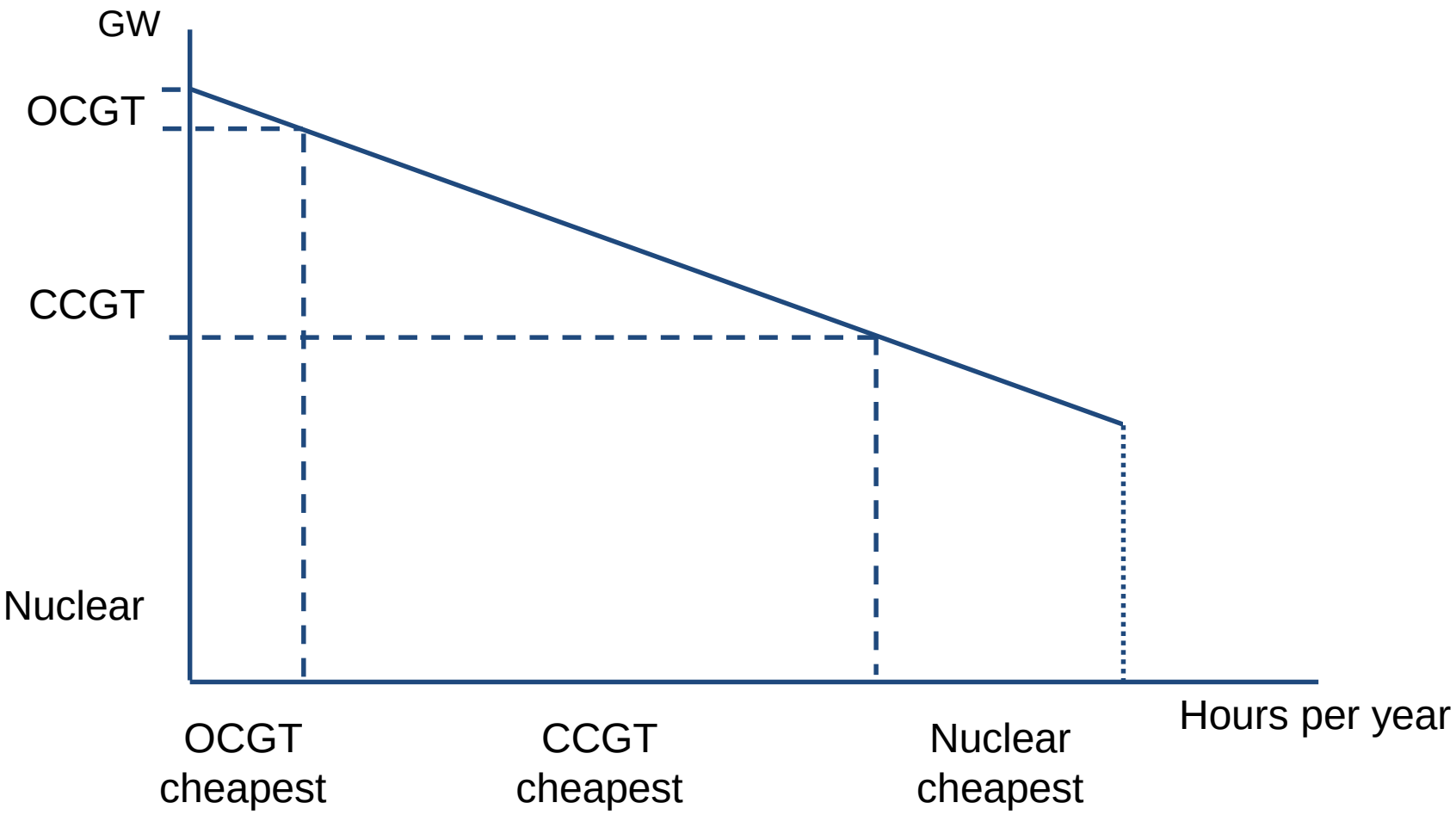
# Load-duration and Capacity



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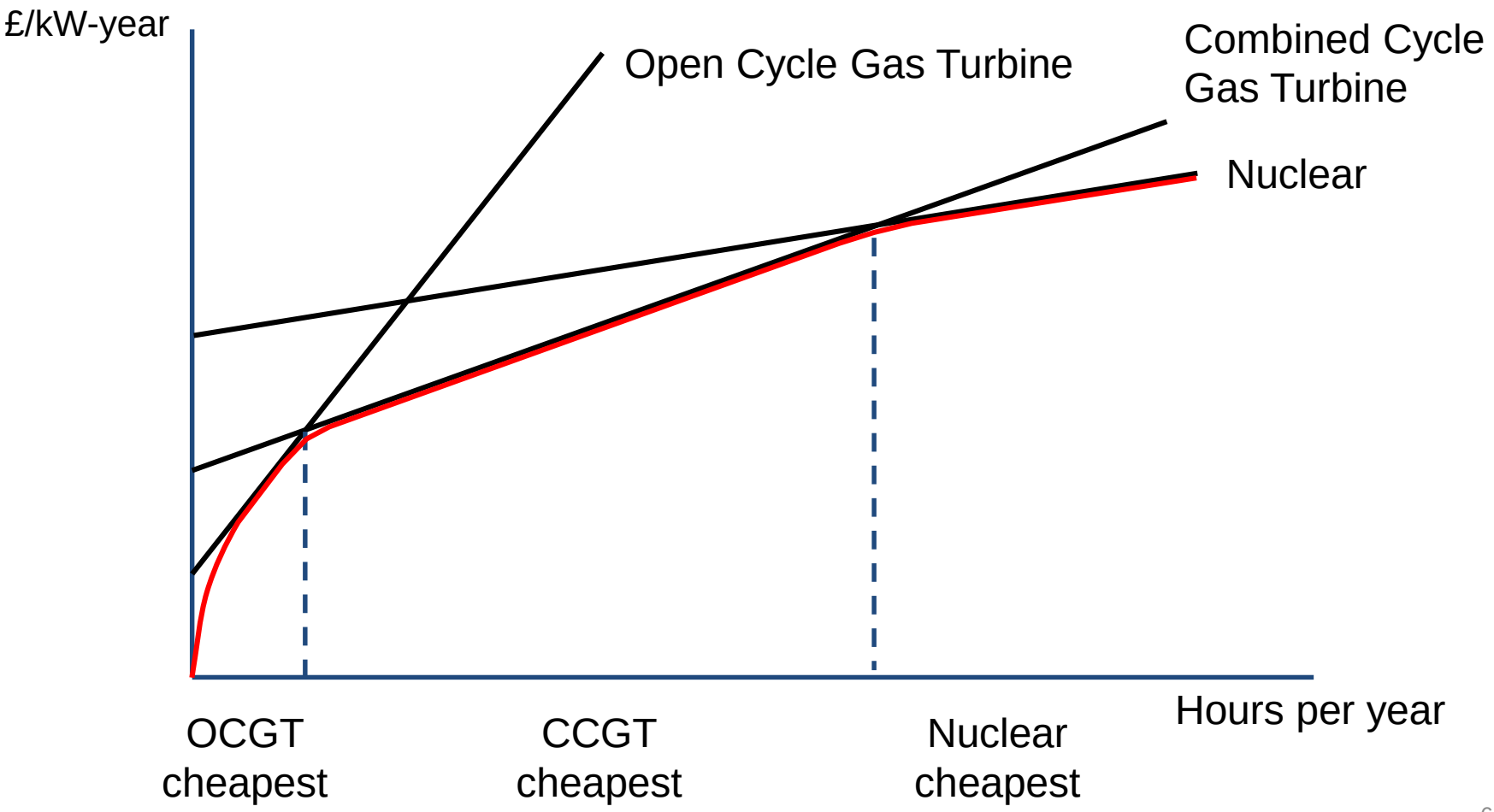
# Generator Costs



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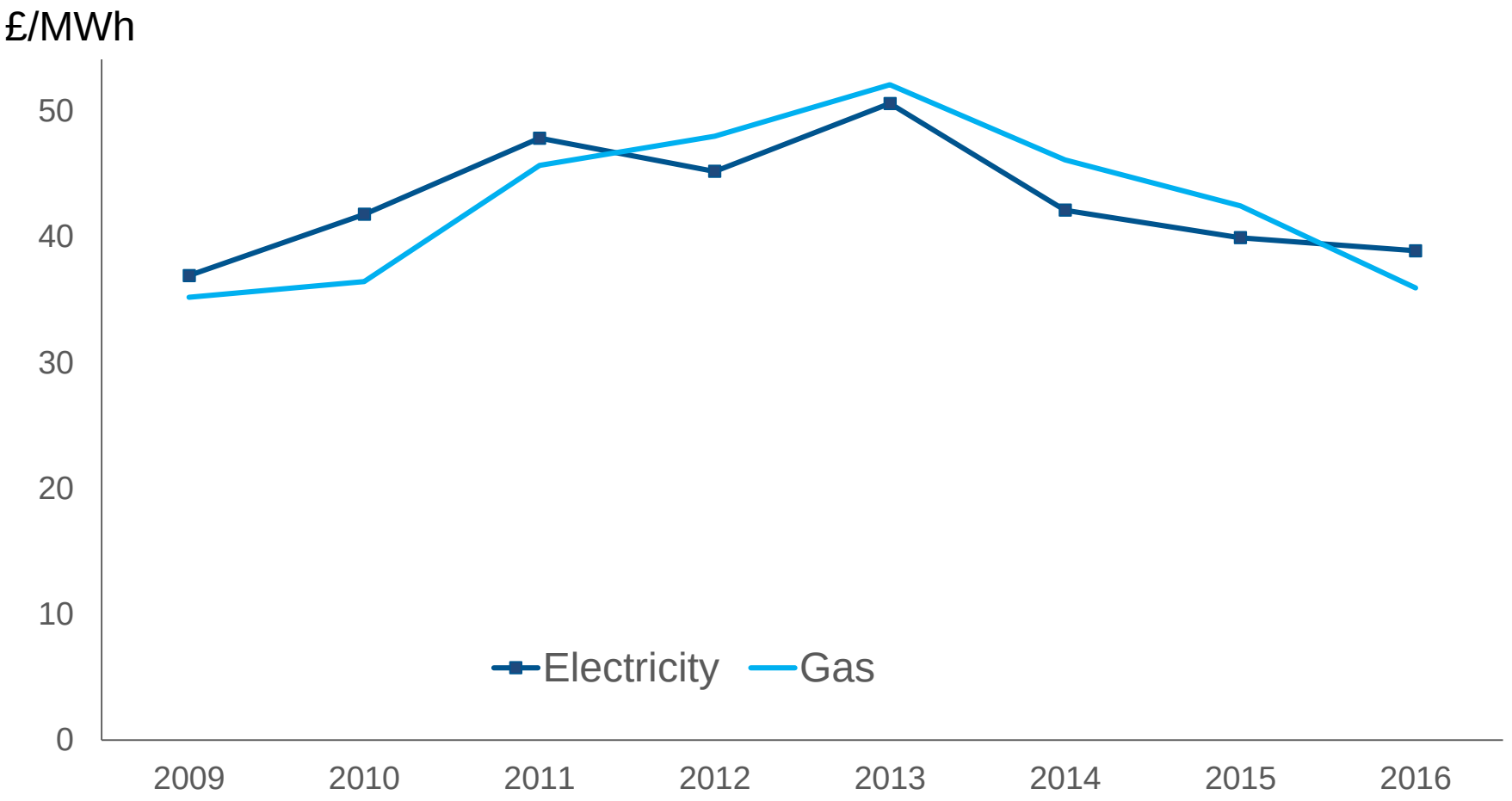
# British Energy Prices

## per MWh of electricity




Source: ElectricInsights.co.uk

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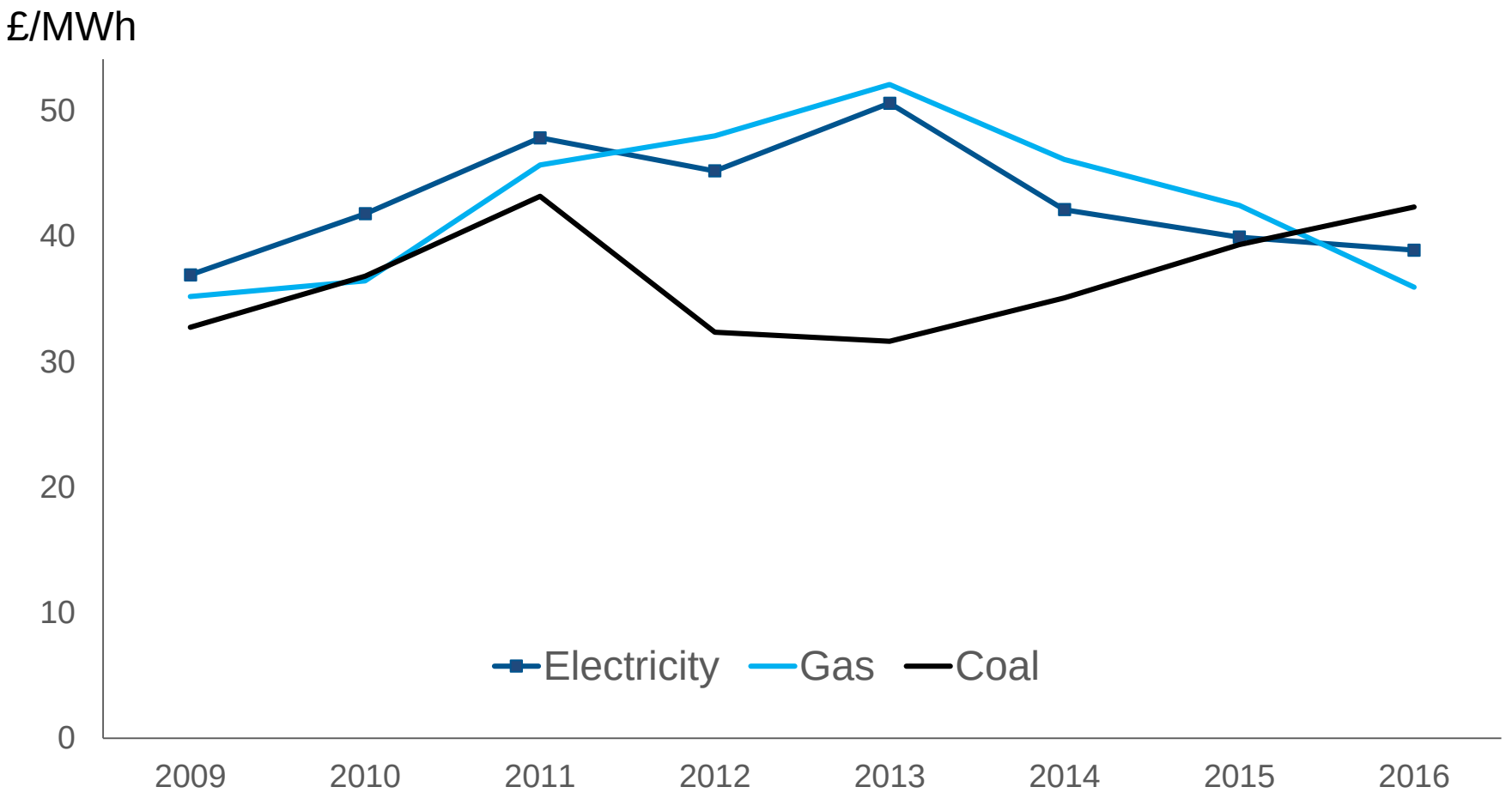
# British Energy Prices

## per MWh of electricity




Source: ElectricInsights.co.uk

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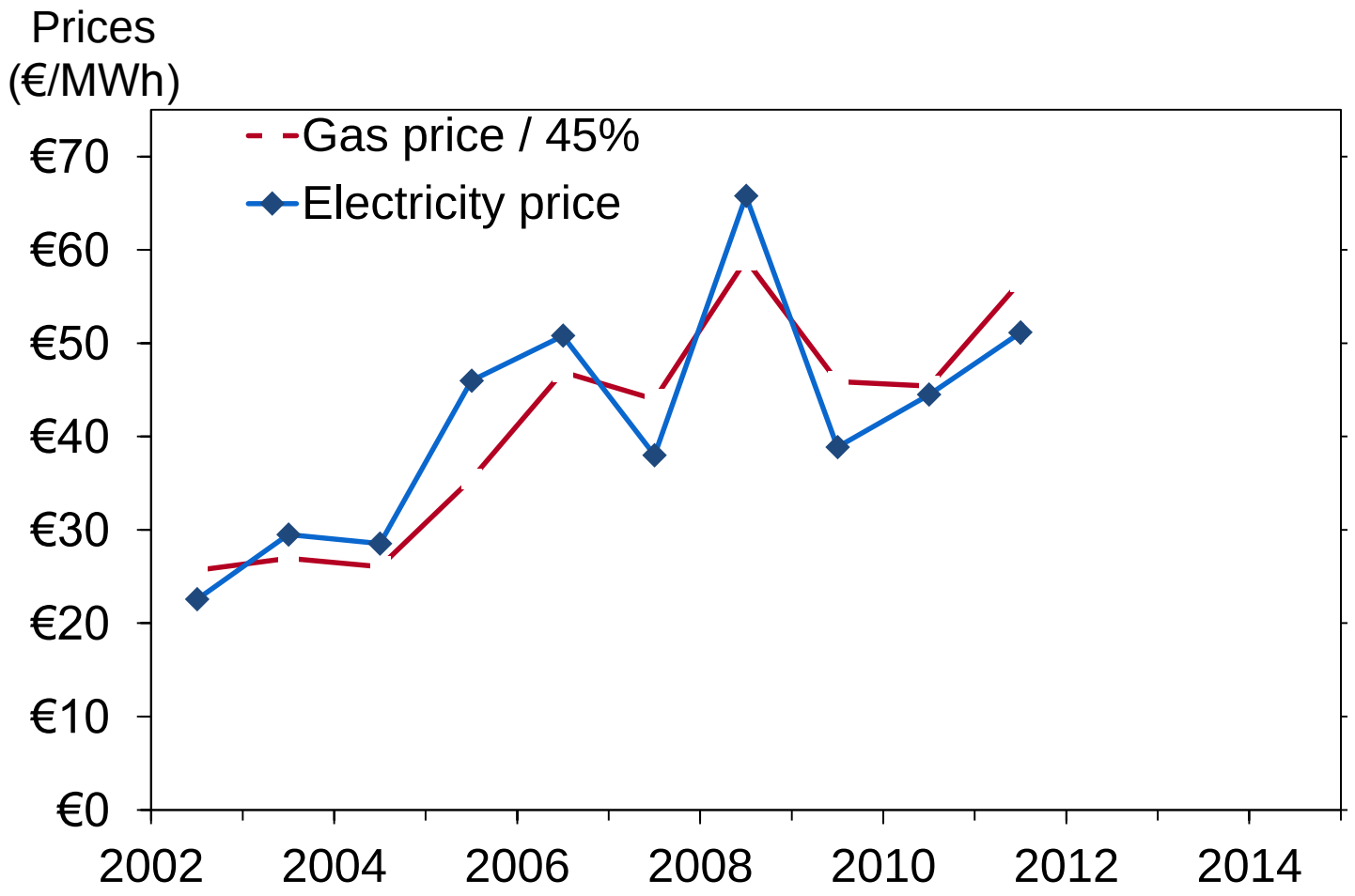
# Austrian Energy Prices: a market working well




