CBAM's Effect on Great Britain's Electricity Flows

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1 The Rationale for a Border Carbon Adjustment

Carbon pricing policies around the globe exhibit significant variation, with some nations enforcing stringent restrictions on greenhouse gas emissions, while others maintain minimal or no such restrictions. This asymmetry in climate policy implementation has critical implications, particularly in the context of energy generation and energy-intensive industries. These industries frequently face the temptation to move to areas with lenient or non-existent emissions policies or to import from such regions, a situation known as leakage. This could lead to two interrelated issues: firstly, it could diminish the global environmental effectiveness of emissions regulations; secondly, it could reduce the global competitiveness of regulated firms.

In this context, a "*border carbon adjustment*" or "*carbon border adjustment mechanism*", CBAM for short, becomes a viable solution. It aims to make sure that companies from different countries face the same carbon-related costs when competing in the same market. Essentially, a BCA adds a fee to the carbon content of imports, adjusted for the difference between the carbon prices in the importing and those in the exporting country. The aim is to ensure that the carbon emissions from foreign producers' products are subject to the same fiscal pressure as those from local producers.

2 Enter the EU Carbon Border Adjustment Mechanism

In that spirit, in October 2023, the European Union (EU) introduced the Carbon Border Adjustment Mechanism, CBAM for short.

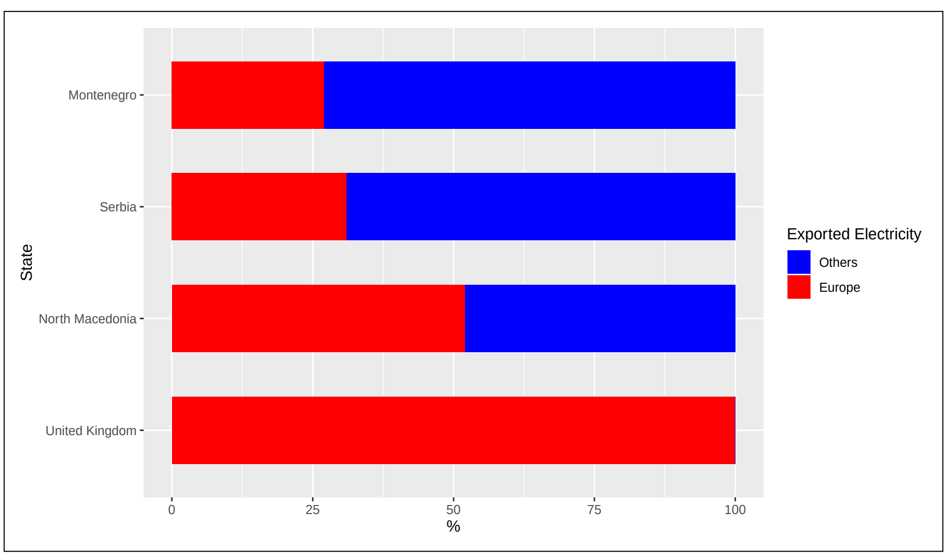

Figure 1: Proportion of electricity exported to Europe (red) compared to total exported electricity. The blue colour indicates exports to non-European countries. All of the United Kingdom's electricity exports are destined for the EU, and therefore subject to CBAM adjustment. Albania and Bosnia and Herzegovina are also highly affected countries, however, data is not available. We thank Geoffroy Dolphin for assistance with the data.

Initially, the CBAM will only apply to cement, iron and steel, aluminium, fertilizers, hydrogen, and certain intermediate inputs and downstream products[1]. Electricity is also subject to CBAM. Consequently, electricity flow to the EU is set to become more expensive, with Great Britain (GB) and Western Balkans expected to be significantly impacted, as illustrated by Figure 1, where we illustrated the proportion of electricity exported to Europe under CBAM (red) compared to total exported electricity.

