Public

Ref: FOI/25/161

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27 November 2025

Dear requester

Request for Information

Thank you for your request for information which we received on 30 October 2025. Your request has been considered under the Environmental Information Regulations 2004 (EIR) as the requested information meets the definition of 'environmental information' provided at Regulation 2(1) of the EIR.

Request

You asked us:

You provided some really useful regional data on carbon intensity via the link below: https://api.carbonintensity.org.uk/.
However, I can only access the current energy generation mix and have no access to past results. Could you please give me access to a dataset with historical records of the energy generation mix for each region?

Our response

NESO does not hold recorded information in scope of your request.

A dataset containing historical records of the energy generation mix for each region used in the calculation of forecast regional carbon intensity is not held.

The Carbon Intensity Regional Forecast Methodology is available on this website: Carbon Intensity. We also enclose a copy, and the National Carbon Intensity Forecast Methodology, with this response.

NESO's Open Data Portal provides access to Carbon Intensity related datasets: Data search | National Energy System Operator (NESO).

This concludes our response to your request.

Next steps

If you are dissatisfied with our handling of your request, you can ask us to review our response. If you want us to carry out a review, please let us know within 40 working days and quote the reference number at the top of this letter. You can find our procedure here: Freedom of Information and Environmental Information Regulations | National Energy System Operator. The ICO's website also provides guidance on the internal review process: What to do if you are dissatisfied with the response | ICO.

If you are still dissatisfied after our internal review, you can complain to the Information Commissioner's Office (ICO). You should make complaints to the ICO within six weeks of receiving the outcome of an internal review. The easiest way to lodge a complaint is through their website: www.ico.org.uk/foicomplaints. Alternatively, they can be contacted at: Wycliffe House, Water Lane, Wilmslow, SK9 5AF.

Thank you for your interest in the work of the National Energy System Operator (NESO).

Regards,

The Information Rights Team, National Energy System Operator (NESO)

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Carbon Intensity
Regional Forecast Methodology

Authors: Dr Alasdair R. W. Bruce, Lyndon Ruff[a], James Kelloway, Fraser MacMillan, Prof Alex Rogers[b]

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Issue: May 2024

National Energy System Operator (NESO), in partnership with Environmental Defense Fund Europe and WWF, has developed a series of Regional Carbon Intensity forecasts for the GB electricity system, with weather data provided by the Met Office.

Introduction

NESO's Carbon Intensity API has been extended to include forecasts for 17 geographical regions of the GB electricity system up to 48 hours ahead of real-time [1]. It provides programmatic and timely access to forecast carbon intensity. This report details the methodology behind the regional carbon intensity estimates. For more information about the Carbon Intensity API see here.

What's included in the forecast

The Regional Carbon Intensity forecasts include CO2 emissions related to electricity generation only. The forecasts include CO2 emissions from all large metered power stations, interconnector imports, transmission and distribution losses, and accounts for regional electricity demand, and both regional embedded wind and solar generation.

This approach considers the carbon intensity of electricity consumed in each region and uses peer reviewed carbon intensity factors of GB fuel types [2][3]. The carbon intensity factors used in this data service are based on the output-weighted average efficiency of generation in GB and DUKES CO2 emission factors for fuels [4]. GB regions are divided according to Distribution Network Operator (DNO) boundaries, see Figure 1.

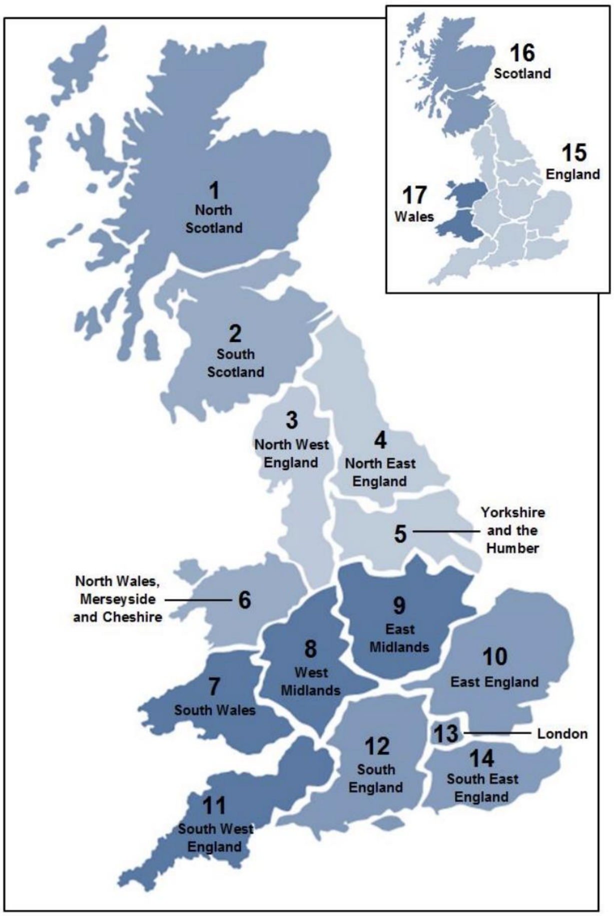

Figure 1: GB Regions and IDs for the API.

