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

Richard Green, IAEE European Conference, 2017
Demand and Supply

Prices reflect Marginal Costs

£/MWh

GW

Nuclear  CCGT  OCGT

Marginal Cost
Annual Generation Costs

- **Open Cycle Gas Turbine (OCGT)**
- **Combined Cycle Gas Turbine (CCGT)**
- **Nuclear**

Costs are shown in £/kW-year, with different technologies plotted against hours per year. The graph indicates:
- OCGT is cheapest up to a certain point.
- CCGT becomes cheapest after OCGT.
- Nuclear is cheapest beyond the point where CCGT takes over.

Imperial College London
Business School
Load-duration and Capacity

GW
OCGT cheapest
CCGT cheapest
Nuclear cheapest

Hours per year
Generator Costs & Revenues

- **Open Cycle Gas Turbine (OCGT)**
  - Cheapest in the short term

- **Combined Cycle Gas Turbine (CCGT)**
  - Cheapest in the short term

- **Nuclear**
  - Cheapest in the long term

The graph illustrates the cost of energy production over hours per year, with the y-axis representing £/kW-year. The lines indicate the cost effectiveness of each type of power generation over time.
British Energy Prices
per MWh of electricity

Source: ElectricInsights.co.uk
German Energy Prices: The Merit Order Effect

Prices (€/MWh)

- Gas price / 45%
- Electricity price

Installed capacity (relative to peak load)

- Solar capacity
- Wind capacity

Source: Green and Staffell, Oxrep, 2016
Renewables in a Power Market
Demand and Supply

The merit order effect

£/MWh

Marginal Cost

GW

Nuclear  CCGT  OCGT
Capacity and Load

GW

OCGT

CCGT

Nuclear

After renewables

Hours per year

OCGT  CCGT  Nuclear
Generators’ Load Factors
UK-wide, including Northern Ireland

Source: Digest of UK Energy Statistics
A Low-Carbon Christmas

Source: ElectricInsights.co.uk
Supply and Demand

£/MWh

Demand

Marginal Cost

Price

GW
A volatile market

Day-ahead Electricity Price (half-hourly)
Great Britain, April 2016-March 2017

Source: ElectricInsights.co.uk
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
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
More need for peaking plant?

2016 Load-duration curves

Source: ElectricInsights.co.uk
More risk for peaking plants?

Usage over 17 years of demand and weather data

Hours/year

No Renewables

Current Renewables
(15 GW Wind, 12 GW PV)

Double Renewables
(30 GW Wind, 24 GW PV)

100-hour mean annual running time

20-hour mean

100 1 2 3 4 5 6 7 8

GW

0 50 100 150 200 250 300 350 400 450
• 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
A simulated future

Week 7 of “2010”

GW

£/MWh

Gas  OCGT  Wind  Solar

Demand  Price (RHS)
A simulated future

Week 44 of "2010"
A barrier to renewables?

Relative revenues by type of plant

- overall
- Gas
- OCGT
- Solar
- Wind
A volatile market

Day-ahead Electricity Price (half-hourly)
Great Britain, April 2016-March 2017

Source: ElectricInsights.co.uk
A less volatile market

Day-ahead Electricity Price (half-hourly)
Norway, April 2016-March 2017

Source: ElectricInsights.co.uk
Renewables in an Energy Market
Supply and Demand

Finn’s bathtub, from Forsund (2007) Hydropower Economics
Low price minimises the risk of throwing away energy

High price minimises the risk of running out of energy

Low price again
A simulated future

Week 7 of “2010”
A simulated future

Week 7 of “2010”
A simulated future

Week 44 of “2010”

GW

£/MWh

Nuclear
Wind
Solar
Storage
Demand
Price (RHS)

© Imperial College Business School
A simulated future

Week 44 of “2010”
Thermal Market Storage Market

Average Gas Peaking/Solar Wind

Revenues by type of plant

A more level playing field?
Stored Energy Levels

8760 hours of “2010”

TWh

- Seasonal Storage

© Imperial College Business School
Stored Energy Levels

8760 hours of “2010”

- Seasonal Storage (LHS)
- Peaking Storage (RHS)
A storage-renewable market

8760 hours in “2010”
What have I left out?

- Balancing
- Uncertainty
- Transmission
- Distribution
- Inertia
- What happens with intermediate amounts of storage
• 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?