Source: Green and Staffell, Oxrep, 2016

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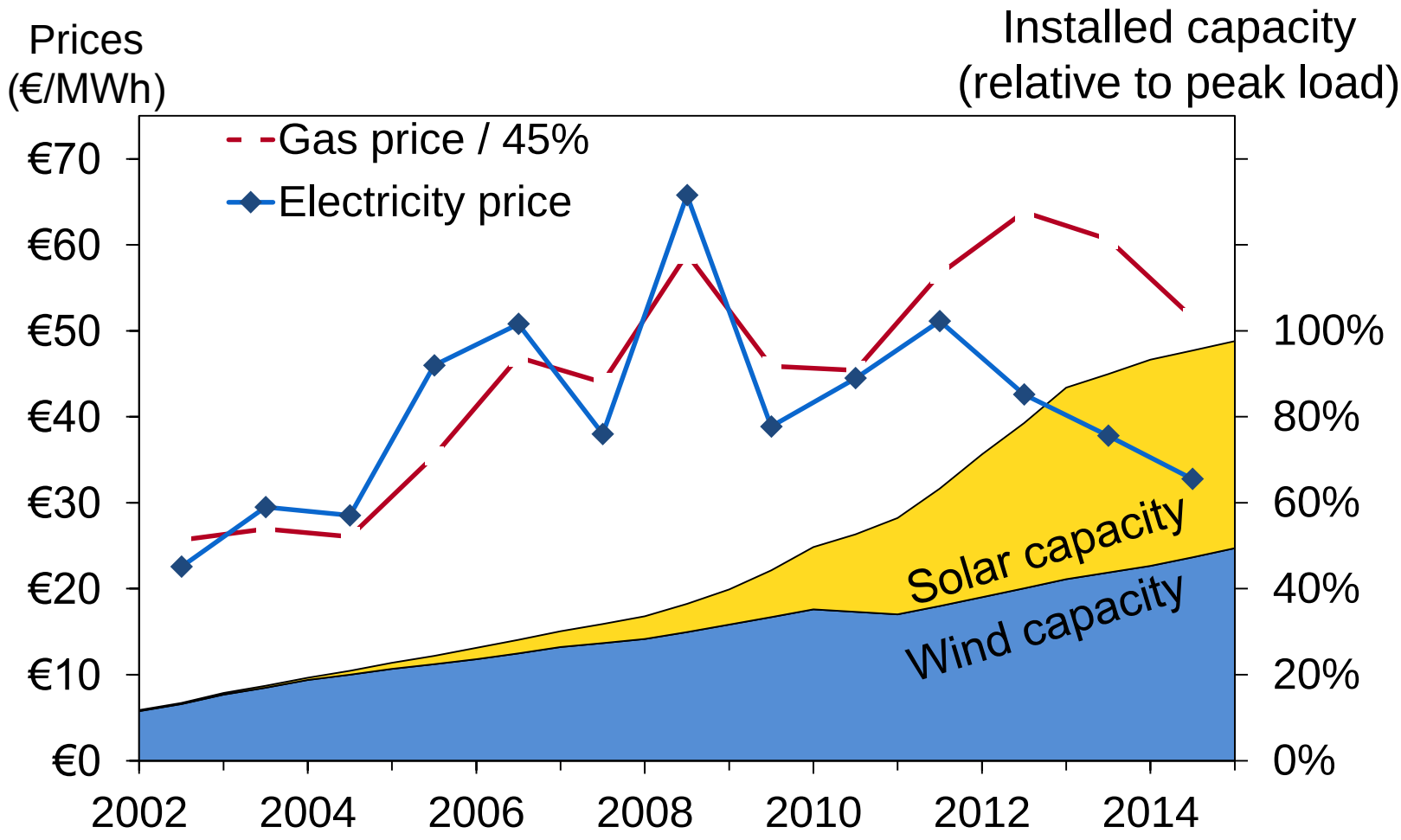
# Austrian Energy Prices: The Merit Order Effect




Source: Green and Staffell, Oxrep, 2016

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# Renewables in a Power Market

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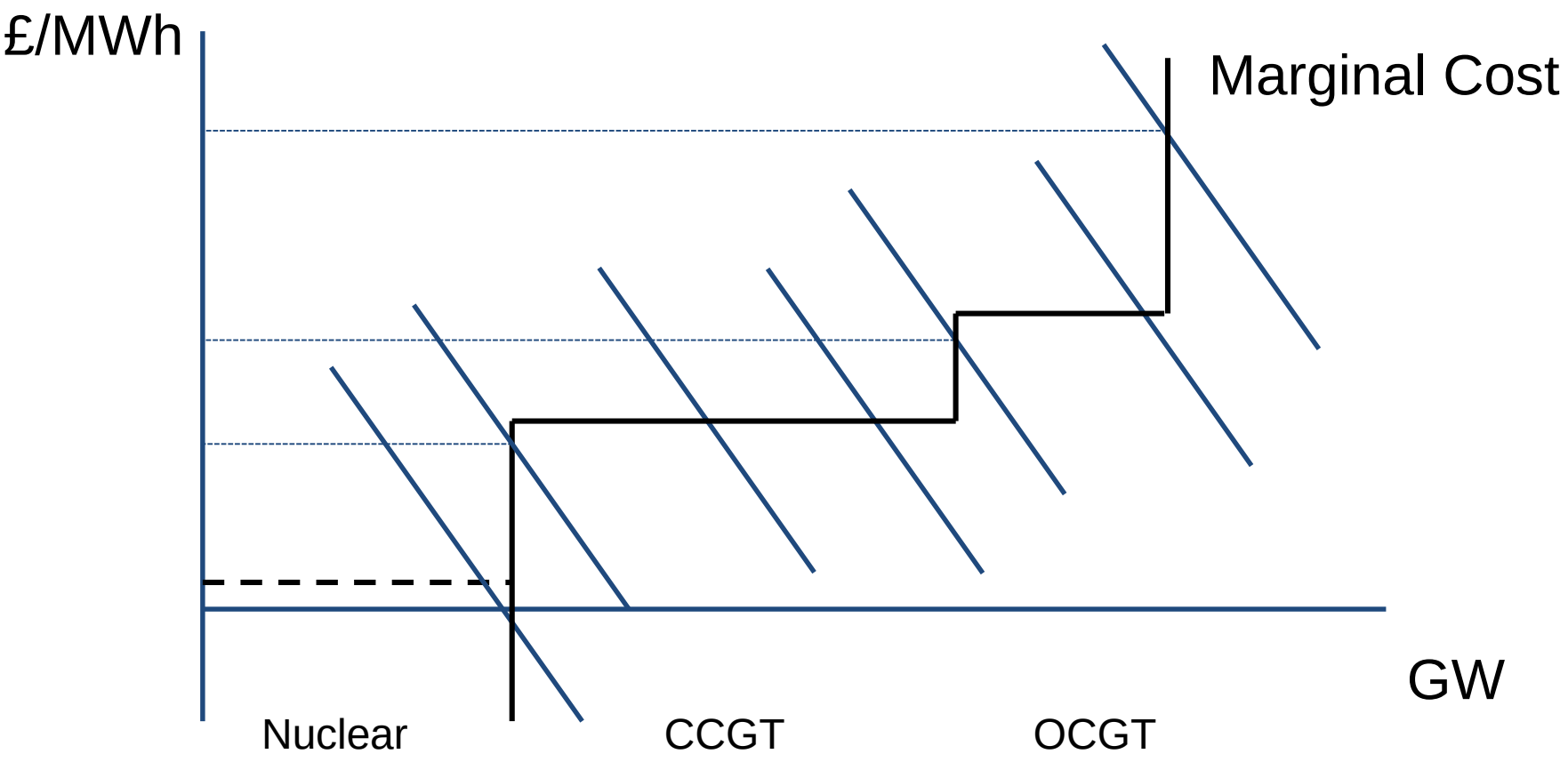
# Demand and Supply

## The merit order effect



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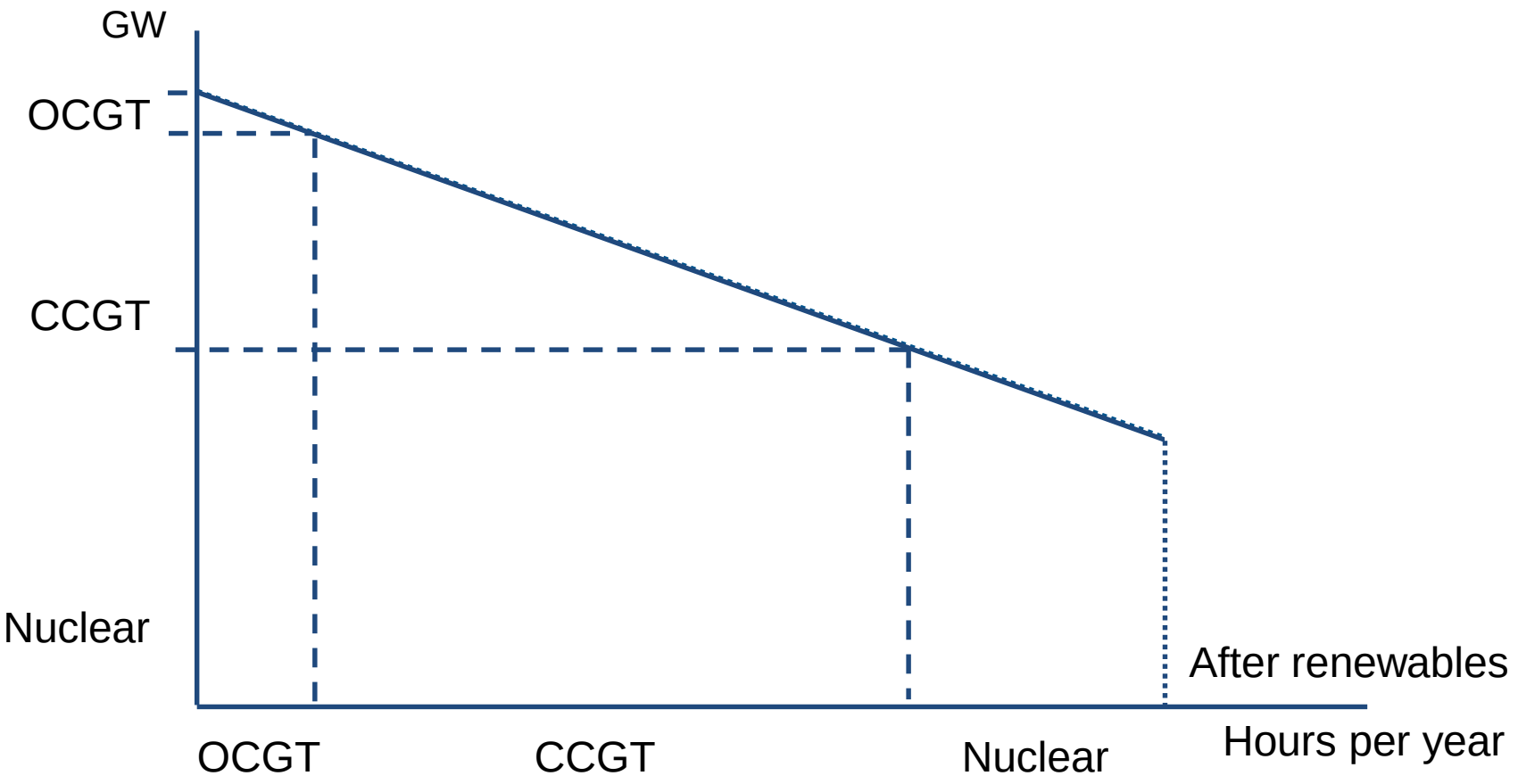
# Capacity and Load



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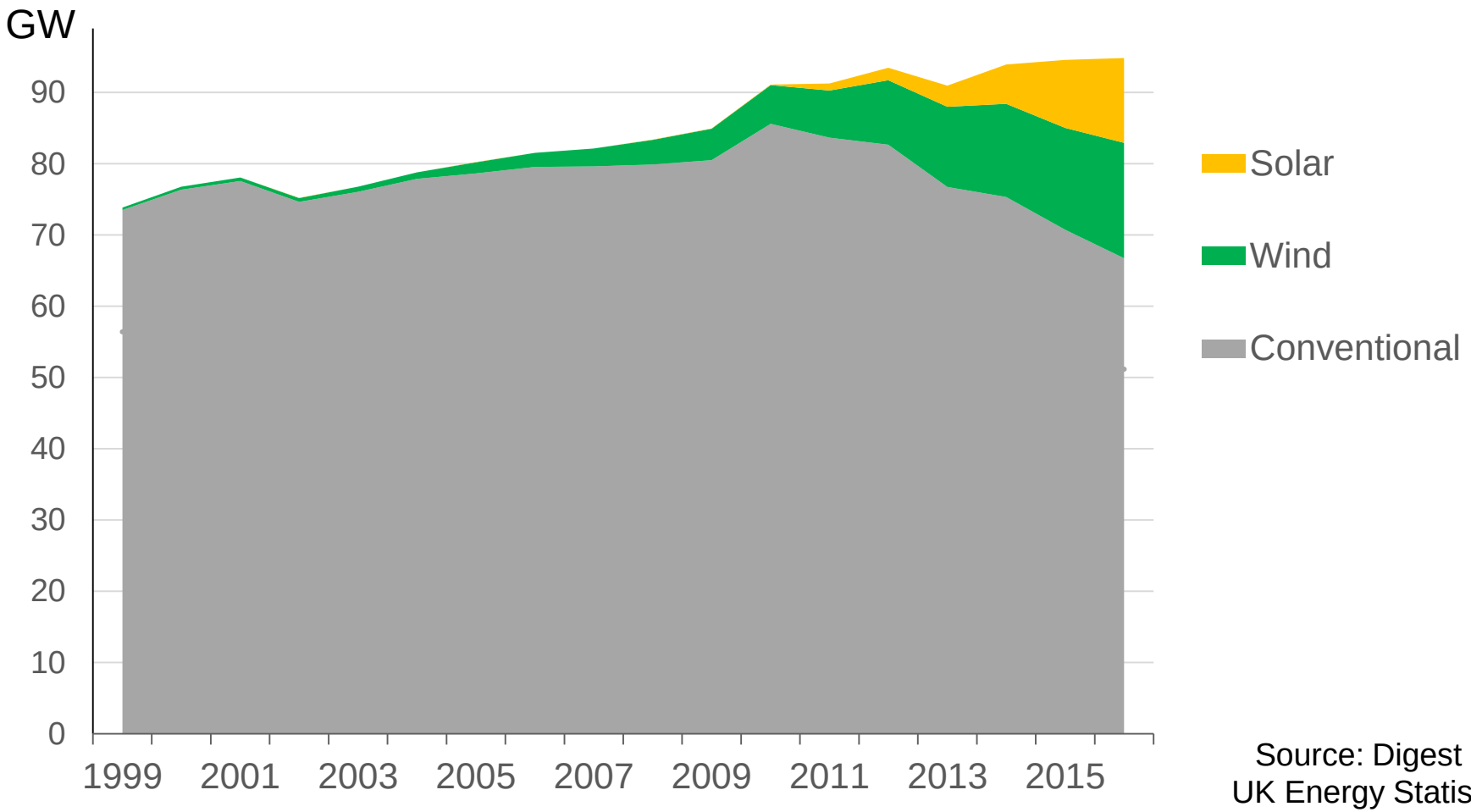
# Generating Capacity

## Great Britain




Source: Digest of UK Energy Statistics

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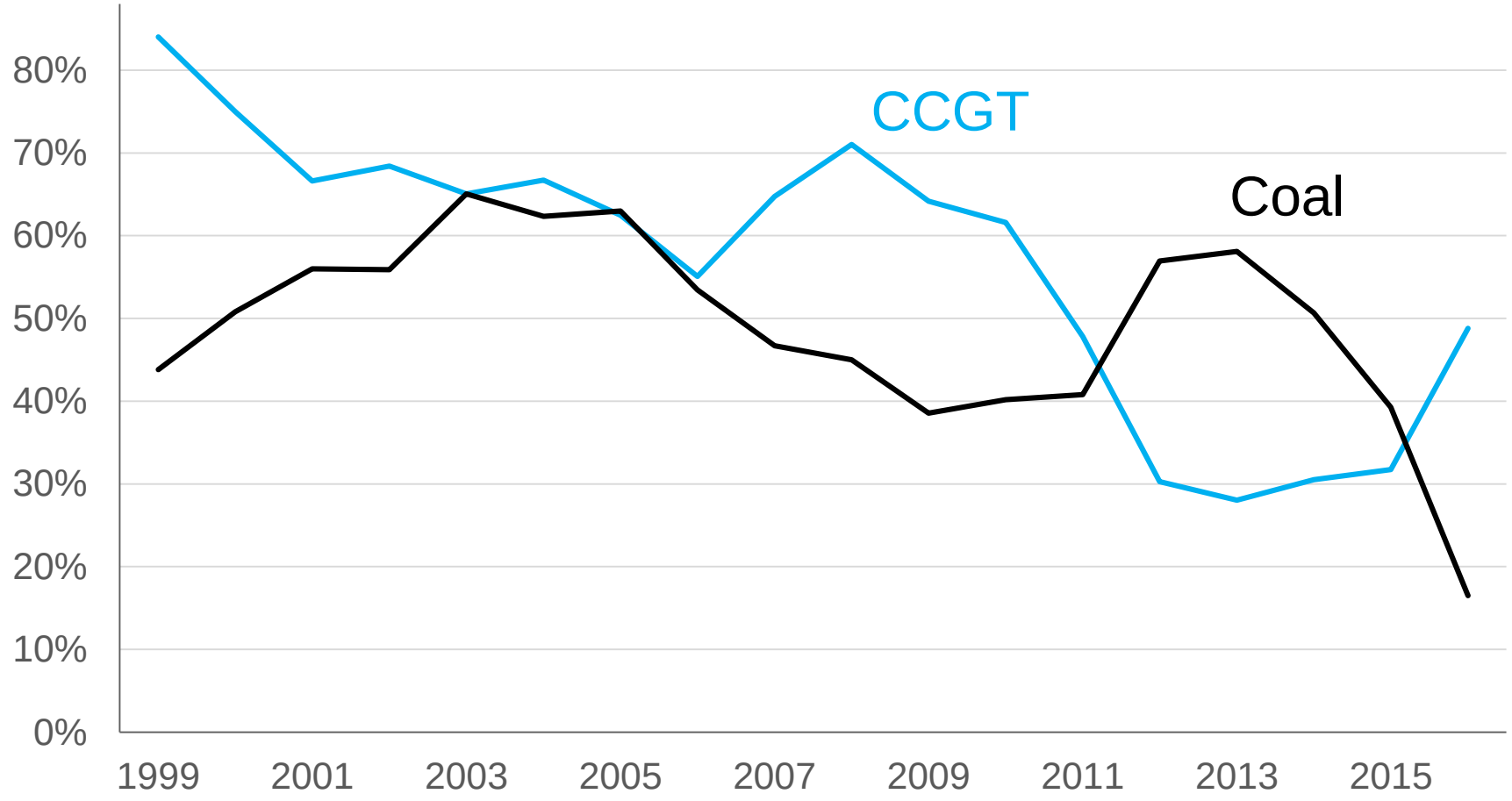
# Generators' Load Factors