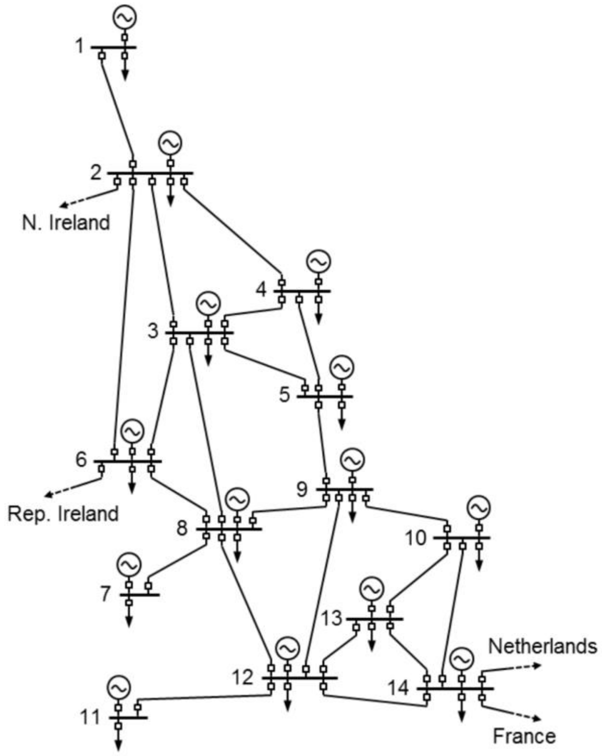

Figure 2: Electrical representation of reduced GB network.

Methodology

A reduced GB network model is used to calculate the CO_2transfers between importing/exporting regions, which takes into account the impedance characteristics of the network, constraints, and system losses. See Figure 2.

Estimating the carbon intensity of the electricity consumed in each region requires modelling the power flows between importing/exporting regions and the carbon intensity of those power flows. The estimated regional carbon intensity of generation uses metered data for each fuel type.

Step 1: Forecasting ahead

The demand (P_i^{dem}), generation (P_i^{gen}), and generation by fuel type for each region is forecast two days ahead at 30-min temporal resolution using an ensemble of state-of-the-art supervised Machine Learning (ML) algorithms. The forecasts are updated every 30 mins using a nowcasting technique to adjust the forecasts a short period ahead.

Step 2: Calculating the generation and CO_2 emissions at each node

The GB power system is divided into regions and represented as an N-bus network connected by lines. The power generation at bus is the sum of the generation in that region:

$$P_i^{gen} = \sum_{g=1}^{G} P_{i,g}^{gen}$$

The CO_2 emissions of each generator is estimated to calculate the CO_2 emissions from generation in each region:

$$E_i^{gen} = \sum_{g=1}^{G} P_{i,g}^{gen} \times c_g$$

Where $c_g$is the carbon intensity of generator's fuel type, see Table 1. Then, the carbon intensity of generation C_i^{gen} is calculated at each node:

$$C_i^{gen} = \frac{E_i^{gen}}{P_i^{gen}}$$

Step 3: Calculate power imbalance between exporting and importing regions

The power imbalance P_i at bus i is calculated by subtracting the regional power generation P_i^{gen} from the regional power demand P_i^{dem}:

$$P_i = P_i^{gen} - P_i^{dem}$$

A region is exporting power if $P_i > 0$ and importing power if $P_i < 0$.

Step 4: Three-phase Newton Raphson AC power flow

A network of N buses and L lines is described by an $L \times N$ incidence matrix A, such that $A_{l,i} = -1$ if line l ends at bus i, $A_{l,j} = -1$ if line l ends at bus j, and $A_{l,k} = 0$ if $k \neq i \neq j$. The power equations for the AC power flow in polar form are:

$$P_i = |V_i| \sum_{j=1}^{N} |V_j| \, |Y_{ij}| \cos(\delta_i - \delta_j - \theta_{ij})$$

$$Q_i = |V_i| \sum_{j=1}^{N} |V_j| \, |Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij})$$

Where $|Y_{ij}|$ is the admittance, $|V_i|$ and $|V_j|$ are the bus voltages, δ_i and δ_j are the phase angles at buses i and j respectively.

