Managing Flexibility Whilst Decarbonising the GB Electricity System

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Energy Research Partnership

ERP Structure

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Department for Business Innovation & Skills
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UNIVERSITY OF CAMBRIDGE
Bosch
Friends of the Earth

Secretariat
Support from DECC

ERP Analysis Team

Hosted by
Imperial College London
Key Messages

A zero- or very low- carbon system with weather dependent renewables needs low carbon technologies to provide firm capacity.

Policy makers and system operators need to value services that ensure grid stability so new providers feel a market.

A holistic approach to system cost would better recognise the importance of firm low carbon technologies and the cost of balancing the system.
ERP Modelling

ERP modelling stacked generation to meet demand exploring different mixes of low carbon technologies on the system. It met the following criteria on an hourly basis:

• Energy balancing – nearly all modelling does this, at least on an annual basis
• Sufficient firm capacity – ensures peak demand can be met
• Sufficient flexibility – the model ensures there’s sufficient reserve, response and inertia at all times.
Firm Zero-C Capacity

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The need for firm capacity

With no new nuclear (or any other zero carbon firm capacity), the best that 60 GW of onshore wind can achieve is about 170 g/kWh.

Infinite storage or demand side response could improve that to 133 g/kWh.

Building 20 GW of nuclear means 50 g/kWh can be achieved with 42 GW of onshore wind.

If wind build didn’t exceed the National Renewable Energy Action Plant then 23 GW of nuclear would achieve 50 g/kWh.
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Load Duration for 20% low carbon

Renewable
- 17 GW PV
- 17 GW Wind
- No ZCF
- 67 GW CCGT
- 330 g/kWh

Mix
- 8 GW PV
- 8 GW Wind
- 4 GW ZCF
- 63 GW CCGT
- 330 g/kWh

Zero Carbon Firm
- No PV
- No Wind
- 8 GW ZCF
- 59 GW CCGT
- 330 g/kWh
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**Load Duration for 80% low carbon**

<table>
<thead>
<tr>
<th>Renewable</th>
<th>Mix</th>
<th>Zero Carbon Firm</th>
</tr>
</thead>
<tbody>
<tr>
<td>68 GW PV</td>
<td>34 GW PV</td>
<td>No PV</td>
</tr>
<tr>
<td>68 GW Wind</td>
<td>34 GW Wind</td>
<td>No Wind</td>
</tr>
<tr>
<td>No ZCF</td>
<td>16 GW ZCF</td>
<td>32 GW ZCF</td>
</tr>
<tr>
<td>67 GW gas</td>
<td>51 GW gas</td>
<td>35 GW CCGT</td>
</tr>
<tr>
<td>128 g/kWh</td>
<td>98 g/kWh</td>
<td>91 g/kWh</td>
</tr>
</tbody>
</table>

- Curtailed
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Load Duration for 80-100% Renewable

6h storage, 80% renew

- 68 GW PV
- 68 GW Wind
- No ZCF
- 67 GW CCGT
- 30 GW 6h store

- 112 g/kWh
- 6% curtailment

48h storage, 80% renew

- 68 GW PV
- 68 GW Wind
- No ZCF
- 67 GW gas
- 30GW 48h store

- 98 g/kWh
- 1% curtailment

48h storage, 100% renew

- 86 GW PV
- 86 GW Wind
- No ZCF
- 67 GW gas
- 30GW 48h store

- 50 g/kWh
- 8% curtailment
Scenario: There’s sufficient weather dependent renewables to meet demand, PV and Wind balanced to eliminate summer/winter imbalance
For storage to eliminate fossil (or other firm capacity) would require ~15GW to hold ~8 TWh ready for lulls in output with 1-2 cycles p.a.
Hence providing security is probably not best role for storage
But 25 cycles above, or diurnal cycles or reserve, response or inertia may be.
Valuing Flexibility

A zero- or very low- carbon system with weather dependent renewables needs low carbon technologies to provide firm capacity.

Policy makers and system operators need to value services that ensure grid stability so new providers feel a market.

A holistic approach to system cost would better recognise the importance of firm low carbon technologies and the cost of balancing the system.
Generator loss incident
1000MW is lost at 13:43. Frequency drops to 49.6 Hz before recovery begins. Statutory limit is 49.5 Hz.

There are 22* ancillary services NG buy, but these four are key for energy balancing + the need for firm capacity > peak demand

* Others include: voltage control; MaxGen, warming and fast start contracts for fossil; intertrips; transmission constraint agreements; SO to SO (interconnector) services; black start.
There are technical services essential for grid stability.