## UK-wide, including Northern Ireland




Source: Digest of UK Energy Statistics

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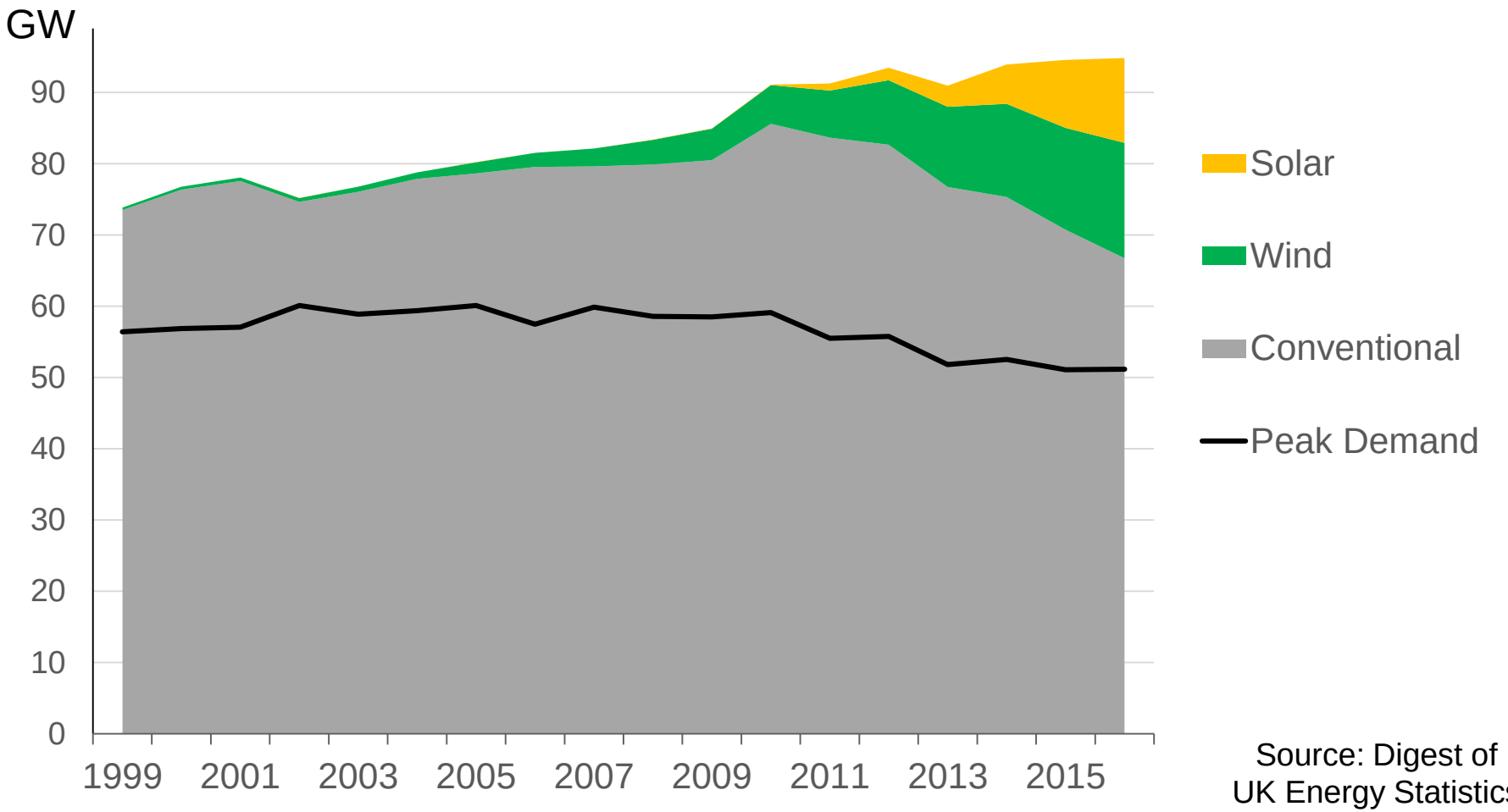
# Capacity and Peak Demand

## Great Britain




Source: Digest of UK Energy Statistics

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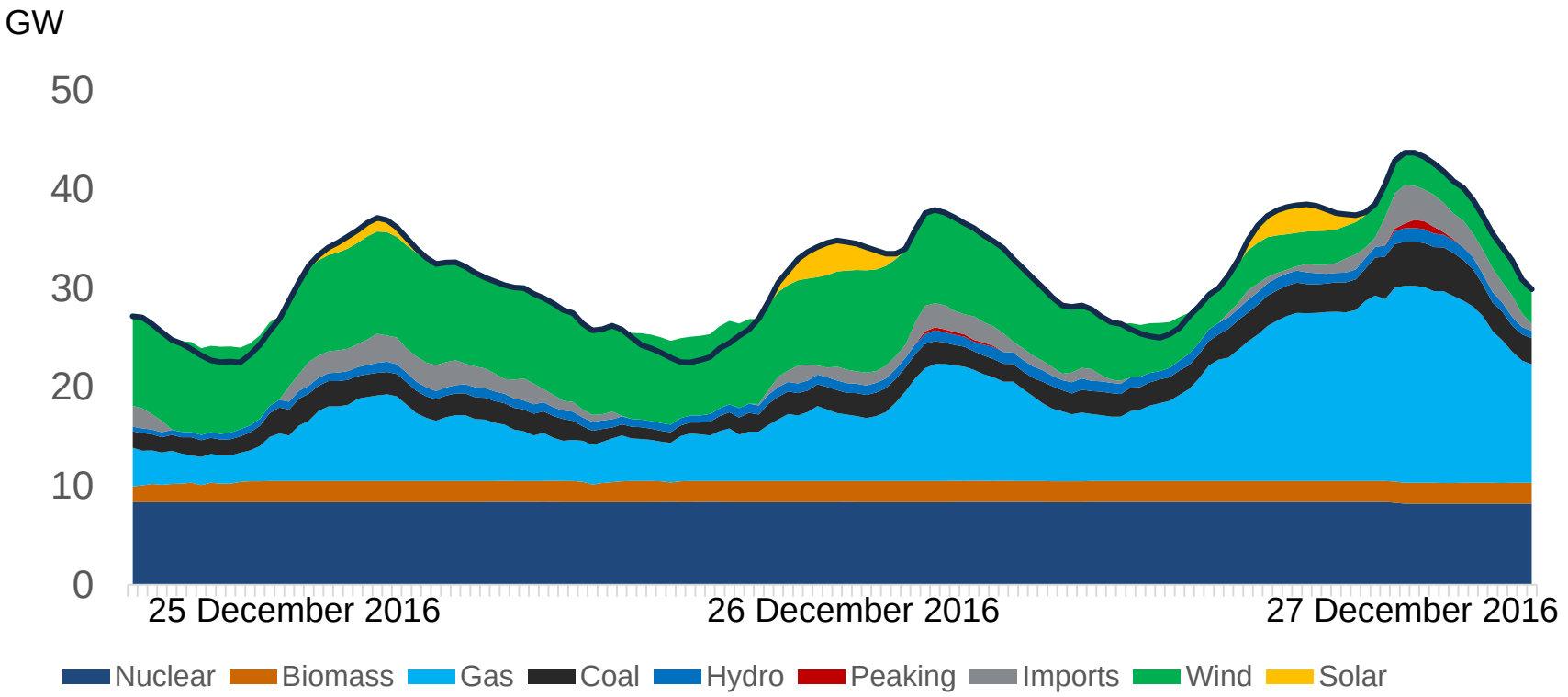
# A Low-Carbon Christmas




Source: ElectricInsights.co.uk

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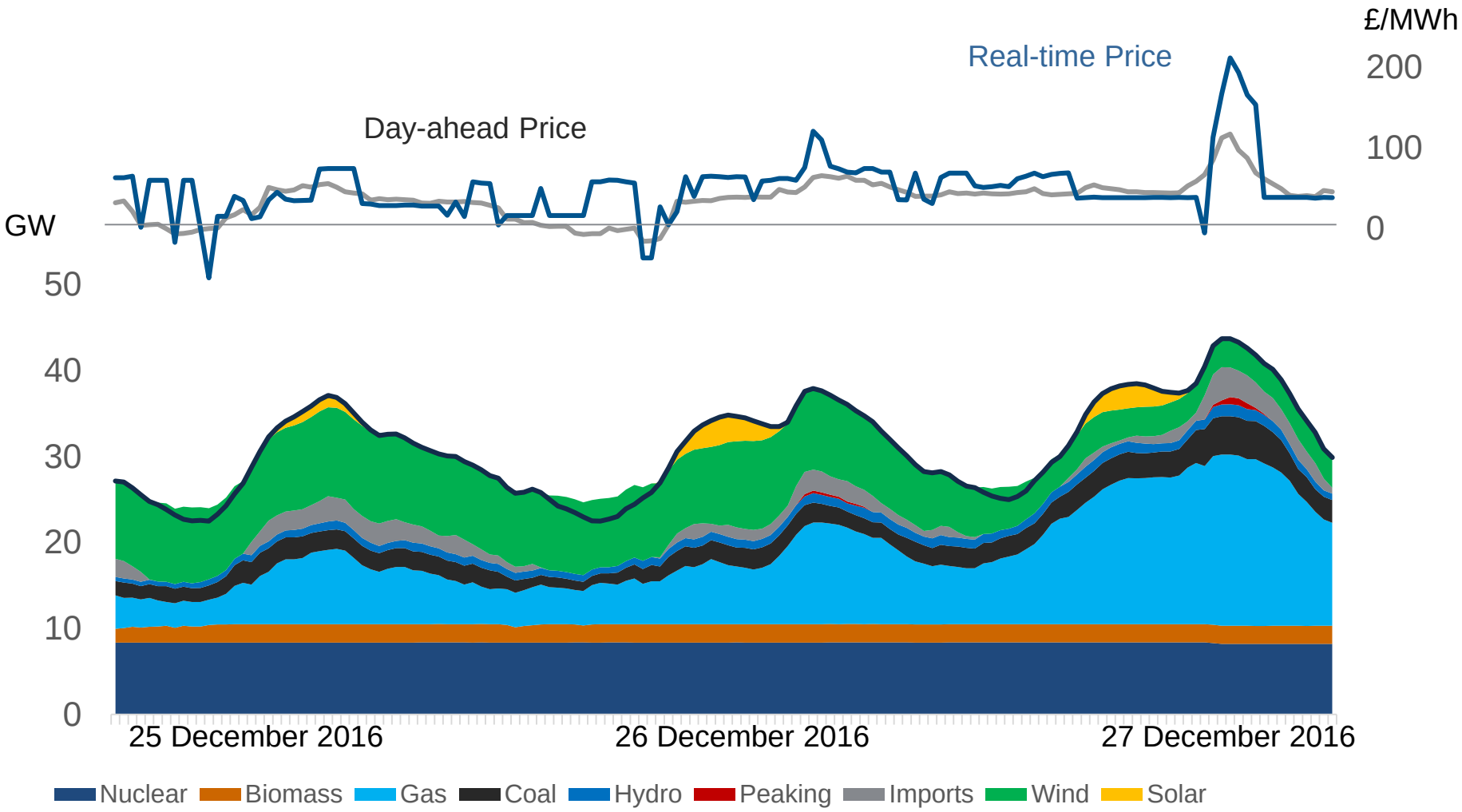


Source: ElectricInsights.co.uk

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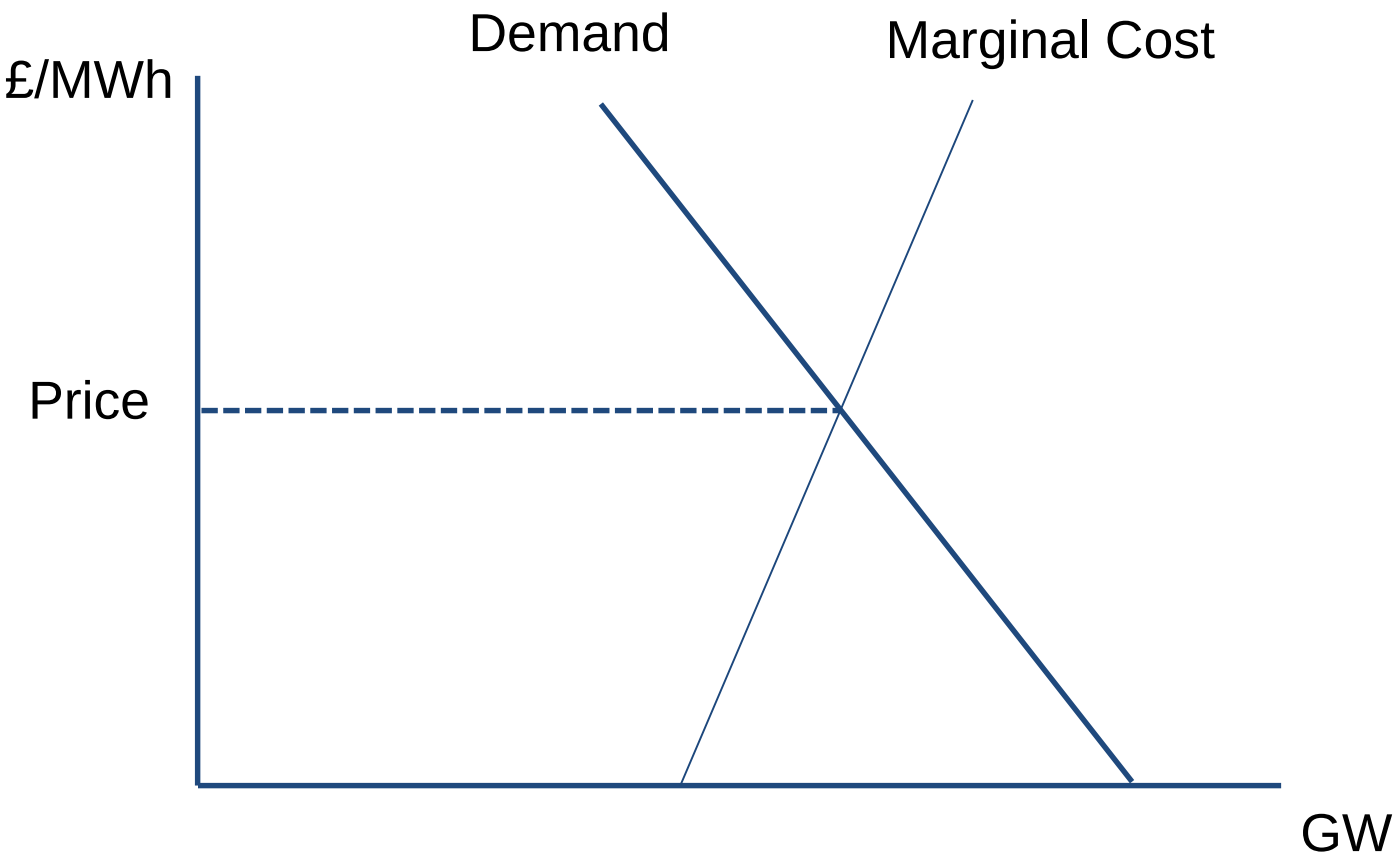
# Supply and Demand



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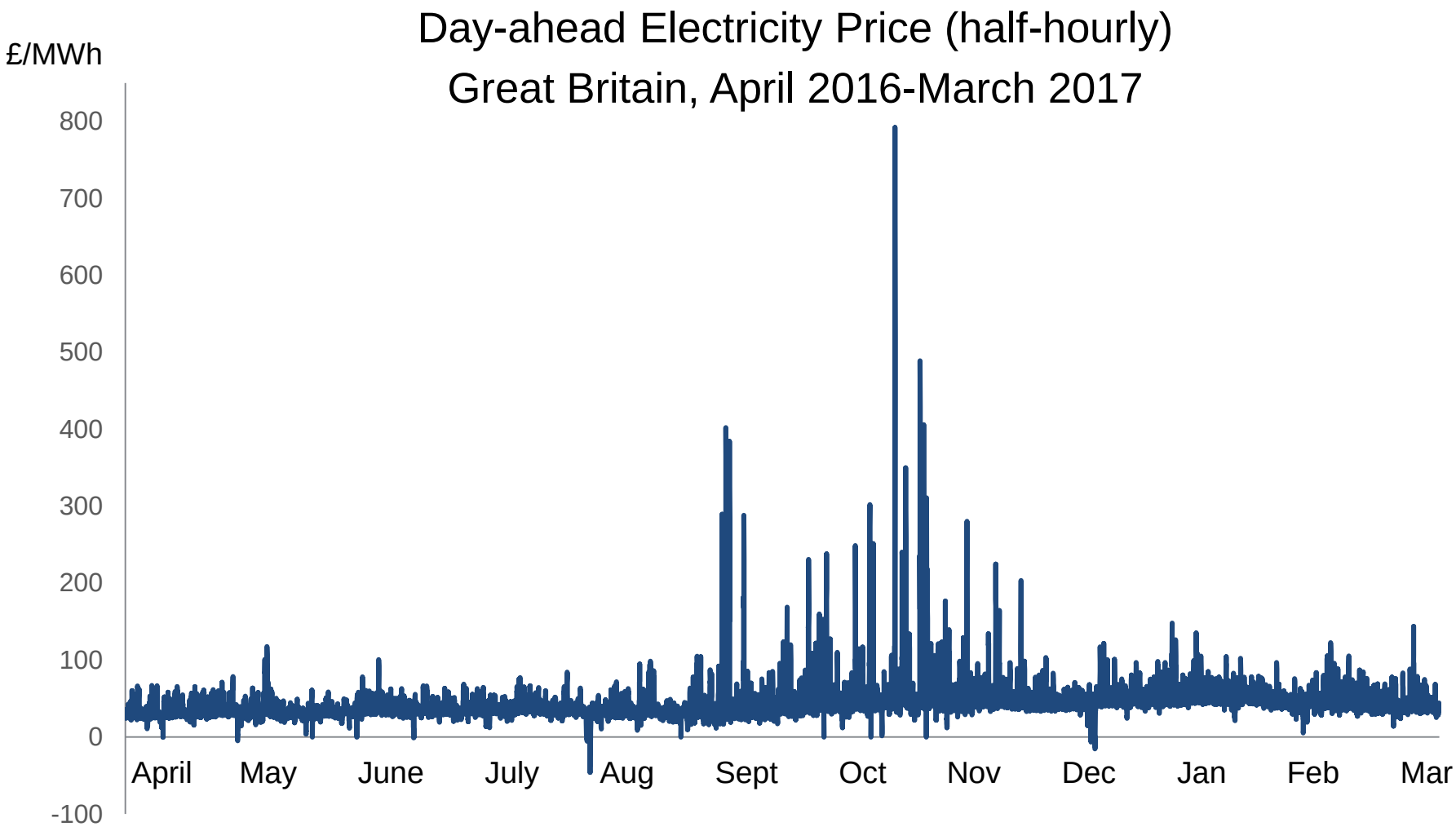
# A volatile market