3 The impact of EU CBAM on GB electricity flow

Great Britain could be one of the most significantly affected regions by the implementation of CBAM on electricity flows. Historically, GB has imported electricity from neighbouring countries – France, Belgium, Denmark, Netherlands, and Ireland – as shown by the blue bars in Figure 2, benefiting consumers from reduced bills and enhanced security of supply.

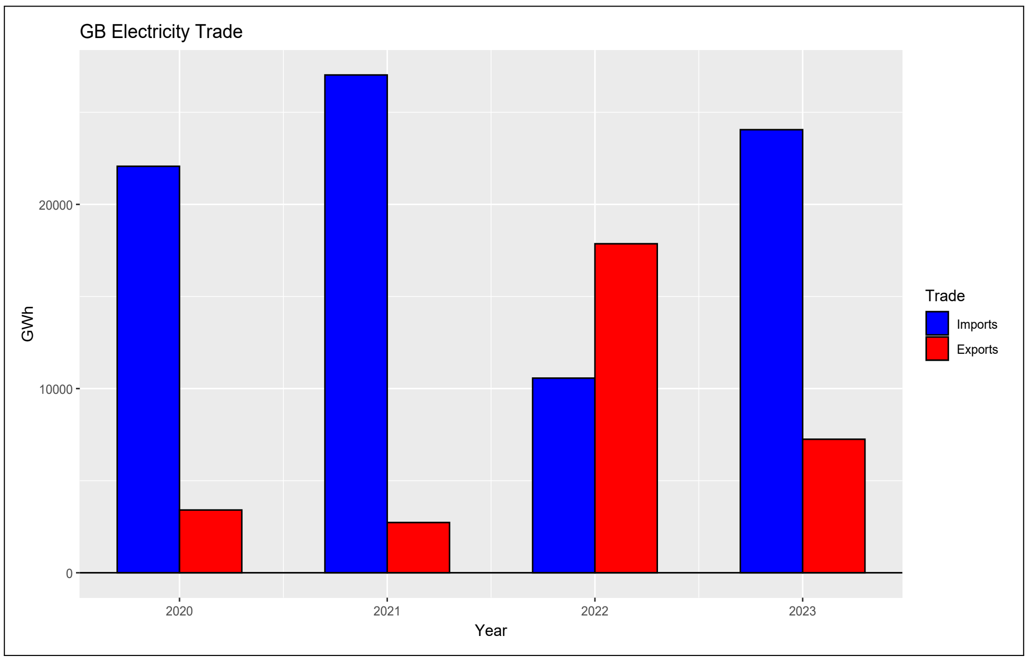

Figure 2: GB's annual electricity imports (blue) and exports (red) with the EU. Units in GWh. Data sourced from GOV-UK platform.

Recently, however, GB has increased its electricity exports to the EU, driven by a rise in renewable generation (primarily wind) and various factors affecting European energy markets, such as reduced reliance on Russian gas, technical issues with the French nuclear fleet, and low water levels in Norway, as indicated by the red bars[2] in Figure 2. This can help explain why the UK became a net electricity exporter in 2022. A key element of the new UK government's climate policy is to accelerate the target of achieving 100% clean power by 2030, with a strong emphasis on renewables. Rachel Reeves, the new Chancellor, took decisive action by ending the "*nine-year-old de facto ban on onshore wind power*" and in September 2024, a further 9.6 gigawatts (GWh) of renewable capacity was awarded through the UK's Contract for Difference auction mechanism. Additionally, the UK regulator recently approved a low-carbon electricity 'superhighway' between Scotland and England.

[1]These products are considered to be at the highest risk of carbon leakage and account for about 50% of overall European Union Emission Trading System (EU ETS) emissions.

[2]Nonetheless, there will still be significant levels of imports, bringing in green power from the continent and contributing to our security of supply.

The UK has explicitly stated its goal to become a net exporter of electricity within the next 10 years. Reaching the goal of clean power by 2030 will necessitate substantial shifts in infrastructure planning and significant investment in electricity transmission.

