Putting wind and solar in their place: Internalising congestion and other system–wide costs with enhanced contracts for difference in Great Britain

Iacopo Savelli, Jeffrey Hardy, Cameron Hepburn, Thomas Morstyn | November, 2022

Summary

The large-scale deployment of renewable energy assets can create system-wide costs due to the impact on congestion management and reserve provision. Moreover, the carbon emission abatement could be limited if renewable energy assets are curtailed. We show how the successful GB incentive scheme for renewable energy, termed Contracts-for-Difference (CfD), can be further enhanced by introducing cost components to account for these system-wide effects. The developed case studies show that one additional MWh of renewable generation in the northern regions of GB increases congestion management cost by £5.61 / MWh (14% of the CfD 2019 price), and that the potential carbon emission abatement is reduced by 9% (23.52 $kgCO_2$ / MWh) due to grid re-dispatch. By contrast, the deployment in the southern regions can decrease congestion cost by £4.04/MWh, and can increase potential carbon abatement by 17% (44.33 $kgCO_2$ / MWh). Finally, one additional MWh of intermittent wind generation in GB can increase reserve provision cost by £6.58 / MWh, while a perfectly predictable technology would decrease reserve cost by £2.44 / MWh.

1. Motivation

Since 2014, the Contracts for Difference (CfD) scheme is the government's main mechanism for supporting low-carbon electricity generation in GB. CfDs incentivise renewable energy by providing investors with a fixed 'strike price' that protects them from uncertain and volatile wholesale prices. The CfD programme has had considerable success, with almost 6 GW of new renewable capacity allocated in the AR3 auction. However, this scheme may increase system-wide costs. These additional costs can be divided into:

- costs for managing congestion due to the deployment of renewable energy assets in network-constrained regions
- costs for reserve provision caused by the presence of intermittent generation.

The fundamental problem affecting the CfD scheme is that these system-wide costs are not borne by those who cause them, but are socialised through a use of system charge and ultimately paid by consumers.

INDUSTRIAL STRATEGY UK Research and Innovation

2. Proposal

Given the current CfD payoff $\Phi_t = M_t\,(s - p_t)$, where M_t is the generator metered output, s is the fixed strike price, and p_t is a reference price, to internalise the system-wide costs we propose to extend the current CfD payoff with two additional components, as follows:

$$\Phi_t = M_t\,(s - p_t - \alpha_z - \beta_m)$$

where the term α_z represents the additional system-wide cost for managing transmission network congestions due to the deployment of a renewable energy asset in the location z, and the term β_m is the additional system-wide cost for reserve provision due to the usage of the technology type m. The values of these parameters are reported in the following section.

Accounting for these system-wide costs will address the issue of negative externalities due to congestion and reserve costs that now are socialized, increasing efficiency. It will signal where renewable assets would be most beneficial from a whole system perspective, while ascribing the additional system-wide costs to those who cause them. It will also promote fairer competition among renewable energy technologies with different degrees of uncertainty, such as wind power with or without energy storage, or tidal power.

3. Results

3.1 Additional Balancing Mechanism costs caused by the deployment of renewable technologies in different locations

The introduction of renewable energy assets with near-to-zero marginal cost can put more expensive marginal generators out of the market. As a consequence, a different rebalancing in the Balancing Mechanism (BM) may be required, leading to an increase or decrease of the system costs. To highlight this problem, we have first computed the BM costs by simulating the rebalancing actions performed by the Electricity System Operator (ESO) at gate closure. This represents our reference case.