Source: ElectricInsights.co.uk

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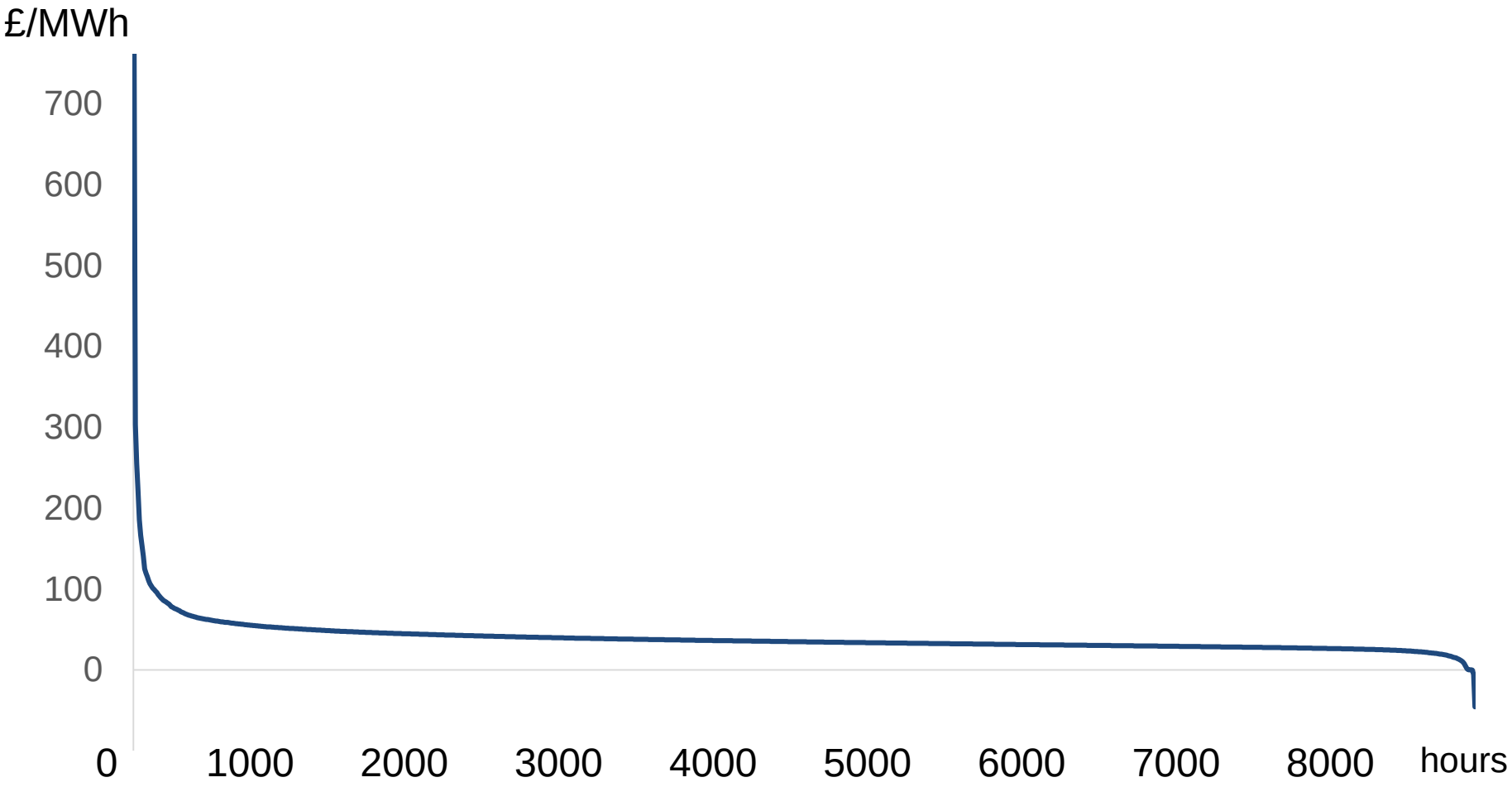
# Day-ahead Prices in 2016




Source: ElectricInsights.co.uk

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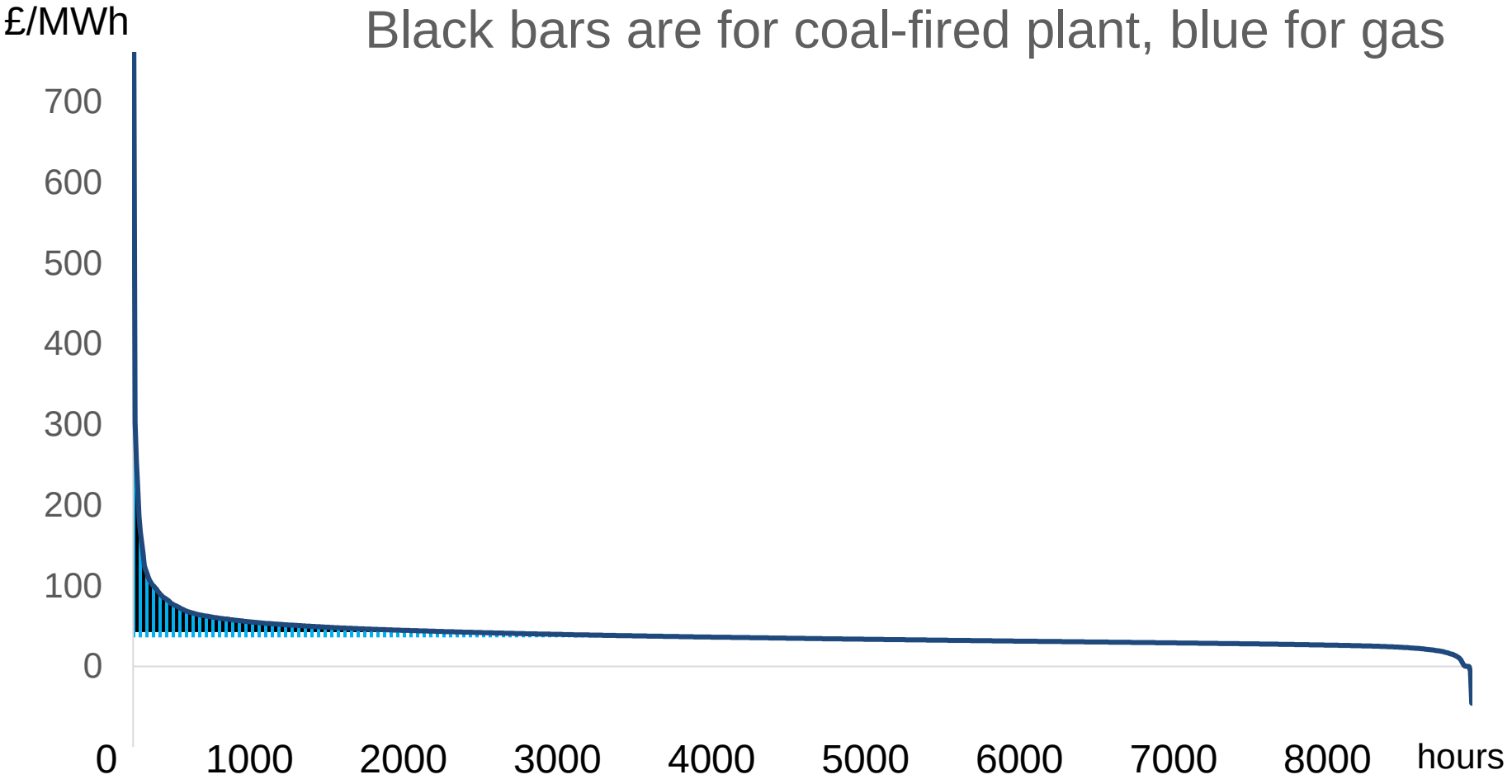
# Day-ahead Prices in 2016

## Surplus over annual average fuel cost

Black bars are for coal-fired plant, blue for gas




Source: ElectricInsights.co.uk

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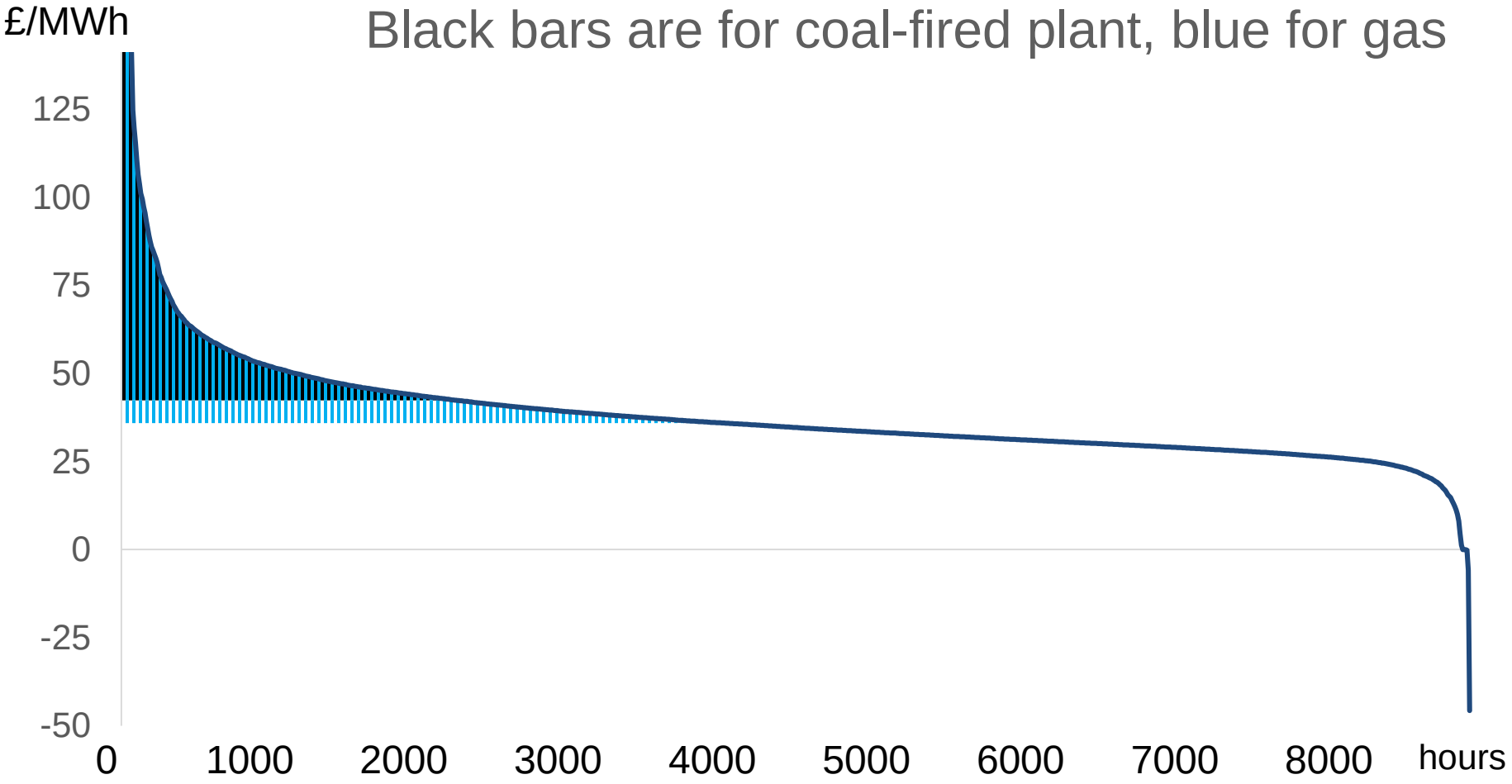


Source: ElectricInsights.co.uk

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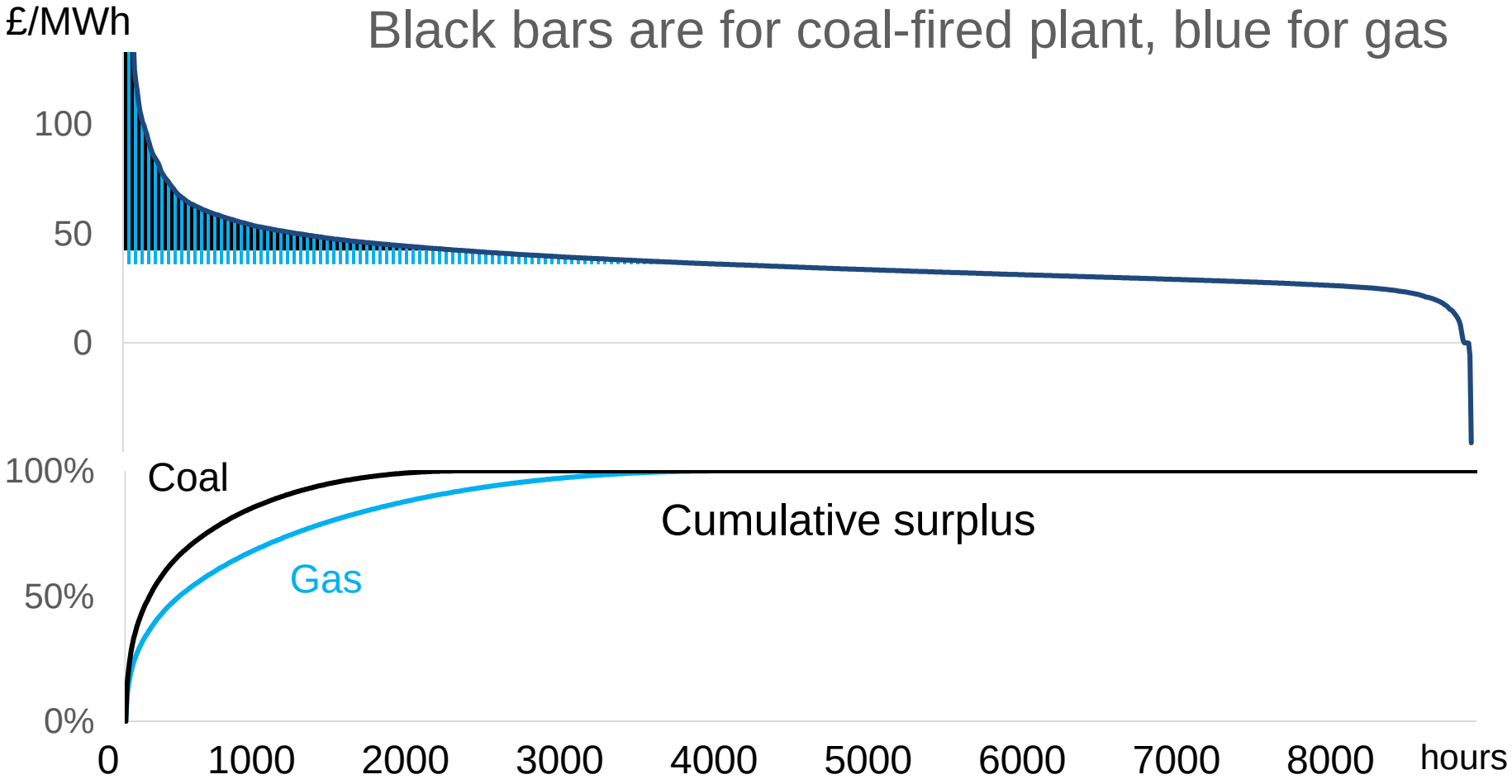


Source: ElectricInsights.co.uk

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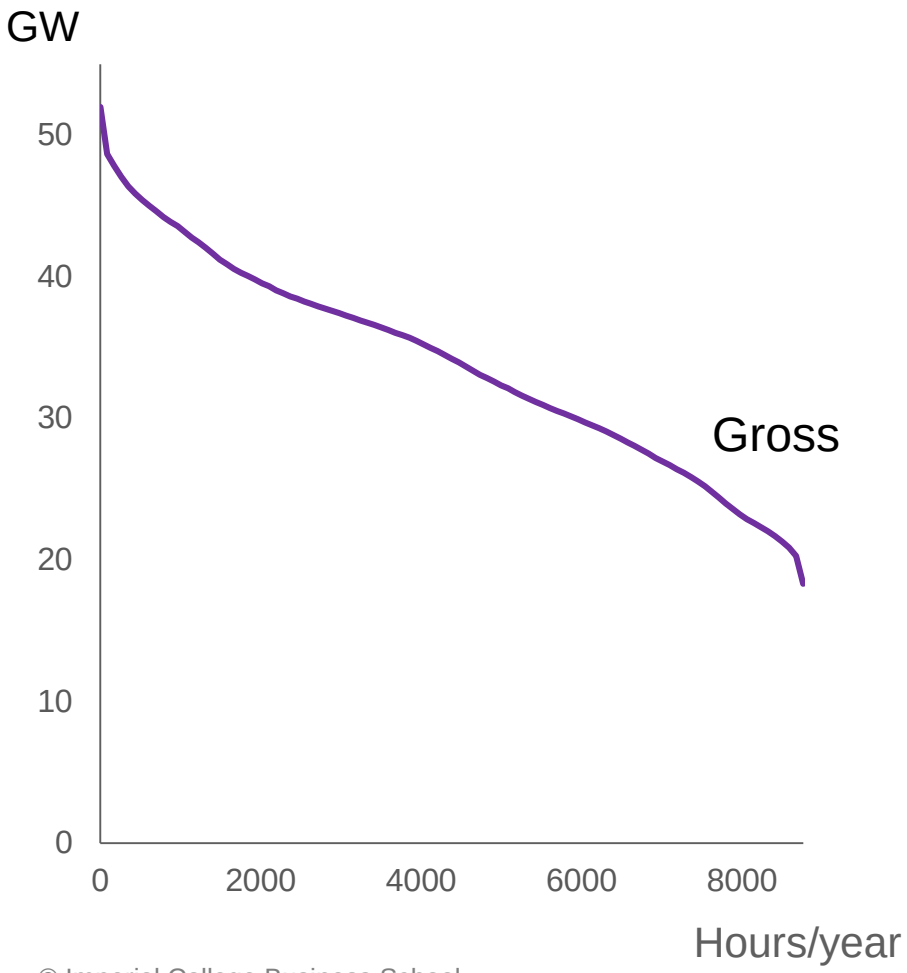
# More need for peaking plant?

## 2016 Load-duration curves




Source: ElectricInsights.co.uk

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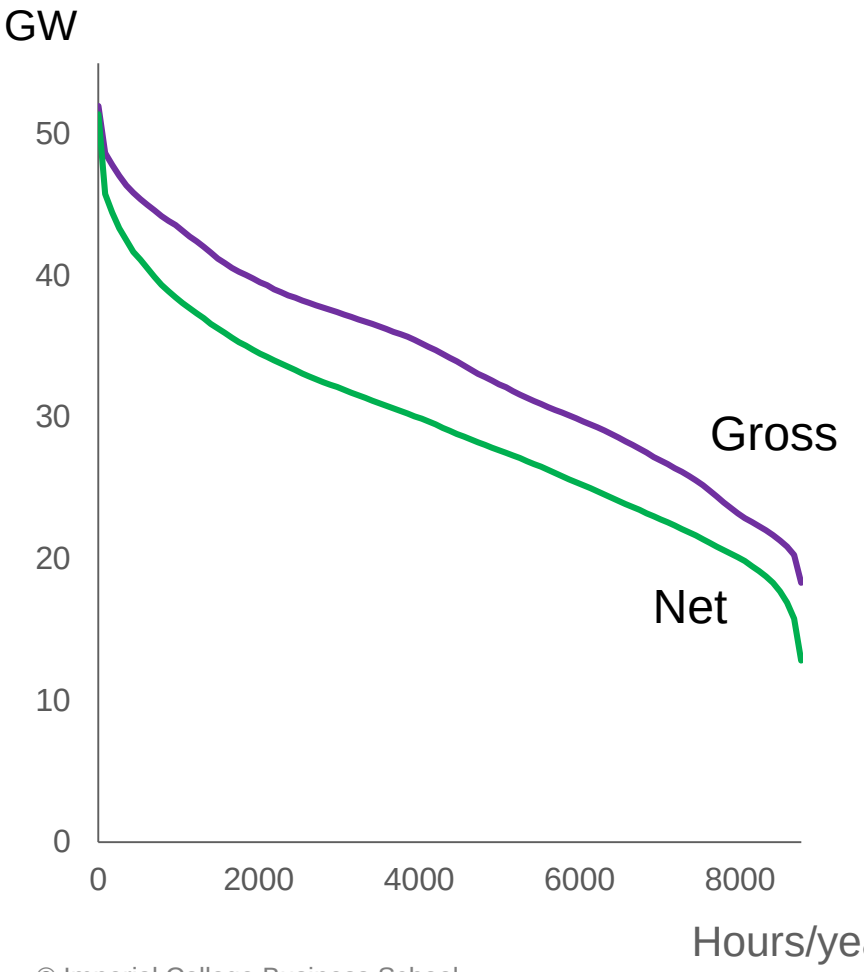
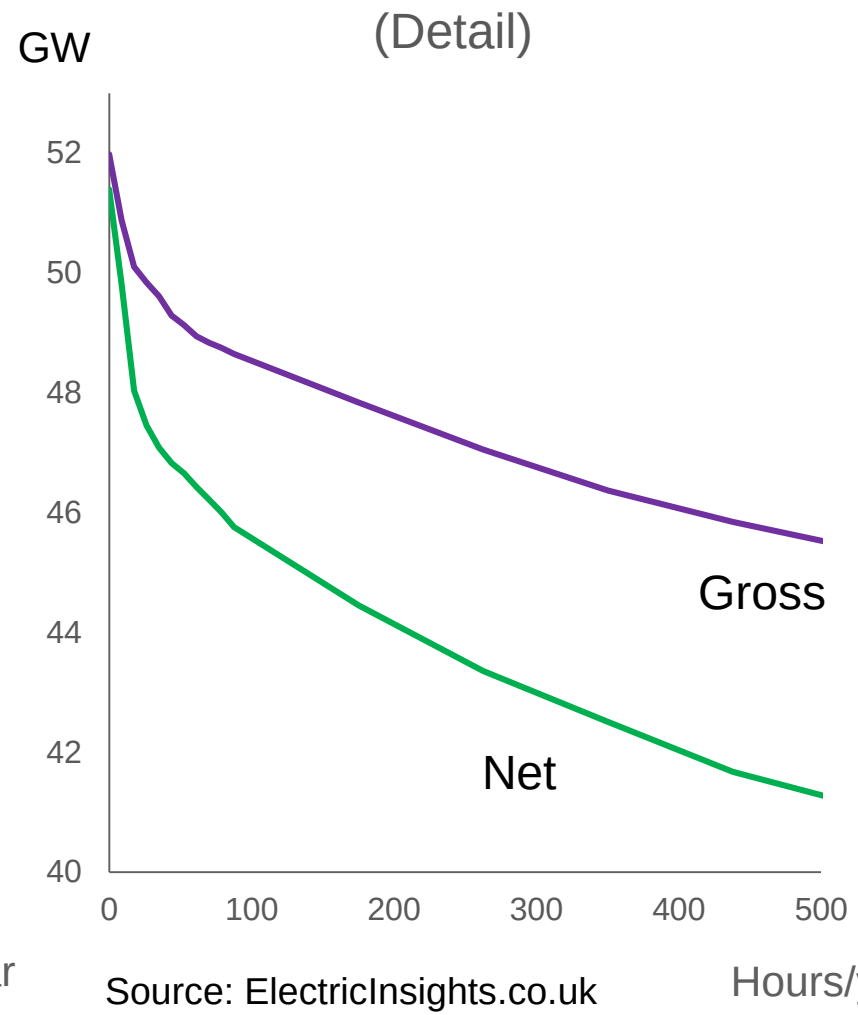
# More need for peaking plant?