**The Need for Market Pull**

Balance of grid services

**SUPPLY** is disappearing

Traditional suppliers are going:
- Closure of coal & …
- Closure of auxiliary gas turbines
- Closure of Oil
- AGR end of life
- Poor economics & low load factors of gas

**NEW SUPPLY?**
- Dynamic use of interconnectors
- Storage
- Existing demand => responsive
- New active demand (EV, HP)
- New gas plant
- New CCS
- Flexible biomass
- Existing embedded generation

DEMAND is increasing

More intermittent renewables + larger unit size (new nuc.):
- Greater need for reserve
- Less inertia (stability)
- Greater demand for response
- Response has to be faster

Little or no value is attributed to some essential grid services. New providers cannot develop if there is no long term market signal.
Holistic Evaluation

A zero- or very low- carbon system with weather dependent renewables needs low carbon technologies to provide firm capacity.

Policy makers and system operators need to value services that ensure grid stability so new providers feel a market.

A holistic approach to system cost would better recognise the importance of firm low carbon technologies and the cost of balancing the system.
The Need for a Holistic Approach

**Traditional approach** – all that matters is delivery of energy so calculate the levelised cost of energy.

\[
\text{LCOE} = \frac{\text{all costs annualised}^*}{\text{annual energy production}^*}
\]

* These can be reduced with an annual discount factor

This is simple and **works well for conventional thermal & hydro comparisons** – When energy is delivered they can all offer other services:

- flexibility (load following, reserve, response)
- inertia
- firm capacity

However this doesn’t work for technologies

- that only deliver some of these services
- deliver no energy
- increase the need for some grid services

**Example using DECC costs**

<table>
<thead>
<tr>
<th>LCOE</th>
<th>£/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1\textsuperscript{st}</td>
<td>Wind</td>
</tr>
<tr>
<td>2\textsuperscript{nd}</td>
<td>Nuclear</td>
</tr>
<tr>
<td>3\textsuperscript{rd}</td>
<td>Gas-CCS</td>
</tr>
</tbody>
</table>

- Wind
- PV
- Nuclear
- Storage
- Demand Resp.
- Interconnectors
The Need for a Holistic Approach

Holistic Approach – is needed when technologies offer different services. Question is “Which technology reduces total system cost by the most” Answer depends on the system as well as the technology characteristics

<table>
<thead>
<tr>
<th>Tech.</th>
<th>Provides Flexibility</th>
<th>Inertia</th>
<th>Firm Cap.</th>
<th>Traditional LCOE (£/MWh)</th>
<th>Net Value to pure gas sys. (£/MWh)</th>
<th>Net Value to Sys with 30 GW wind (£/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>doubtful</td>
<td>yes</td>
<td>yes</td>
<td>87</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Wind</td>
<td>demands</td>
<td>very little</td>
<td>very little</td>
<td>81</td>
<td>-3</td>
<td>-17</td>
</tr>
<tr>
<td>Gas-CCS</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>91</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

- Previous 1\(^{st}\) choice is different
- Value changes with the system
- There’s a diminishing returns affect

The values here are not important, but it illustrates fact that the holistic approach gives different answers and ones that vary with current grid mix.
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Could UK Have it’s Own EnergieWende?

In essence – yes – UK needs a strategic narrative:
- Public engagement
- Policy Stability
- Investor Confidence

http://erpuk.org/project/public-engagement/

The same as Germany’s– no – GB & German systems and objectives are chalk & cheese

- Drive for low price
- Build gas stations
- Close all coal stations
- Close coal mines
- Life extend old nuclear
- Island - Weak interconnection

- Acceptance of high subsidies
- Mothball new gas
- Building coal stations
- Subsidise coal mines
- Close old nuclear early
- Small part of large System
June 2014 showing how exports (pink below) correlate strongly with PV generation (yellow).

Lignite (with the highest CO2 emissions) is inflexible so a large proportion of renewable generation is exported to avoid de-loading it.
### Key Messages

A zero- or very low- carbon system with weather dependent renewables needs companion low carbon technologies to provide firm capacity

| Cannot decarbonise to 50 g/kWh by weather dependent renewables alone |
| Storage, demand side & interconnection help |
| 15-20GW of new nuclear, biomass or fossil CCS is essential |
| Provides clean supply for dark, windless weeks |

Policy makers and system operators need to value services that ensure grid stability so new providers feel a market

| Some necessary services (e.g. inertia/frequency response) are free or mandated |
| Demand for them is growing |
| Traditional providers (fossil) are disappearing |
| Weather dependent renewables are not consistent suppliers |
| New providers can’t develop with no market |

A holistic approach to system cost would better recognise the importance of firm low carbon technologies and the cost of balancing the system

| The value of a technology is dependent on |
| the existing generation mix |
| the grid services it provides |
| So it cannot be valued by a single number such as levelised cost of energy (LCOE) |