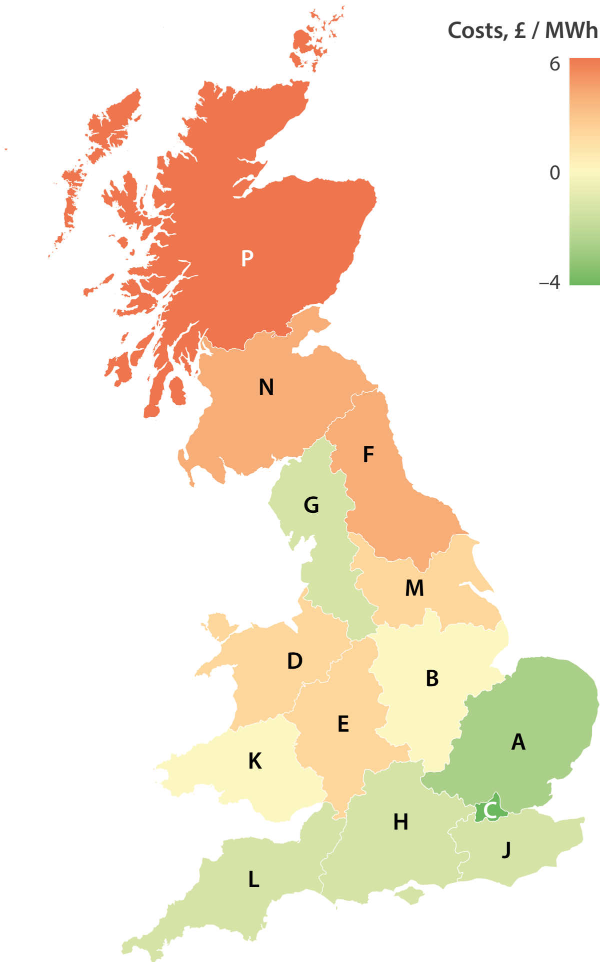

Figure 1: We can observe an increase of BM costs as a result of deploying renewable energy assets in the northern regions, particularly North Scotland. The opposite effect is obtained if these assets are built in the southern regions.

Then, we have removed 1 MW from the marginal units, and added a renewable energy asset providing 1 MW in a Distribution Network Operator (DNO) area (e.g. North Scotland). We have repeated this for each one of the 14 DNO areas that divide GB, obtaining 14 different test cases. The difference of the BM costs between each test case and the reference case gives an estimate of how the location where a renewable energy asset is deployed can affect BM costs at the system level. Figure 1 visually shows these values through a heat map for each DNO area.

These results show that the deployment of a renewable energy asset in the northern regions of GB leads to an increase in BM costs at the system level, where the greatest increase is measured when the renewable energy technology is deployed in North Scotland (labelled as "P" in Figure 1), which increases the overall costs in the BM by £5.61/MWh. In contrast, BM costs decrease if renewable energy units are deployed in the southern regions, particularly in the London area (labelled as "C"), where the decrease is equal to £4.04/MWh.

3.2 Change in reserve requirements due to the deployment of renewable energy assets

This section reports the additional reserve requirement due to the deployment of renewable energy assets. We compare a base case (where no power is added or subtracted), with different test cases, obtained by removing 1 MW of power from the marginal units and adding 1 MW of power provided by renewable energy assets. We tested two types of renewable energy technologies: (i) wind power, and (ii) a perfectly predictable renewable energy technology, which can be regarded as a wind power plant coupled with a sufficiently large energy storage device used to offset forecast errors. Figure 2 reports the results obtained, showing the change in the total reserve requirements with respect to the base case.

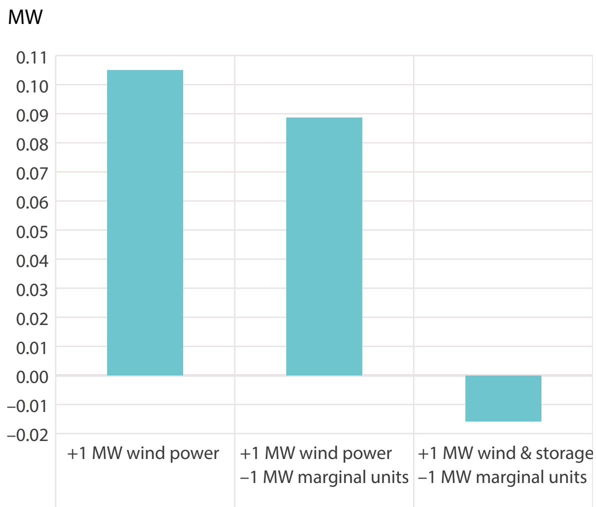

Figure 2: The figure shows the change in the total reserve requirement with respect to the base case.

The first column in the figure shows that adding 1 MW of wind power requires 0.105 MW of additional power as reserve, on average, raising the costs for reserve provision by £9.02/h. The second column highlights that if the displacement of marginal units is considered, then the net requirement reduces to 0.089 MW, with a total cost increase for reserve provision by £6.58/h. By contrast, the third column shows that if wind power was perfectly predictable, for example thanks to the usage of energy storage devices to offset forecast errors, then the change in reserve requirements would be negative instead, decreasing the overall reserve requirements of 0.016MW, and the cost for reserve would decrease by £2.44/h.