## 2016 Load-duration curves




Source: ElectricInsights.co.uk

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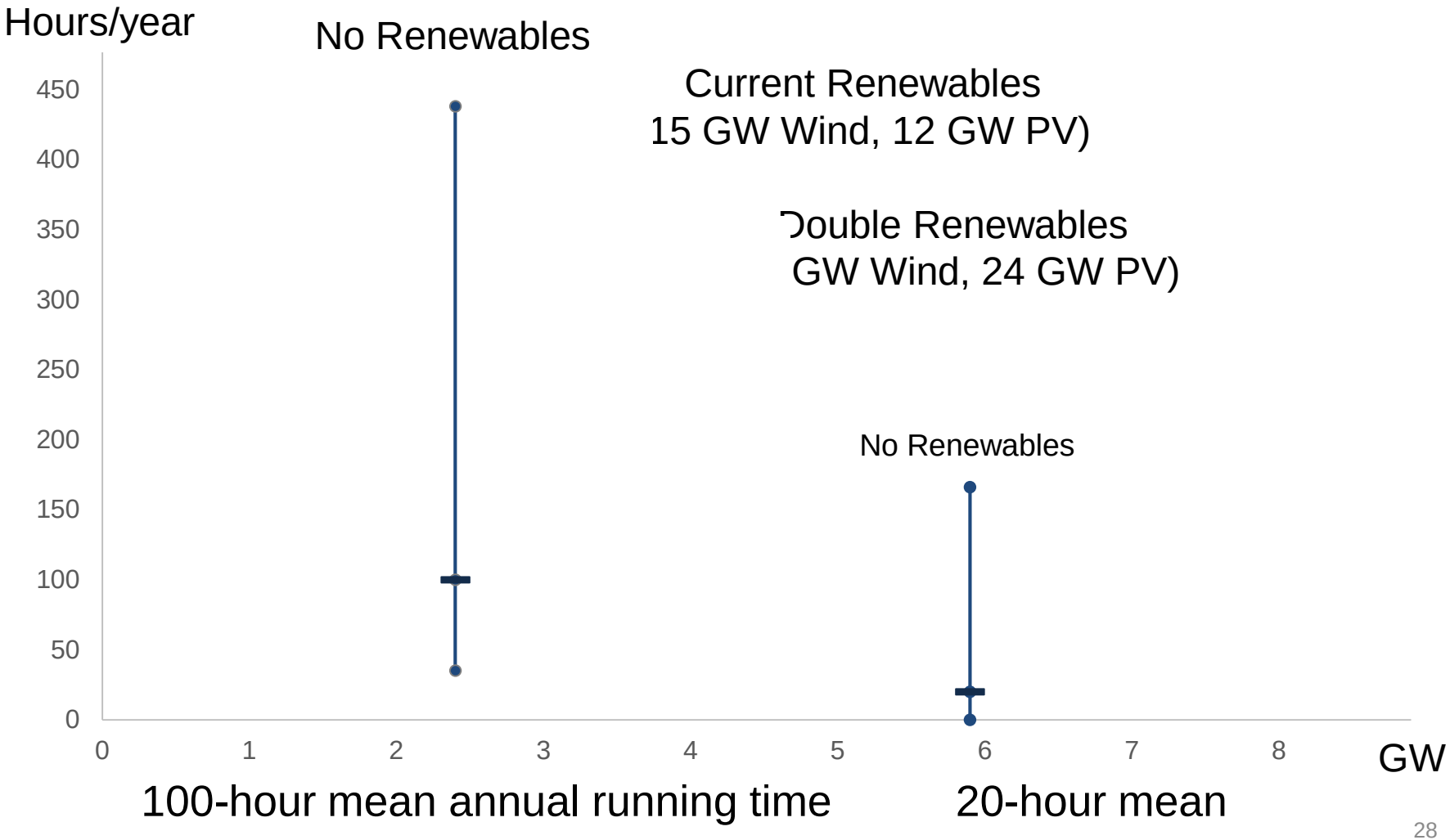
# More risk for peaking plants?

## Usage over 17 years of demand and weather data



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# A market of the future…

## The Model With No Name

- Scheduling model with start costs and no-load costs
  - Capacity assumed infinitely divisible
- Reserve requirement of 3GW in all periods
- Demands from GB load profiles, scaled to common base
- Demand reduction linear in price above £40/MWh
- Renewable profiles for wind and PV from Iain Staffell and Stefan Pfenninger: renewables.ninja
- Assume 15 GW onshore wind
  50 GW offshore wind
  15 GW Solar PV

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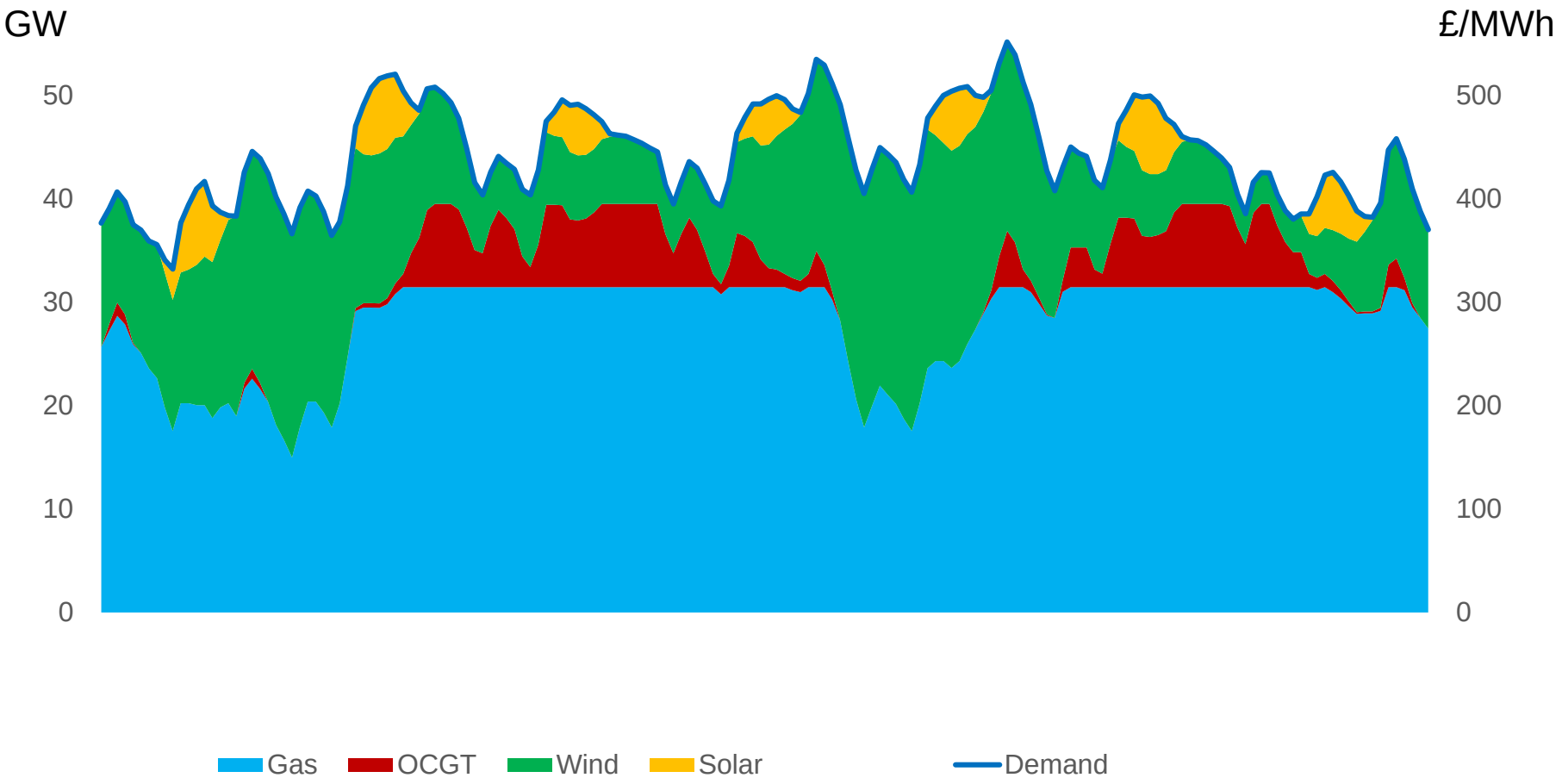
# A simulated future

## Week 7 of “2010”



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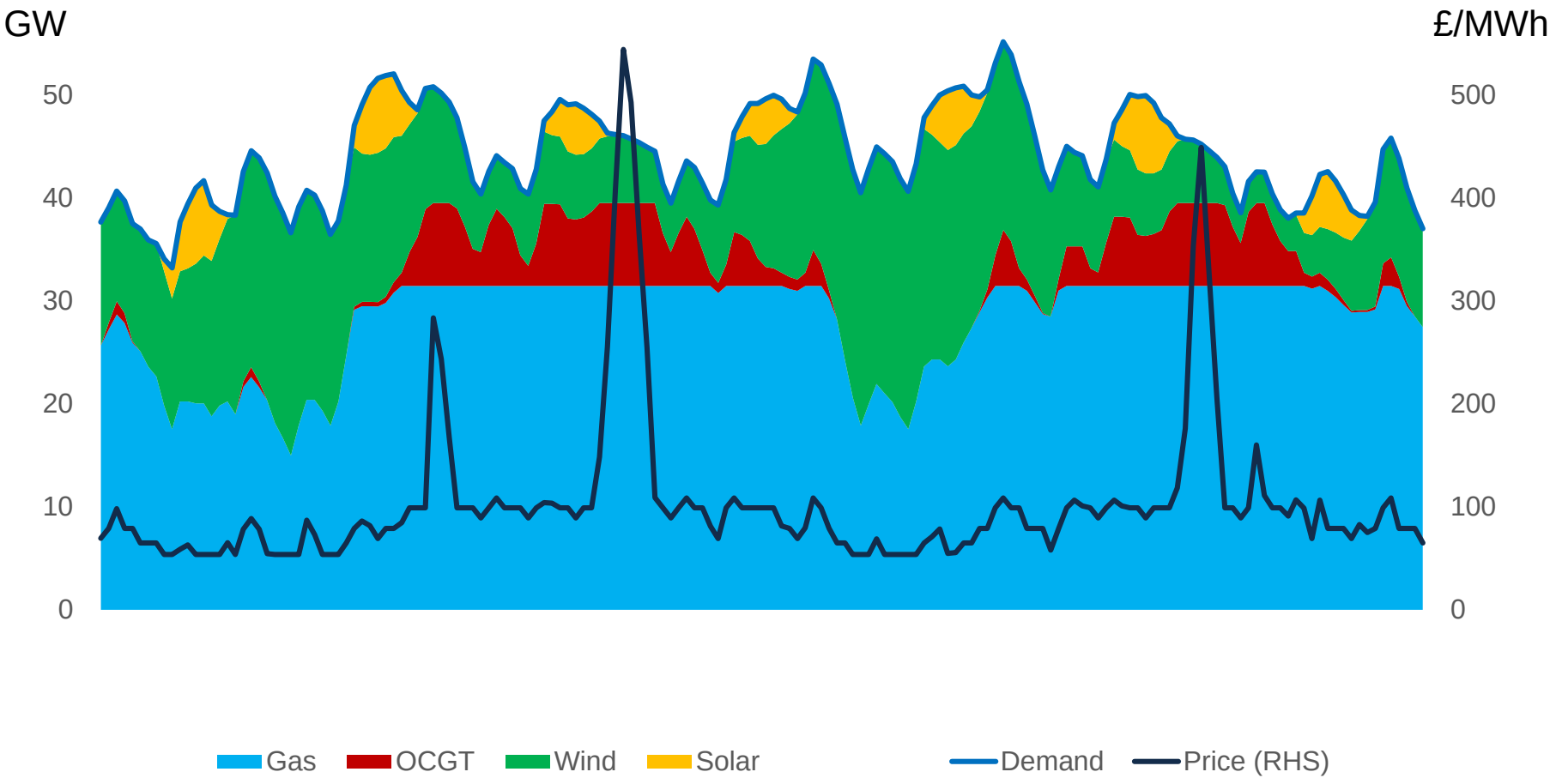
# A simulated future

## Week 7 of “2010”



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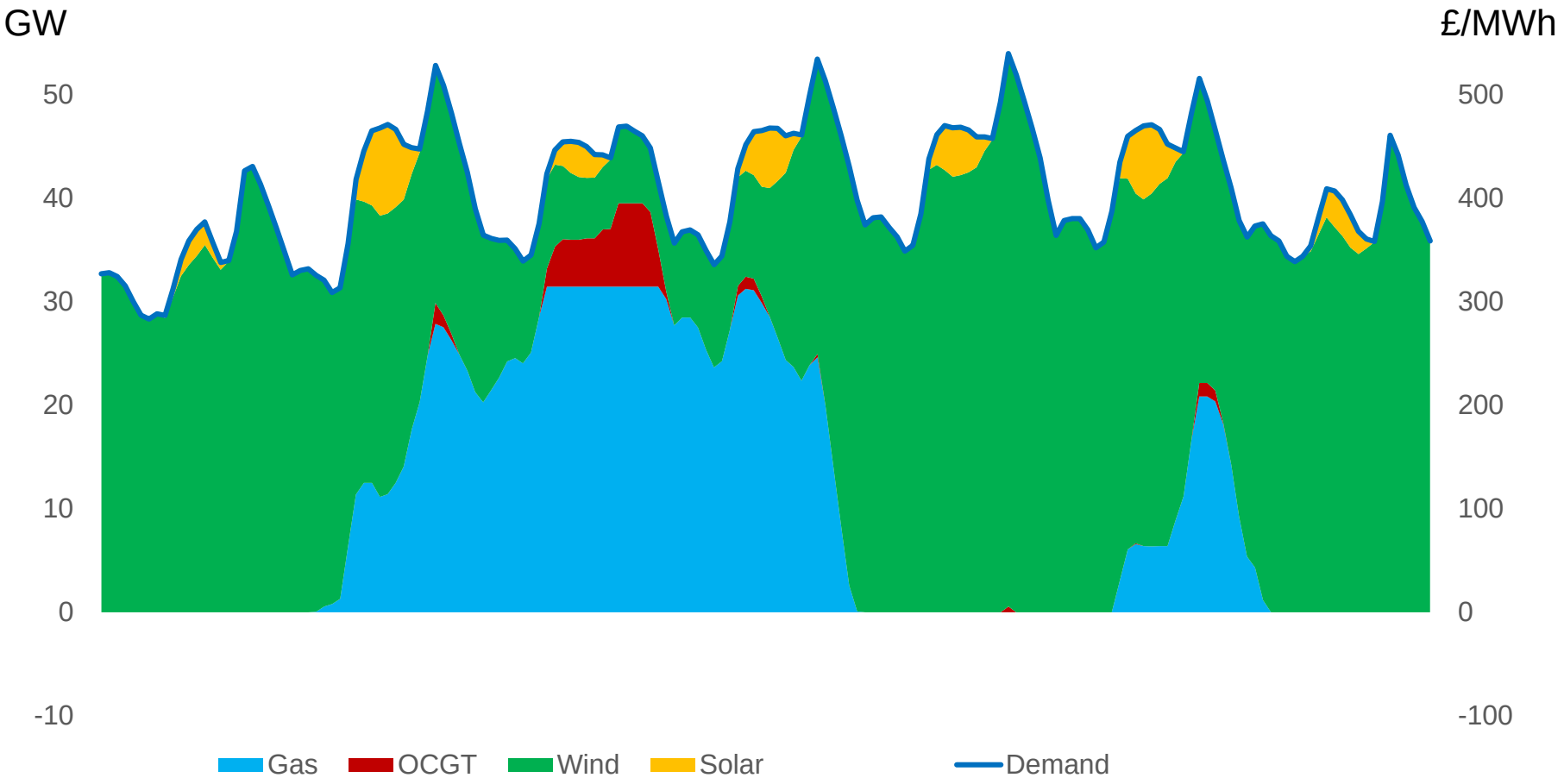
# A simulated future