A challenge with applying a CBAM to electricity imports is the difficulty in identifying the exact source of imported electricity and any carbon price already paid in the exporting jurisdiction, in this particular case in Europe. Electricity is traded anonymously via exchange-based platforms, and a single electron of electricity may be traded multiple times before crossing borders. Due to the difficulty in determining whether an imported electron originates from renewables or a thermal power plant, regulators have decided to base CBAM adjustments on average historical carbon intensity.

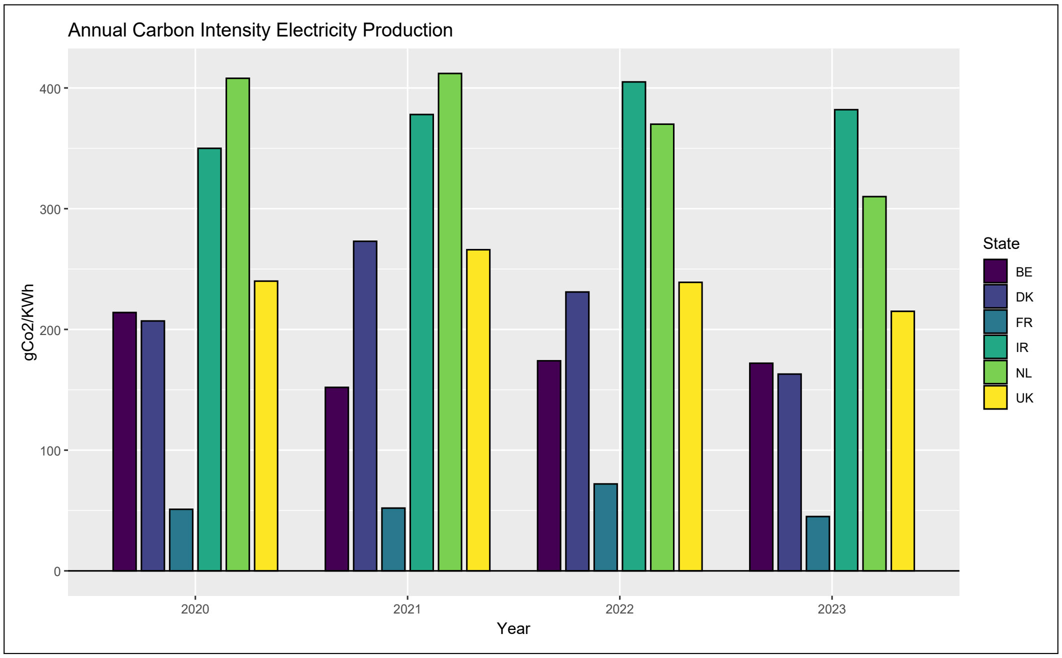

Figure 3: Average annual carbon intensity of electricity generation in Great Britain and EU countries (France, Belgium, Denmark, Netherlands, and Ireland). Data sourced from Electricity Map.

This pragmatic choice of using a single coefficient representing the market-wide carbon intensity, combined with the rapid decarbonization of UK power in recent years, means that the calculation of the CBAM adjustment may not accurately reflect the UK's current, significantly lower carbon intensity. In fact, from 2020 to 2023, the annual carbon intensity of electricity generation in Great Britain was consistently lower than that of the Netherlands and Ireland, and was comparable to the annual carbon intensity of electricity generation in Denmark, as illustrated in Figure 3.

A potential negative outcome of the introduction of CBAM is that electricity flows from the GB to the EU could diminish. Depending on the penetration of renewables, this may force both GB and EU countries to rely more on domestic thermal power generation to fill the supply gap in response to fluctuating conditions of wind and solar generation, instead of importing electricity from each other. This could significantly complicate the UK's new government's ambition to decarbonize the power grid by 2030 and slow down the delivery of net zero emissions across the economy. In the case of GB, it could deter investment in renewable power plants, as the business incentive to export to the EU would diminish, making it even more challenging for the UK government to resolve issues in the transmission and distribution system.