A three phase Newton Raphson iteration is performed to calculate the active and reactive power flows between buses i and j.

Step 5: Calculate the carbon intensity of power flows

Once the inter-regional power flows have been determined from the power flow analysis, it is possible to calculate the carbon intensity of power flows through every line.

The carbon intensity of power flows through lines L between N buses is represented as a matrix, where the carbon intensity of power flowing out of a bus is equal to the weighted average of the carbon intensity of power flowing into that bus.

Step 6: Calculate the carbon intensity of power consumed in each region

It is then possible to calculate the carbon intensity of electricity in each region. If the region is exporting power, then that region consumes electricity equal to its carbon intensity of generation. If the region is importing power, then the carbon intensity of the power that it consumes is equal to the weighted sum of its regional generation plus the power flow from the lines it is importing from.

Limitations

This work does not include any commercially sensitive market information about generator positions, outages, or price data. The forecasts only consider historic generation data and forecast weather data.

This work does not consider the CO_2 emissions of embedded generators that NESO does not have visibility of or access to metered data. Future work will look at estimate the contributions of these embedded generators to regional and national carbon intensity.

Interconnector carbon intensity factors

Daily at 6am, the average generation mix of each network the GB grid is connected to through interconnectors is collected for the previous 24 hours through the ENTSO-E Transparency Platform API [6].

The factors from Table 1 are applied to each technology type for each import generation mix to calculate the import carbon intensity factors. If the ENTSO-E API is down, the import carbon factors default to those listed in Table 1.

Fuel Type	Carbon Intensity gCO_2/kWh
Biomass[i]	120
Coal	937
Gas (Combined Cycle)	394
Gas (Open Cycle)	651
Hydro	0
Nuclear	0
Oil	935
Other	300
Solar	0
Wind	0
Pumped Storage	0
French Imports	~ 53
Dutch Imports	~ 474
Belgium Imports	~ 179
Irish Imports	~ 458

Contact

For any suggestions, comments or queries please contact: lyndon.ruff@nationalgrideso.com

References

[1] Carbon Intensity API (2017): www.carbonintensity.org.uk

[2] GridCarbon (2017): www.gridcarbon.uk

[3] Staffell, Iain (2017) “Measuring the progress and impacts of decarbonising British electricity”. In Energy Policy 102, pp. 463-475, DOI: 10.1016/j.enpol.2016.12.037

[4] DUKES (2017):
www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

[5] BM Reports (2017):
https://www.bmreports.com/bmrs/?q=generation/

[6] ENTSO-E Transparency Platform:
https://transparency.entsoe.eu/

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[i] Using ‘consumption-based’ accounting, the carbon intensity attributable to biomass electricity is reported to be 120 ± 120 gCO_2/kWh [2]. The large uncertainty relates to the complex nature of biomass supply chains and the difficulty in quantifying non-biogenic emissions.

Publicly Available

Carbon Intensity Forecast Methodology

Authors: Dr Alasdair R. W. Bruce, Lyndon Ruff[a], James Kelloway, Fraser MacMillan, Prof Alex Rogers[b]

[a] **St. Catherine's Lodge, Wokingham, NESO,** [b] **Department of Computer Science, University of Oxford**

Issue: May 2024

National Energy System Operator (NESO), in partnership with Environmental Defense Fund Europe and WWF, has developed a series of Regional Carbon Intensity forecasts for the GB electricity system, with weather data provided by the Met Office.

Introduction

NESO's Carbon Intensity API provides an indicative trend of carbon intensity for the electrical grid of Great Britain up to 48 hours ahead of real-time [1]. It provides programmatic and timely access to forecast carbon intensity. This report details the methodology behind the regional carbon intensity estimates. For more information about the Carbon Intensity API see here.

What's included in the forecast

The Regional Carbon Intensity forecasts include CO_2 emissions related to electricity generation only. The forecasts include CO_2 emissions from all large metered power stations, interconnector imports, transmission and distribution losses, and accounts for national electricity demand, and both regional embedded wind and solar generation.

While we recognise upstream emissions and indirect land use change impacts and other GHG emissions are important, it is only CO_2 emissions related to electricity generation that are included in the forecast. This work does not consider the CO_2 emissions of unmetered and embedded generators for which NESO does not have visibility of.

Methodology

The Carbon Intensity forecast is particularly sensitive to short-term forecast errors in demand, wind and solar generation, as this impacts the amount of dispatchable generation that is required to meet demand.