## Week 44 of “2010”



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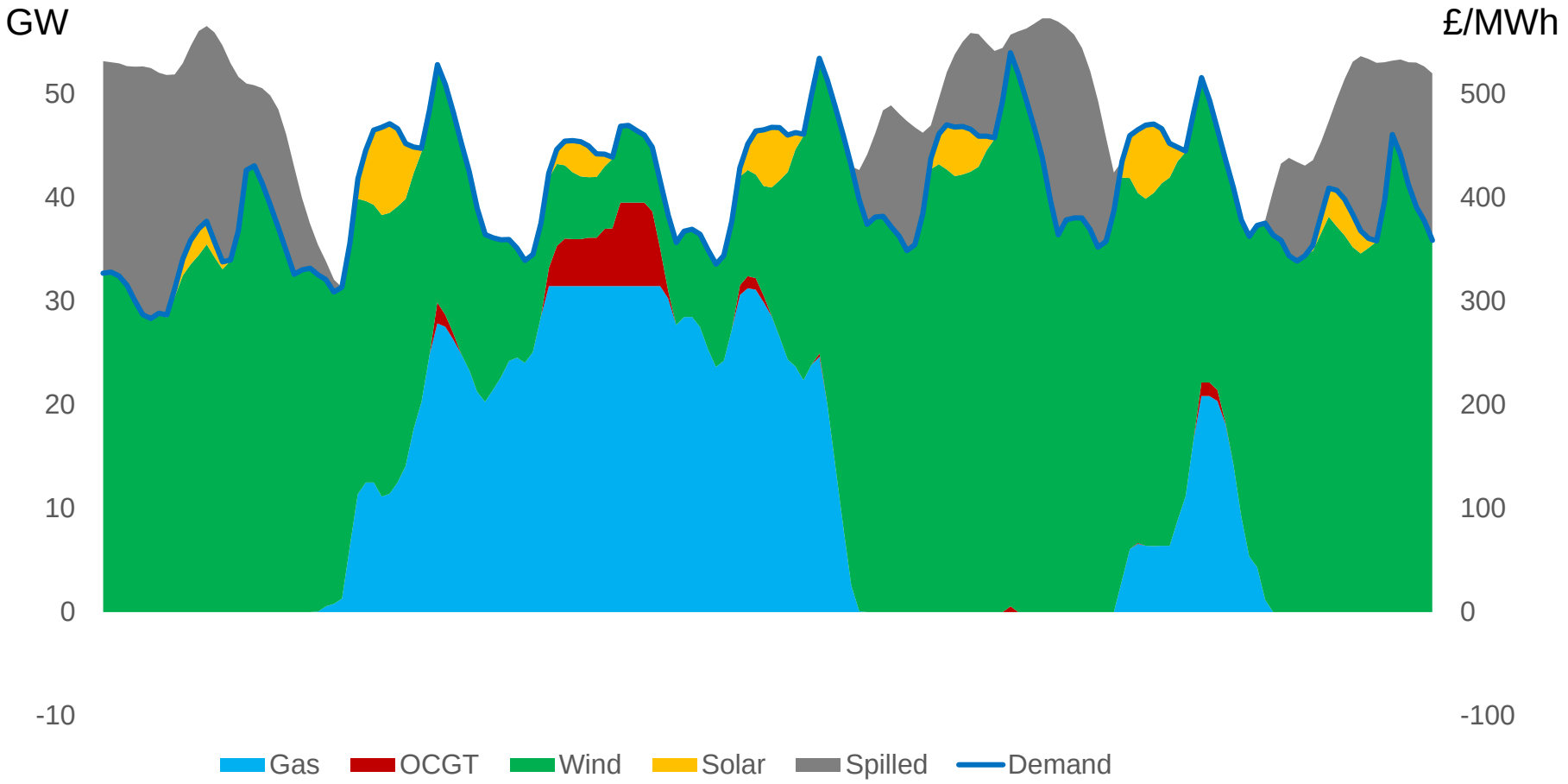
# A simulated future

## Week 44 of “2010”



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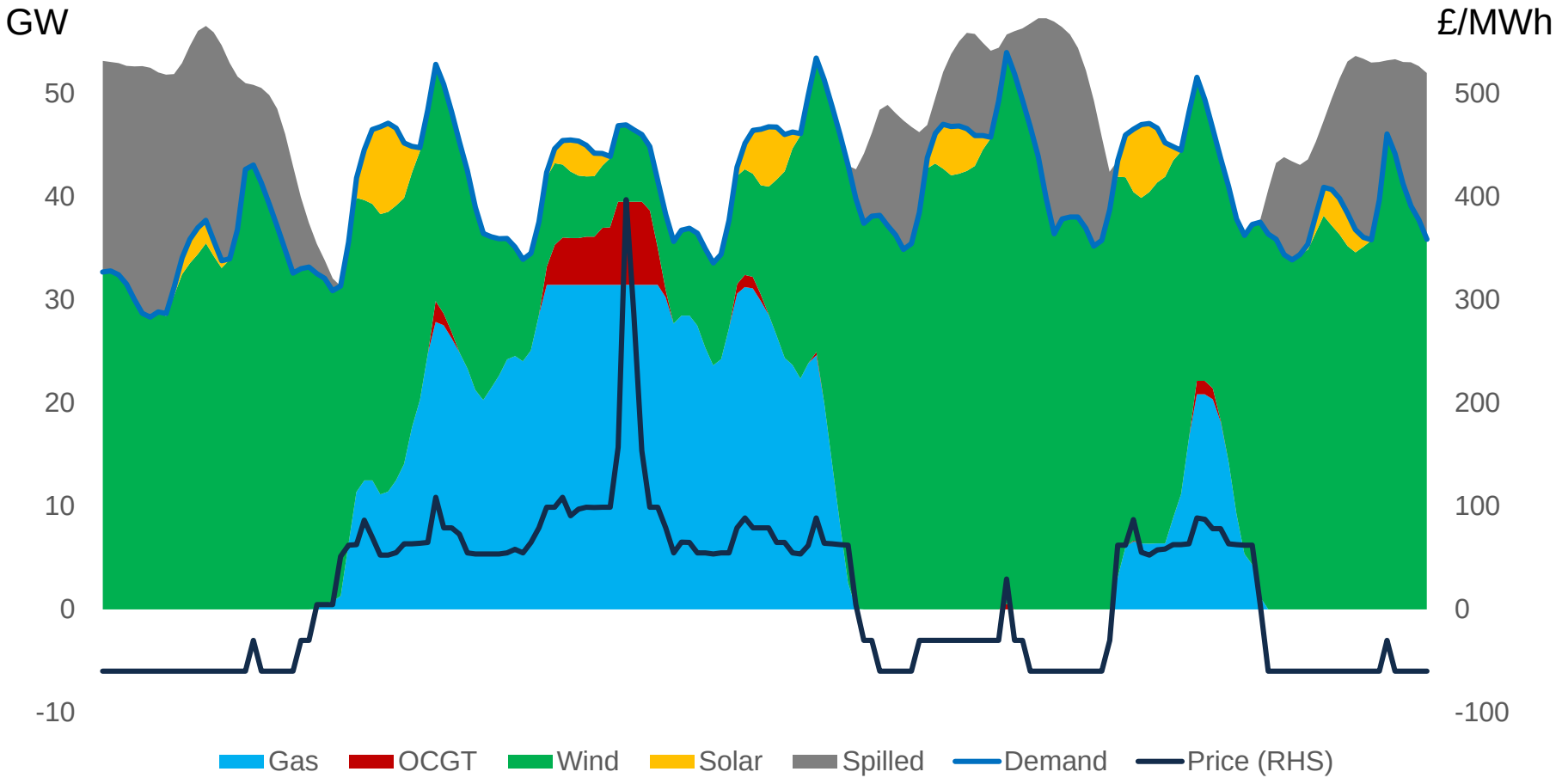
# A simulated future

## Week 44 of “2010”



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# A barrier to renewables?

## Relative revenues by type of plant

overall

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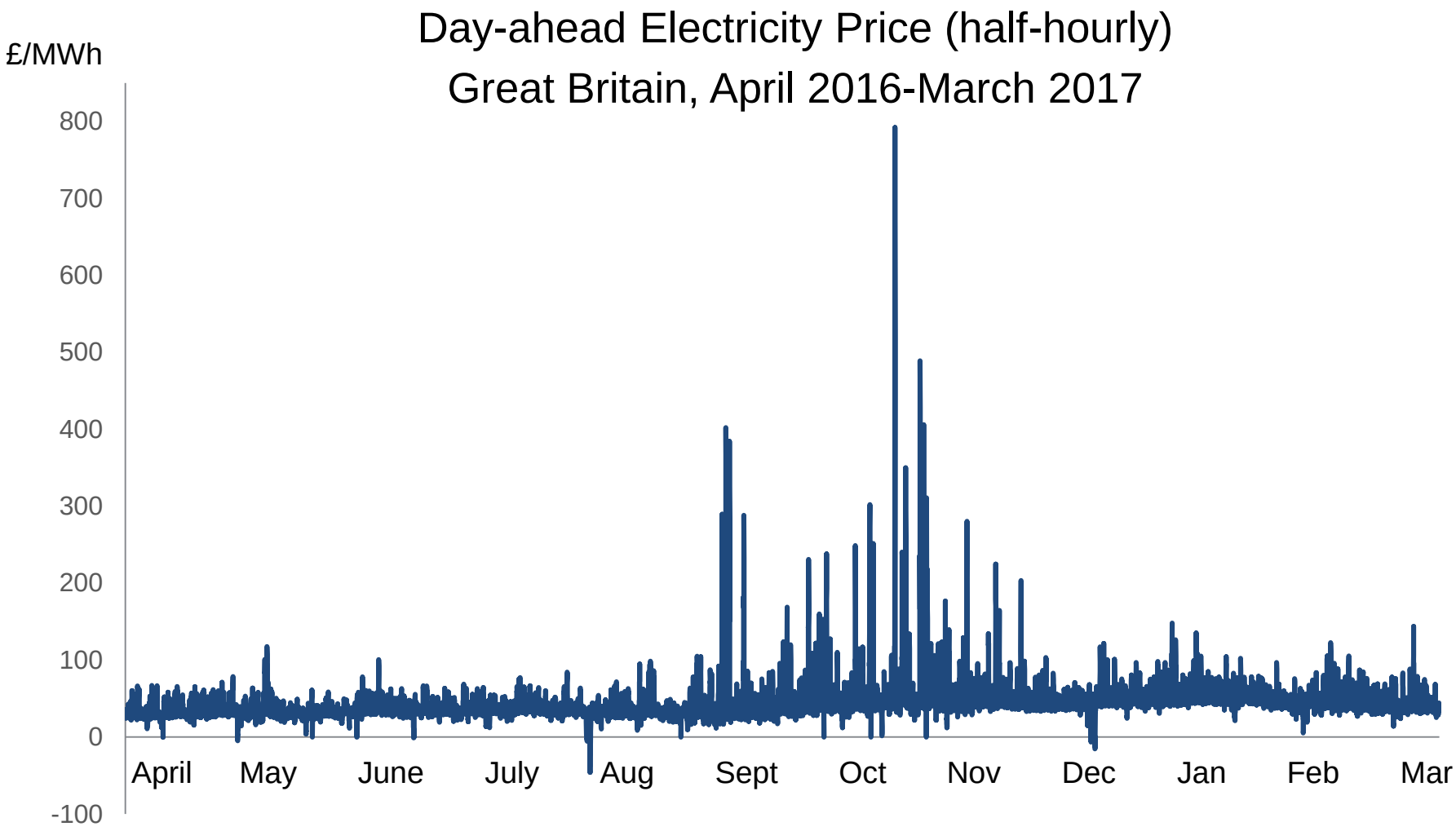
# A volatile market




Source: ElectricInsights.co.uk

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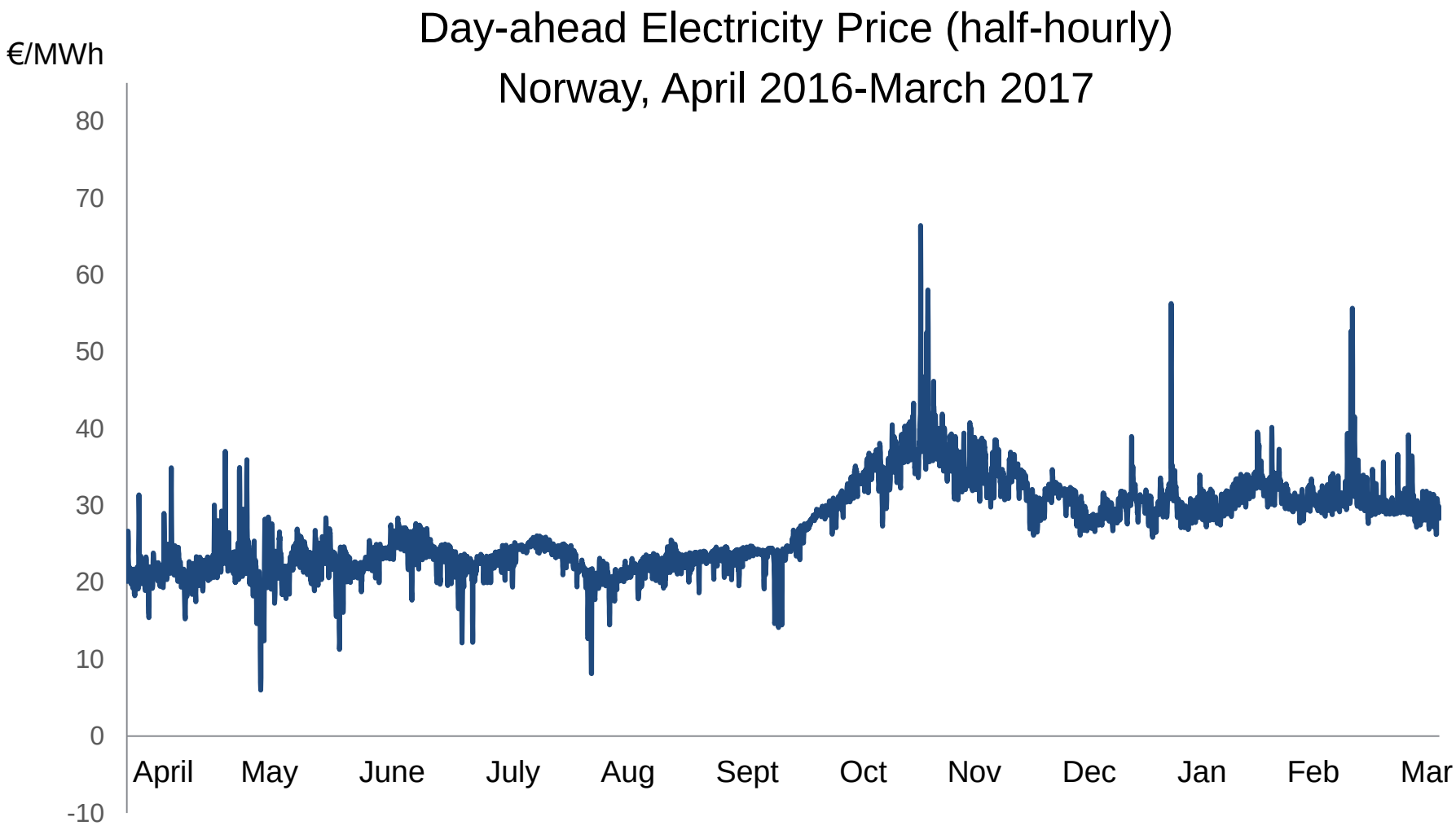
# A less volatile market




Source: ElectricInsights.co.uk

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# Renewables in an Energy Market

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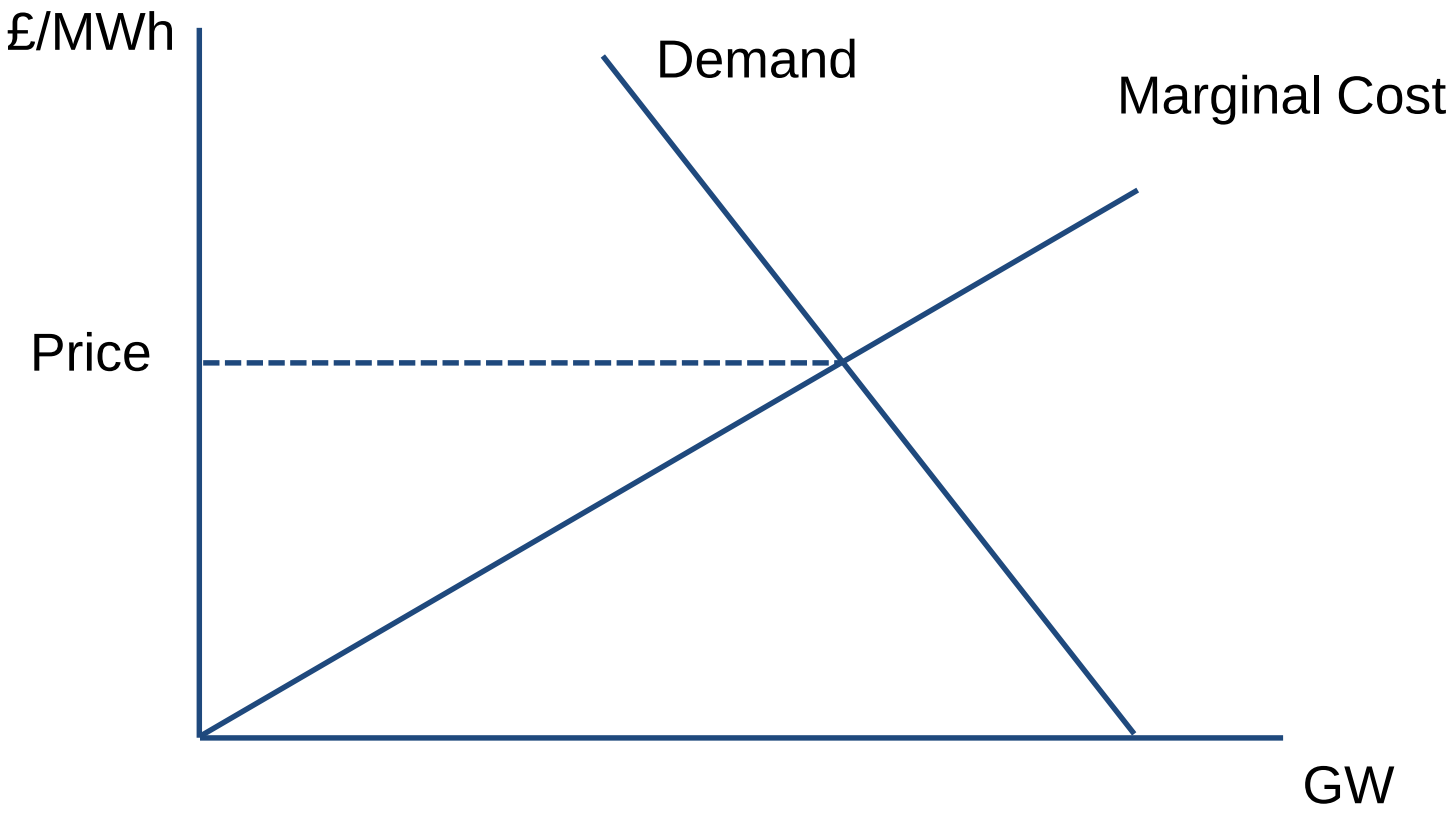
# Supply and Demand