3.3 Carbon emission abatement due to the deployment of renewable technologies in different locations

In GB, a reduction of 1 MW of electrical power from marginal units should lead to a decrease of carbon emissions equal to 259 $kgCO_2$ per hour (see reference 1). However, this is true only if the BM activities do not affect these carbon emissions. To assess this, for each BM unit we computed the power output difference between the test and the reference cases defined in Section 3.1. Then, we determined how these power output differences translate into greater or smaller carbon emissions, as shown in Figure 3. This map highlights that deploying renewable energy technologies is beneficial in all regions. However, the actual reduction can be significantly affected by the grid re-dispatch. In particular, the map shows that change in carbon emission in the BM has an amplifying (beneficial) effect in carbon reduction in the southern regions. The opposite effect is obtained if assets are deployed in North Scotland. The beneficial effect in East Midlands is due to the presence of the last British coal-fired stations, where changes in renewable generation have a relatively large impact on their output and hence emissions.

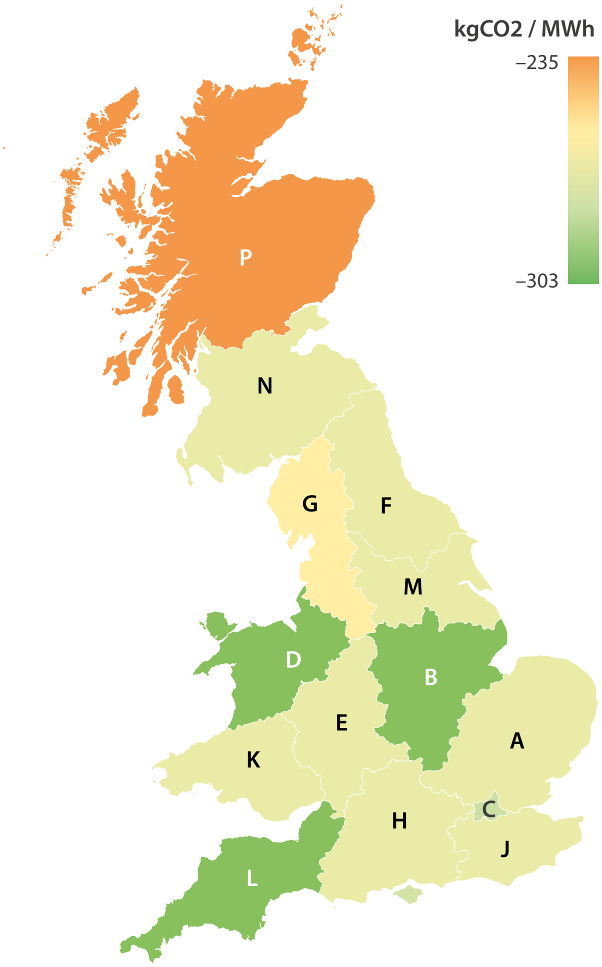

Figure 3: The figure depicts the total carbon emission reduction (including the change in emissions due to the grid re-dispatch) caused by the deployment of 1MW of renewable energy in a region, and the simultaneous reduction of 1MW from the marginal units.

Contacts

For more information, please contact:

isavelli@ed.ac.uk | thomas.morstyn@ed.ac.uk

This briefing should be referenced as:

Savelli, I., Hardy, J., Hepburn, C. and Morstyn, T. 2022. Putting wind and solar in their place: Internalising congestion and other system-wide costs with enhanced contracts for difference in Great Britain. EnergyREV, University of Strathclyde Publishing: Glasgow, UK. ISBN: 978-1-914241-30-7

References

Savelli, I., Hardy, J., Hepburn, C. and Morstyn, T. 2022. Putting wind and solar in their place: Internalising congestion and other system-wide costs with enhanced contracts for difference in Great Britain. *Energy Economics*, **113**. doi: 10.1016/j.eneco.2022.106218

EnergyREV WP3.2: Policy, regulation and market enablers.

About EnergyREV

EnergyREV was established in 2018 (December) under the UK's Industrial Strategy Challenge Fund Prospering from the Energy Revolution programme. It brings together a team of over 50 people across 22 UK universities to help drive forward research and innovation in Smart Local Energy Systems.

EnergyREV is funded by UK Research and Innovation, grant number EP/S031898/1.

www.energyrev.org.uk

@EnergyREV_UK

info@energyrev.org.uk