Electricity, Wind and Carbon

Professor Richard Green
Two recent trends:
The Rise of Wind

The Reduction in CO₂ Emissions
Maximising the Carbon Impact of Wind Power

1) Improve wind output simulations based on reanalysis weather data

2) Estimate hourly emissions for the British power sector

3) Assess the impact of wind output, fuel prices, and wind forecast accuracy
Wind simulations from Renewables.Ninja
Stefan Pfenninger and Iain Staffell
Where do the emissions come from?
Electricity Generated and CO₂ emissions in GB, 2010

g/kWh

Source: www.electricinsights.co.uk (Imperial College and Drax Power)
Electricity Generated and CO₂ emissions in GB, 2016/7

Source: www.electricinsights.co.uk (Imperial College and Drax Power)

1 million tonnes of CO₂

Shaded areas sum to the change from 2010
What’s behind the big picture?
Demand and Emissions of CO₂

21 March 2017
Changes in Demand and Emissions of CO₂

21 March 2017

\[ \Delta \text{Emissions} = 0.3642 \Delta \text{Demand} \]

\[ R^2 = 0.8746 \]
Preliminary answer?

- An extra MWh of demand raises emissions by $493 \pm 1$ kg
- An extra MWh of wind output cuts emissions by $462 \pm 10$ kg
- An extra MWh of solar output cuts emissions by $510 \pm 8$ kg


- These are averages of marginal emissions factors that are likely to change over time, and hence VERY preliminary
Generation in Great Britain, 13-19 December 2014

Sources: Elexon and National Grid
Generation in Great Britain, 6-12 August 2016

Sources: Elexon and National Grid
What caused the change?
Shares of Thermal Generation

- Gas
- Biomass
- Coal

Yearly shares for 2010 to 2016/7 are shown in the chart.
GB Fuel Prices

Fuel prices are for the amount needed per MWh of electricity output at typical efficiency.

Sources:
Elexon, BEIS and ICE
GB Fuel Prices

Fuel prices are for the amount needed per MWh of electricity output at typical efficiency.

- **Coal + Carbon**
- **Gas + Carbon**
- **Gas**
- **Biomass**
- **Coal**

Sources: Elexon, BEIS and ICE
Preliminary answer?

When Coal is the marginal fuel (2009Q3 – 2011Q2, 2015Q4 – 2017Q1)
- An extra MWh of demand raises emissions by 521 ± 1 kg
- An extra MWh of wind output cuts emissions by 481 ± 15 kg
- An extra MWh of solar output cuts emissions by 526 ± 11 kg

When Gas is the marginal fuel (2009Q1 – Q2, 2011Q3 – 2015Q3)
- An extra MWh of demand raises emissions by 468 ± 1 kg
- An extra MWh of wind output cuts emissions by 454 ± 13 kg
- An extra MWh of solar output cuts emissions by 451 ± 12 kg


We will be “digging deeper” into the causal factors
Maximising the Carbon Impact of Wind Power

1) Improve wind output simulations based on reanalysis weather data

2) Estimate hourly emissions for the British power sector

3) Assess the impact of wind output, fuel prices, and wind forecast accuracy

4) Model future investment and operating decisions changing with wind
The MOSSI model
Merit Order Stack with Step Investment

£/MWh

01-Oct 11-Oct 21-Oct 31-Oct

Imperial College Business School

Imperial means Intelligent Business
The MOSSI model

Merit Order Stack with Step Investment

**Investment module**
Build and retire capacity so that all technologies cover their costs

**Dispatch module**
Simulate plant operation within the year to give lowest cost of electricity

Loop over periods until investment decisions reach equilibrium

- Proposed plant capacities
- Investment module
- Dispatch module
- Available technologies
- Capital costs
- Discount rates
- Plant utilisation, revenues and profits, wholesale prices, welfare and surpluses

- Demand profile
- Renewable output profile
- Plant data
- Fuel prices
- Market rules
Future Electricity Output
Renewables held at 2017 levels, £50 Carbon price in 2050

Electricity storage is not yet included at a significant scale

Source: MOSSI, given input assumptions
Future Electricity Output
Renewables continue to grow, £50 Carbon price in 2050

TWh

kg/MWh

Electricity storage is not yet included at a significant scale

Source: MOSSI, given input assumptions
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Thank you