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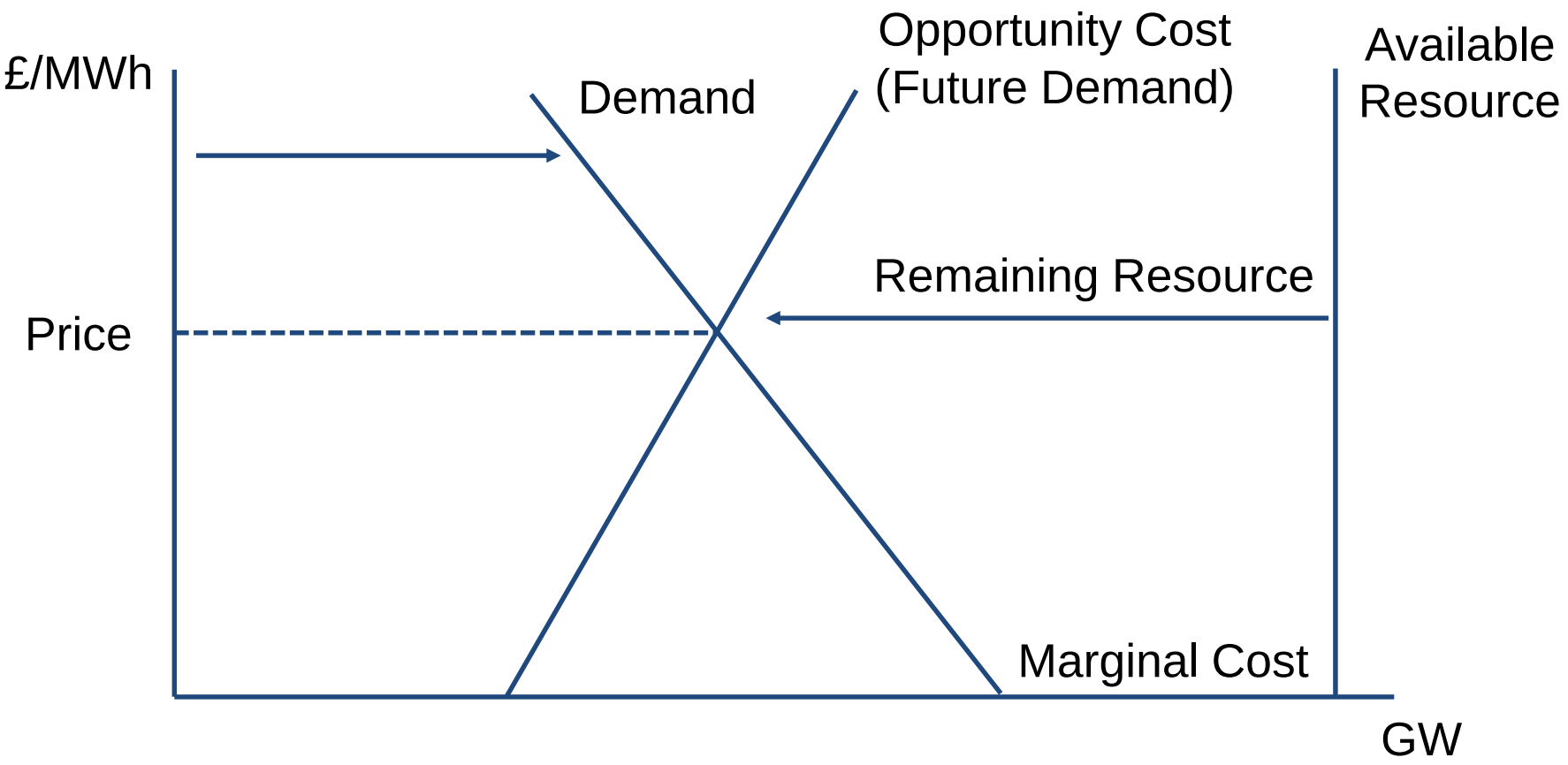
# Supply and Demand




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

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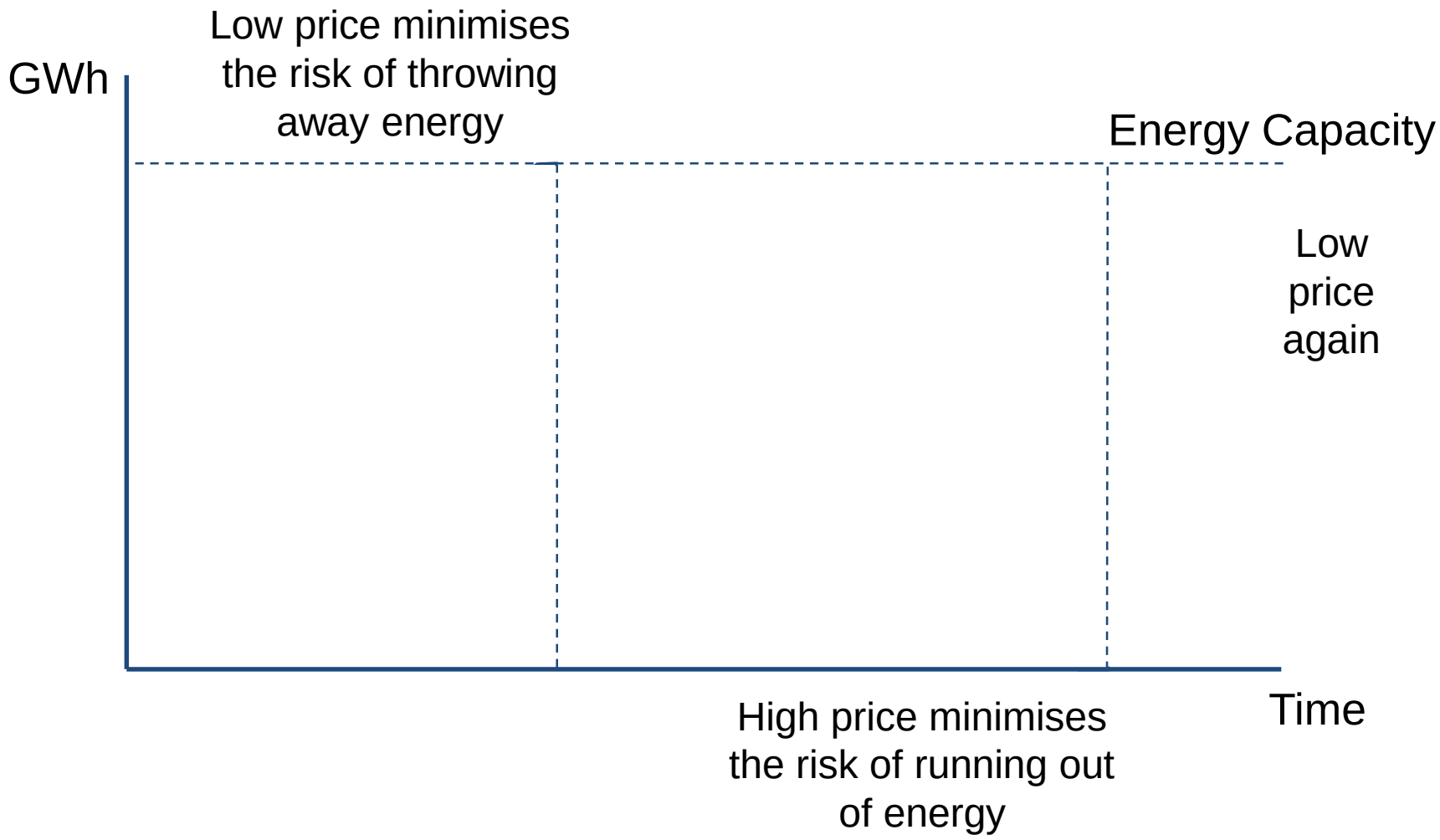
# Reservoir Levels



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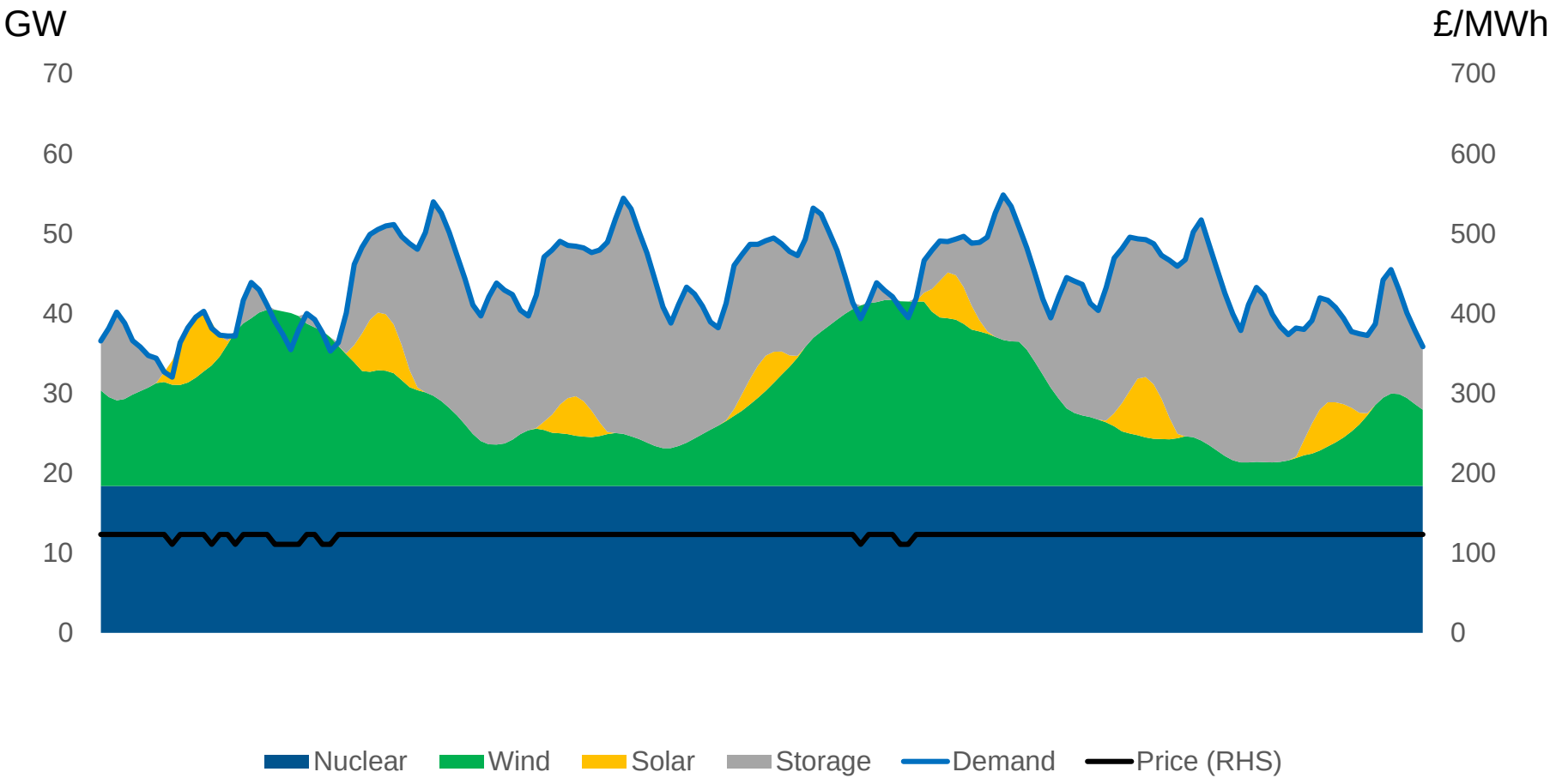
# A simulated future

## Week 7 of “2010”



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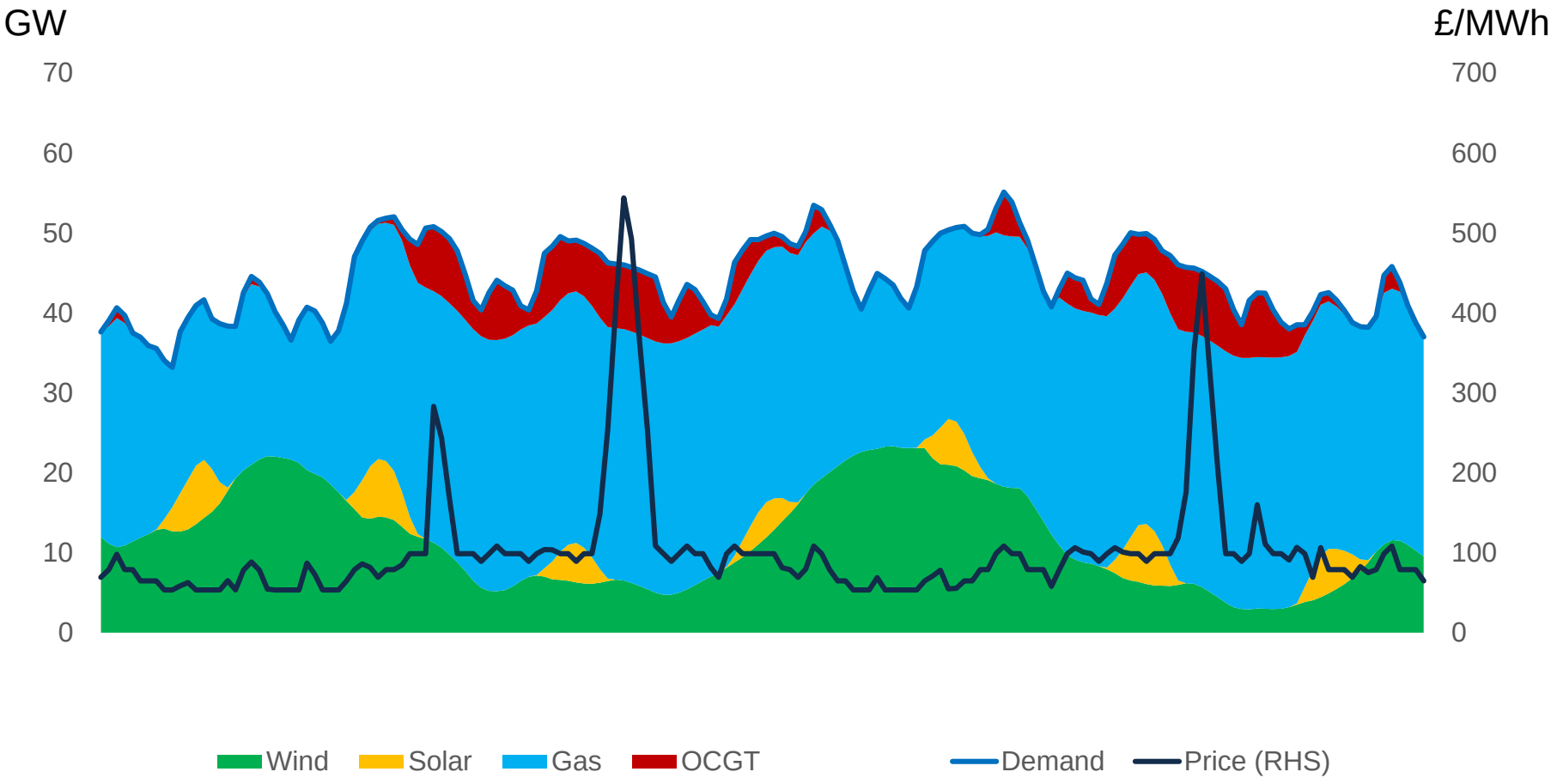

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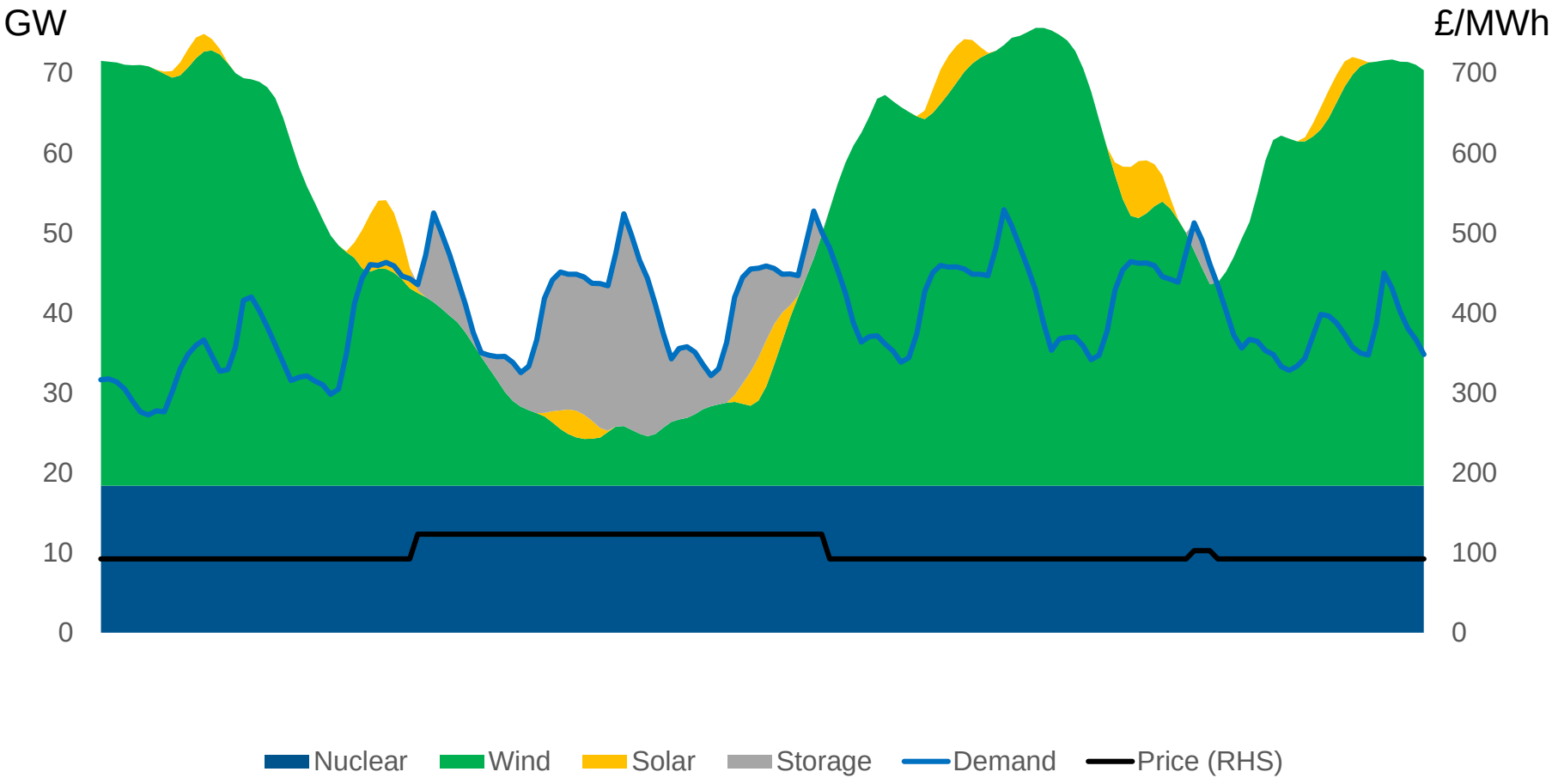