The forecast also makes use of historic generation data to make predictions about future generation, which invariably changes per system conditions. It is therefore important to note that these forecasts are likely to be less accurate than forecasts such as electricity demand, since it includes the confluence of uncertainties from demand, wind, solar, and CO2 emissions by fuel type.

Estimated carbon intensity data is provided at the end of each half hour settlement period. Forecast carbon intensity is provided 48 hours ahead of real-time for each half hour settlement period and uses NESO's latest forecasts for national demand, wind and solar generation.

The GB carbon intensity C_t at time t is found by weighting the carbon intensity c_g for fuel type g by the generation $P_{g,t}$ of that fuel type. This is then divided by national demand D_t to give the carbon intensity for GB:

$$C_t = \frac{\sum_{g=1}^{G} P_{g,t} \times C_g}{D_t}$$

The carbon intensity is then corrected to account for transmission losses to give the intensity of consumption [3]. Table 1 shows the peer-reviewed carbon intensity factors of GB fuel types used in this methodology. Carbon intensity factors are based on the output-weight average efficiency of generation in GB and DUKES CO2 emission factors for fuels [4].

Interconnector carbon intensity factors

Daily at 6am, the average generation mix of each network the GB grid is connected to through interconnectors is collected for the previous 24 hours through the ENTSO-E Transparency Platform API [6].

The factors from Table 1 are applied to each technology type for each import generation mix to calculate the import carbon intensity factors. If the ENTSO-E API is down, the import carbon factors default to those listed in Table 1.

Fuel Type	Carbon Intensity gCO_2/kWh
Biomass[i]	120
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Other	300
Solar	0
Wind	0
Pumped Storage	0
French Imports	~ 53
Dutch Imports	~ 474
Belgium Imports	~ 179
Irish Imports	~ 458

The estimated carbon intensity uses metered data for each fuel type, which is also available from ELEXON via the Balancing Mechanism Reporting Service, and includes fuel types such as metered wind, nuclear, combined cycle gas turbines, coal etc. Estimated data is used for embedded wind and solar generation.

Weather data, such as wind speeds and solar radiation, are procured separately by NESO and so are not publicly available. A rolling-window linear regression for each fuel type is performed and used with forecast demand, wind, and solar data to estimate forecast carbon intensity.

An index for carbon intensity has been developed to illustrate times when the carbon intensity of GB system is high/low. Table 2 (overleaf) shows the numerical bands for the Carbon Intensity index.

Table 2: Numerical bands for the Carbon Intensity Index. Carbon Intensity values are given in gCO_2/kWh:

Year / Index	Very Low	Low	Moderate	High	Very High
2017	0 to 99	100 to 199	200 to 299	300 to 399	400+
2018	0 to 79	80 to 179	180 to 279	280 to 380	380+
2019	0 to 59	60 to 159	160 to 259	260 to 360	360+
2020	0 to 54	55 to 149	150 to 229	230 to 350	350+
2021	0 to 49	50 to 139	140 to 219	220 to 330	330+
2022	0 to 44	45 to 129	130 to 209	210 to 310	310+
2023	0 to 39	40 to 119	120 to 199	200 to 290	290+
2024	0 to 34	35 to 109	110 to 189	190 to 270	270+
2025	0 to 29	30 to 99	100 to 179	180 to 250	250+
2026	0 to 24	25 to 89	90 to 169	170 to 230	230+
2027	0 to 19	20 to 79	80 to 159	160 to 210	210+
2028	0 to 14	15 to 69	70 to 149	150 to 190	190+
2029	0 to 9	10 to 59	60 to 139	140 to 170	170+
2030	0 to 4	5 to 49	50 to 129	130 to 150	150+

Limitations

There are several limitations with this methodology. This approach does not use Physical Notifications (PNs) of Balancing Mechanism (BM) units in the forecast. This is to ensure that the commercial sensitivities surrounding the balancing market are maintained. This means that only historic data is used in the analysis, limiting forecast accuracy. Finally, this work does not consider the emissions of embedded generation of which NESO does not have visibility. Future work will look at estimating these contributions to GB carbon intensity.

Contact

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References

[1] Carbon Intensity API (2017): www.carbonintensity.org.uk

[2] GridCarbon (2017): www.gridcarbon.uk

[3] Staffell, Iain (2017) “Measuring the progress and impacts of decarbonising British electricity”. In Energy Policy 102, pp. 463-475, DOI: 10.1016/j.enpol.2016.12.037

[4] DUKES (2017): www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

[5] BM Reports (2017): https://www.bmreports.com/bmrs/?q=generation/

[6] ENTSO-E Transparency Platform: https://transparency.entsoe.eu/

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