A simple example illustrates this point. In Figure 4, we plot the price difference (on a logarithmic scale for clarity) between the price in GB and the average electricity price in the five EU countries where GB exports electricity, essentially where there is a connector and electricity flows. For the sake of the example, we consider the period between January 2022 and December 2022. During this period, the price difference (GB-EU) smooth trend (blue line) fluctuated from positive (indicating net imports of electricity into the GB) to negative (indicating exports of electricity), and back to positive (indicating imports again).

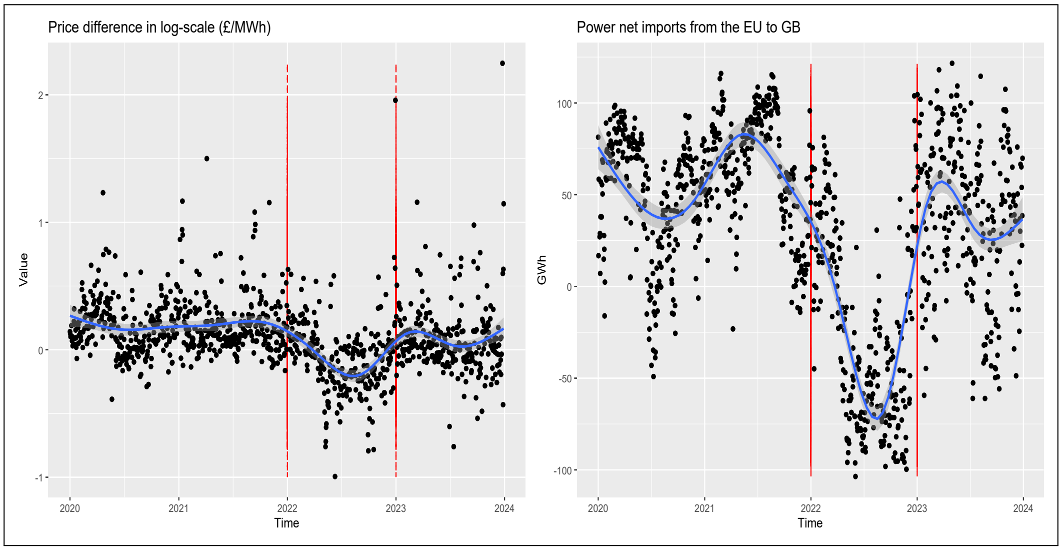

Figure 4: Left: Daily log-scale differences between electricity prices in Great Britain and EU countries (France, Belgium, Denmark, Netherlands, and Ireland). Right: Daily net imports of Great Britain with the EU. Red dashed lines mark the beginning and end of 2022. Electricity prices are stated in £/MWh. The blue line represents the smoothing model (GAM). Data sourced from ENTSO-e, Electricity Map and EPEX SPOT.

Depending on the magnitude of the border carbon adjustment, specifically the level of the CBAM price adjustment, the negative price differential needed to support GB exports to the EU could be significantly reduced. This means that in a future where renewable generation in GB becomes more prominent, resulting in cheaper electricity due to the larger share of low marginal cost renewable energy, the added cost of CBAM could make it less competitive compared to domestic EU electricity. The competitiveness of Great Britain's electricity exports might diminish, potentially leading to a decrease in export opportunities, which could, in turn, dampen investment in new renewable projects and slow the progress of the UK's energy transition and its efforts to achieve net-zero emissions[3]. For example, in 2021, Great Britain imported \$3.63 billion worth of electricity from the EU, while its exports amounted to only \$0.739 billion. However, by 2022, exports rose to approximately \$4.28 billion, while imports from the EU dropped to \$2.91 billion, resulting in a net export value of around \$1.37 billion[4].

[3] While the EU CBAM may not pose a major issue for large, diversified electricity producers, it could significantly impact entities that rely solely on renewable electricity sales or electricity transmission. Specifically, the impact on interconnectors is clear and consistently negative due to restricted electricity flows.