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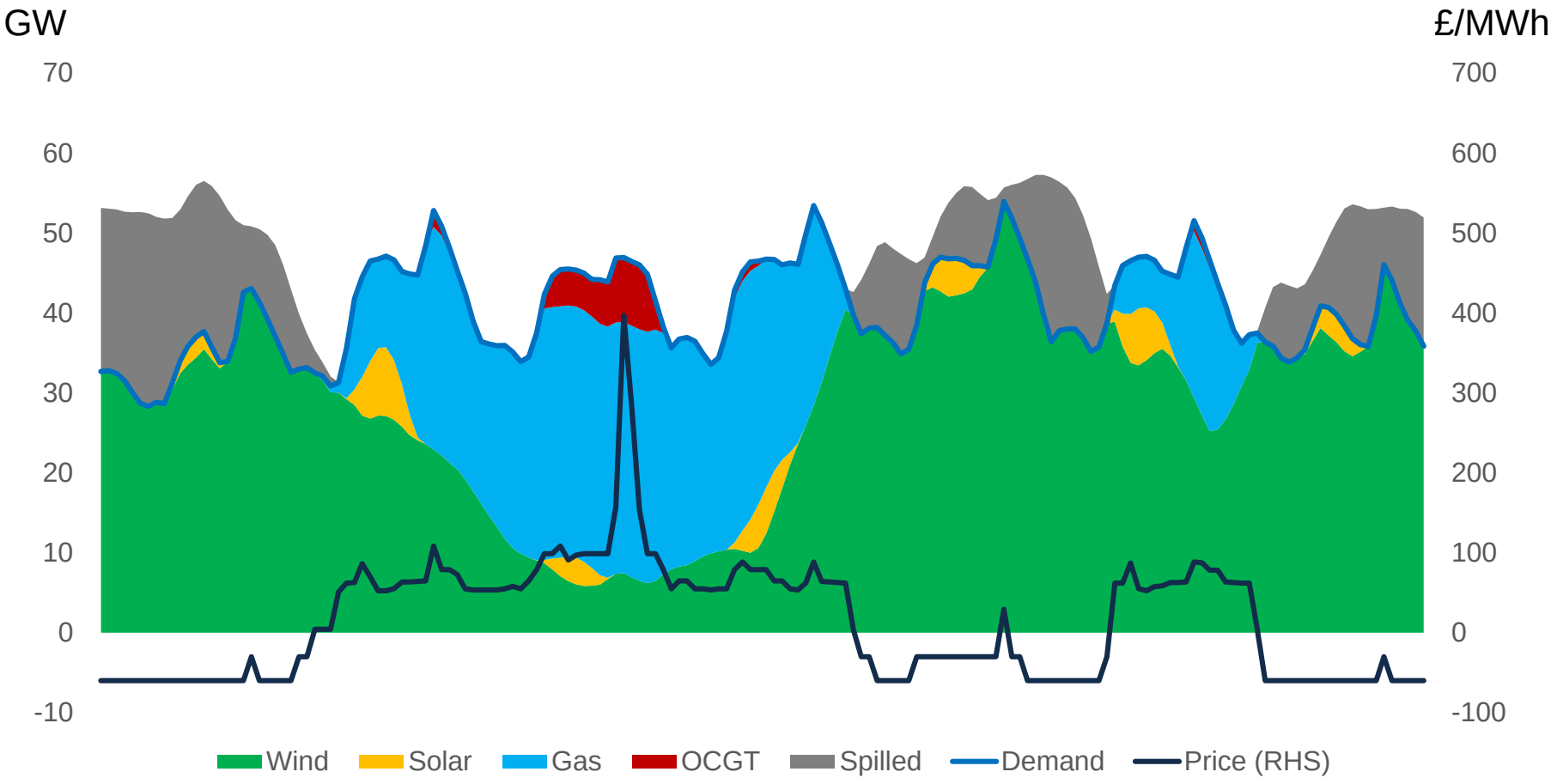

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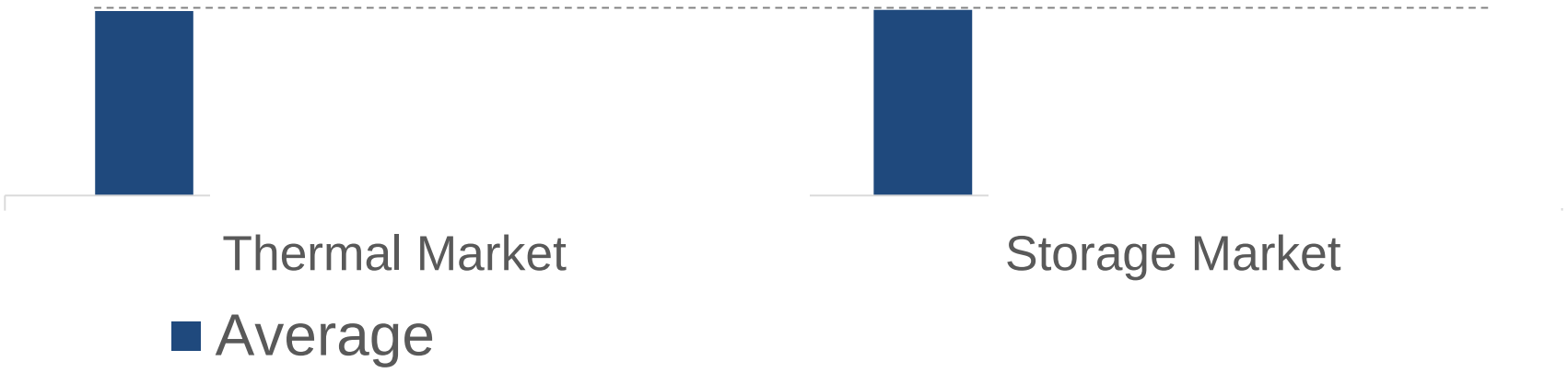
# A more level playing field?

## Revenues by type of plant



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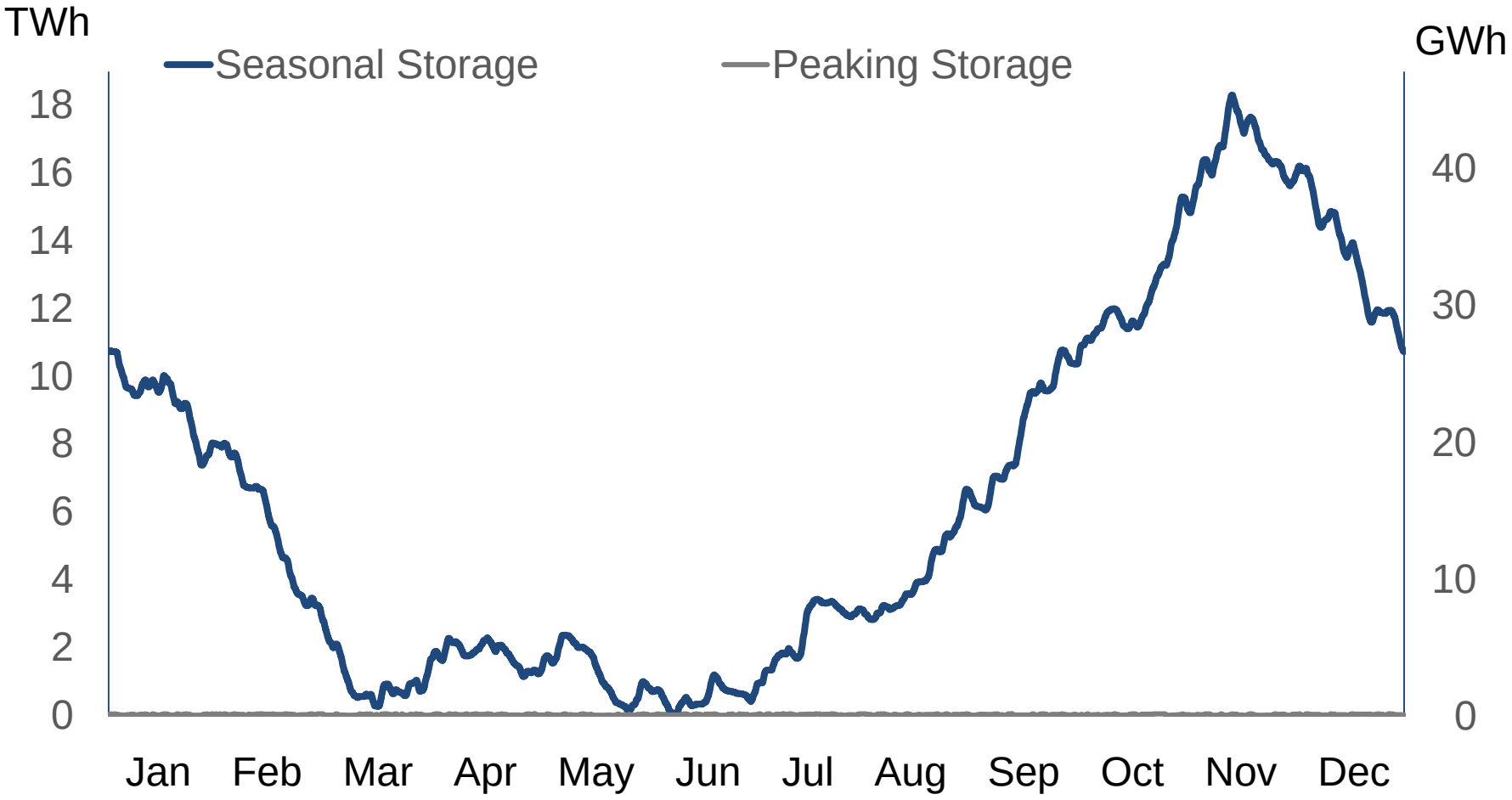
# Stored Energy Levels

## 8760 hours of “2010”



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# Stored Energy Levels

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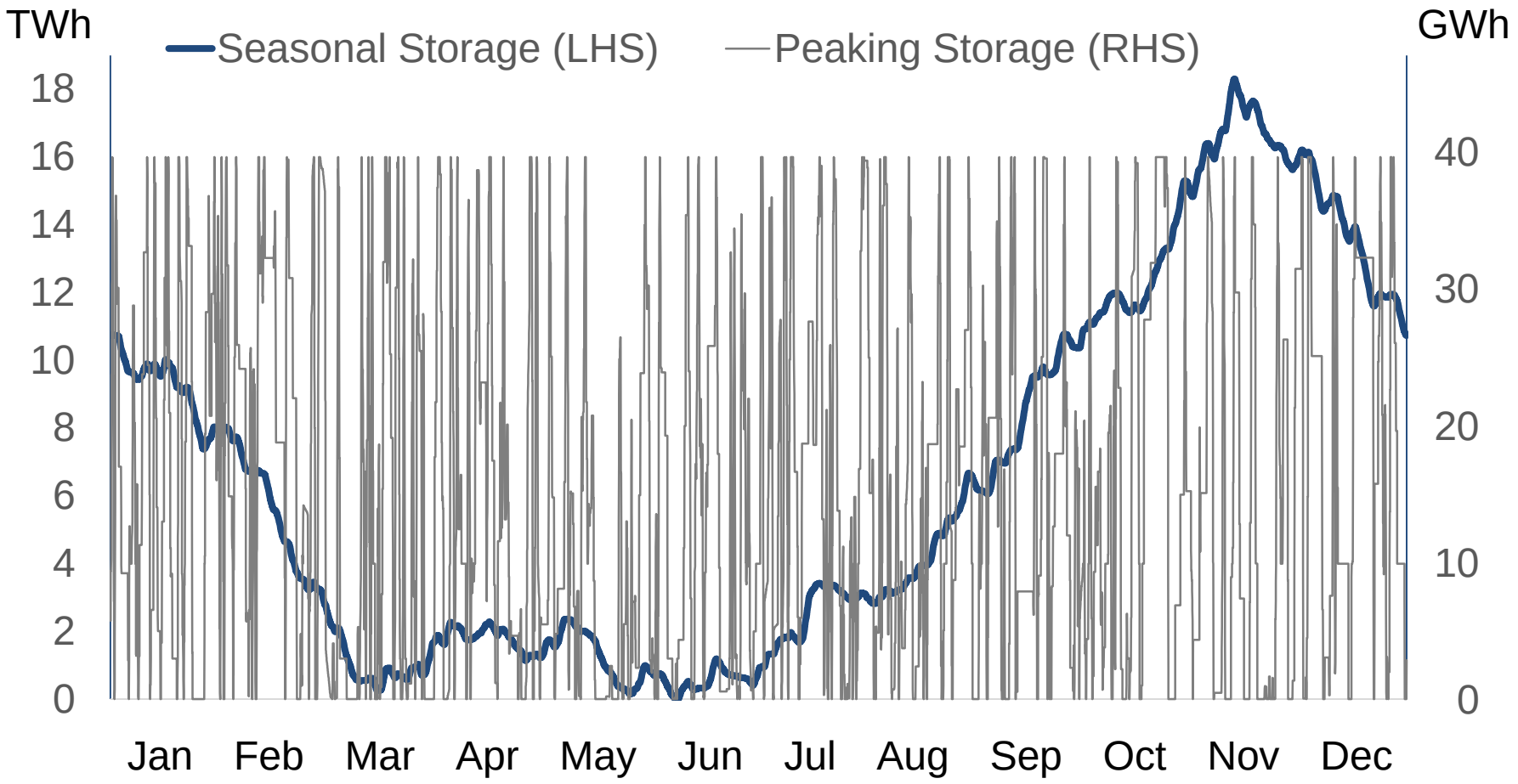

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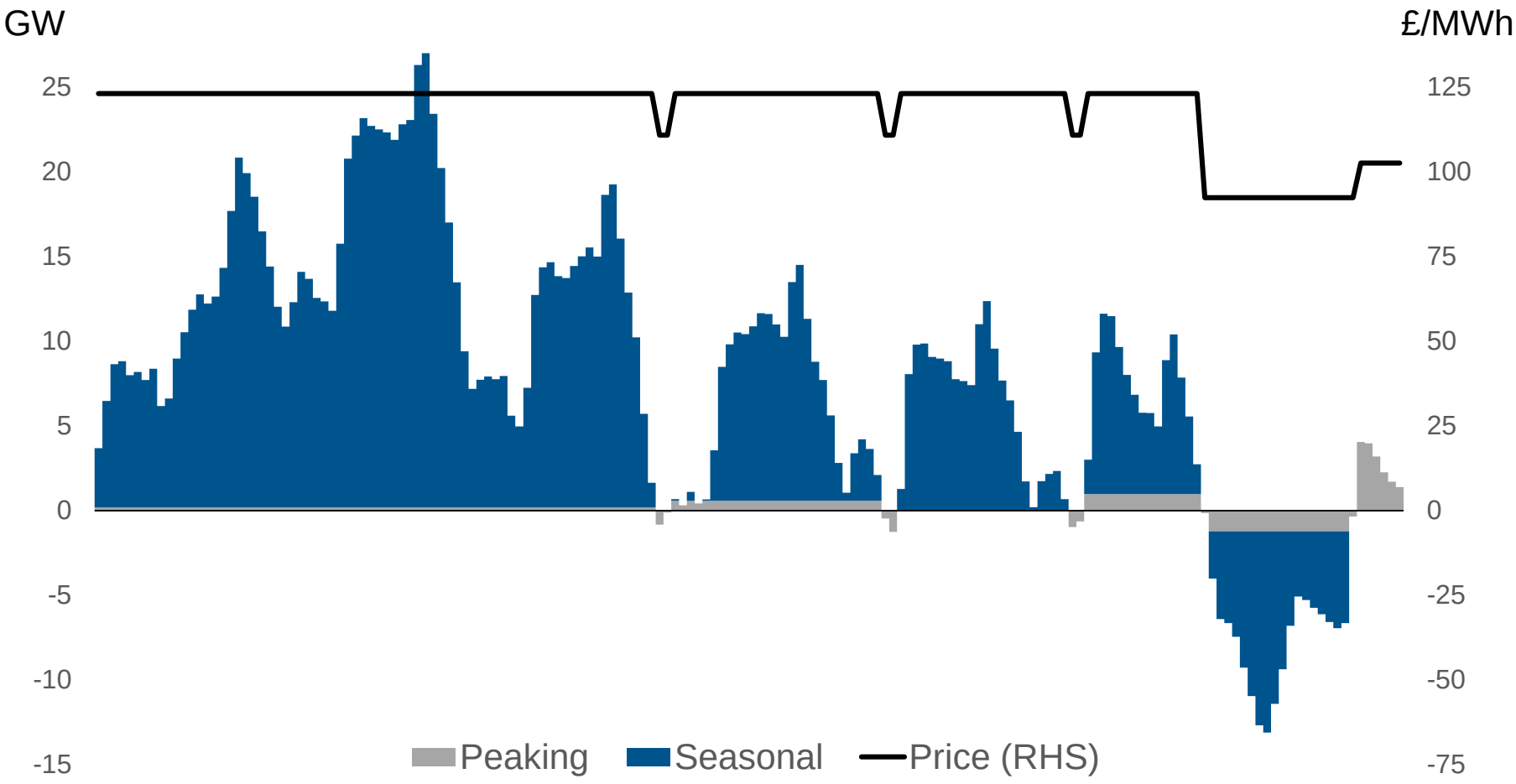
# Storage flows and prices

## Week 47 of “2010”



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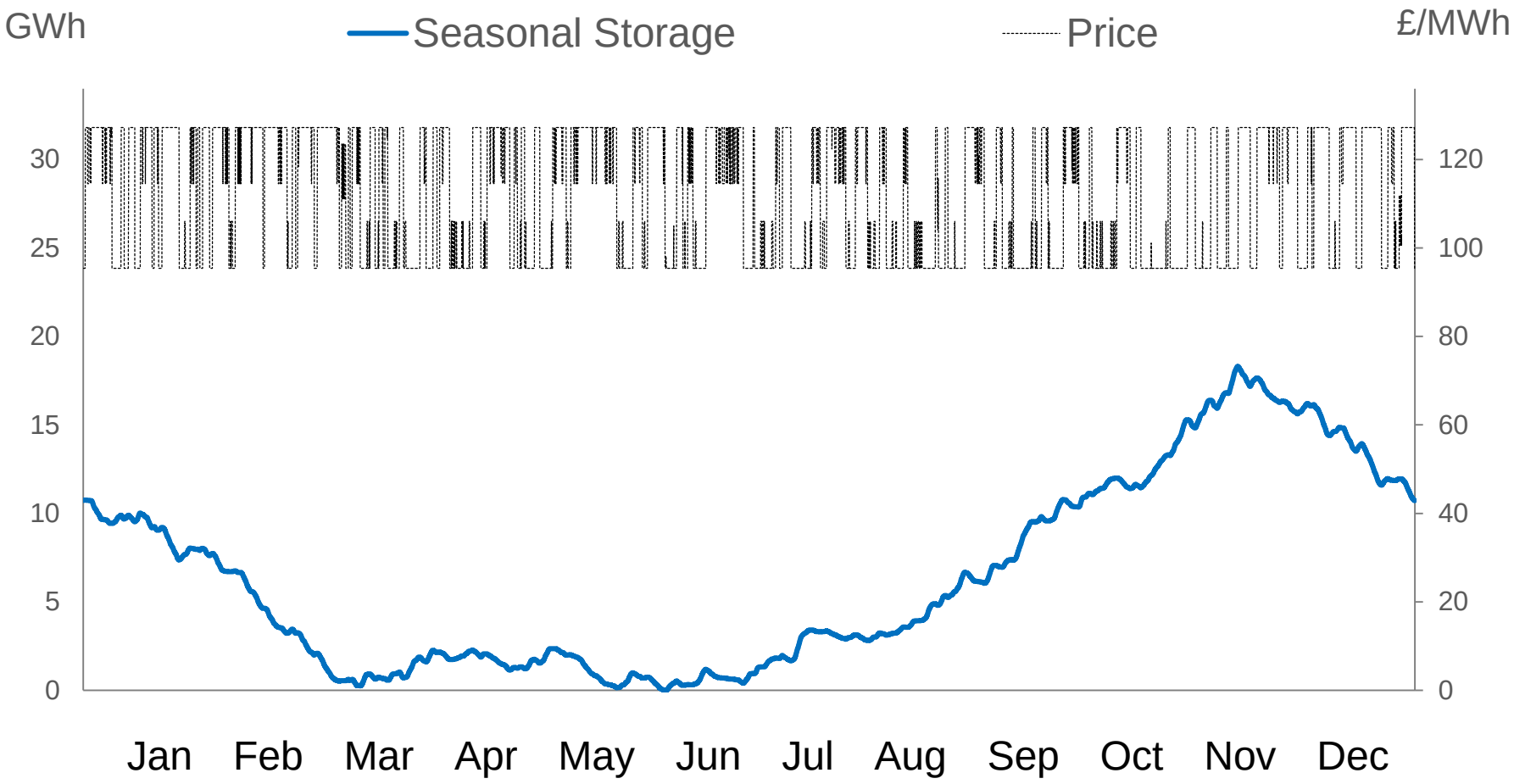
# A storage-renewable market

## 8760 hours in “2010”



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# What have I left out?

- Balancing
- Uncertainty
- Transmission
- Distribution
- Inertia

- What happens with intermediate amounts of storage

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# Conclusions

- Markets based on power will have volatile prices in a high-renewable world
- Storage can smooth these prices, creating markets based on energy
- Prices would be set to meet the energy constraint over long periods of time
- Would we value generators on their expected energy output?

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