[4] Data sourced from the OEC platform.

4 Simulating the impact of EU CBAM on GB's electricity flow

To evaluate the potential impact of the CBAM on GB's electricity flow, we need to consider two key factors: how the CBAM obligation and CBAM adjustment are calculated, and the sensitivity of GB's electricity net export to GB-EU electricity price difference. These factors are essential for estimating potential changes in electricity flow due to CBAM.

Regarding the first factor, the CBAM obligation is calculated based on the daily carbon emission factor of electricity generated in GB[5]. The higher the carbon emissions associated with GB electricity relative to EU electricity, the greater the CBAM obligation would be for its exports. This amount is then multiplied by the CBAM adjustment, which accounts for carbon pricing in the exporting countries. The adjustment is determined by the difference between the carbon price already paid in the UK and that in the EU ETS[6]. Formally the relative adjustment in electricity prices is:

$$\frac{P_{GB,d}}{P_{EU,d}} + \frac{EI_{GB,d} \cdot (p_{UK} - p_{EU})_d^+}{P_{EU,d}}, \tag{1}$$

where, $P_{GB,d}$ is the electricity price (£/MWh) in GB on day d; $P_{EU,d}$ is the electricity price (£/MWh) in EU on day d; $EI_{GB,d}$ represents the emission intensity of electricity production (tCO_2/MWh) in GB on day d; and p_{UK} and p_{EU} are the permit prices (£/tCO_2) in the UK and EU ETS, respectively on day d (only the positive difference is considered).

Since the UK and the EU have different ETS systems with varying carbon prices, the CBAM adjustment changes accordingly. As shown in Figure 5, the CBAM adjustment is zero when the carbon price in the UK ETS is higher than in the EU ETS, meaning no additional cost is added to GB electricity exports since the UK has already paid a higher carbon price.

Conversely, a non-zero CBAM adjustment occurs when the carbon price in the UK is lower than in the EU. In such cases, the difference in carbon prices triggers an adjustment, adding an extra cost to GB electricity exports. Therefore, if the carbon price in the UK ETS continues to be lower than in the EU ETS, the price of exported electricity will be adjusted based on the emission intensity of the electricity being exported to the EU. This adjustment ensures that GB electricity exports do not undercut EU electricity prices due to differences in carbon pricing.

Then, we need to assess the sensitivity of GB's electricity net export to electricity price differences. To estimate the change in GB's electricity net export in response to changes in electricity price differences, we use an ARIMAX model, which is commonly employed in this context to account for electricity time series data with external factors. This model is estimated using a restricted sample of observations from January 1, 2022, to December 31, 2023. The model results, presented in the Appendix, show that as expected the larger the price difference between EU and GB electricity prices, the larger (and more positive) the effect on net exports from GB to the EU. Specifically, for a 1% increase in the logarithm of the ratio (P_{GB}/P_{EU}), there is an estimated daily reduction of 170 MWh in net exports from GB to the EU. This daily reduction translates to 62,050 MWh per year.

[5]The Official Journal of the European Union specifies that, to account for the impact of decarbonization policies—such as increased renewable energy production and weather conditions, such as particularly cold years, on the yearly electricity production in exporting countries– the carbon emission factor should be calculated based on the weighted average over a five-year period ending two years before the reporting period. In this example, we consider daily difference because it is technically feasible, and we later compare the final results with a modified version that considers an average over a year. The use of the last year is necessary because we only have data from the last year. The simulation can easily be adjusted to align with the specific CBAM requirements for electricity.

[6]For a detailed description of CBAM obligations, CBAM adjustment, and precise calculation of the average prices, we refer to the DG TAXUD CBAM website.

Figure 5: Allowance prices in the UK and EU's ETS from January 2022 to August 2024 (top) and the positive difference between the UK and EU allowance prices (bottom). Data sourced from Refinitv Eikon.

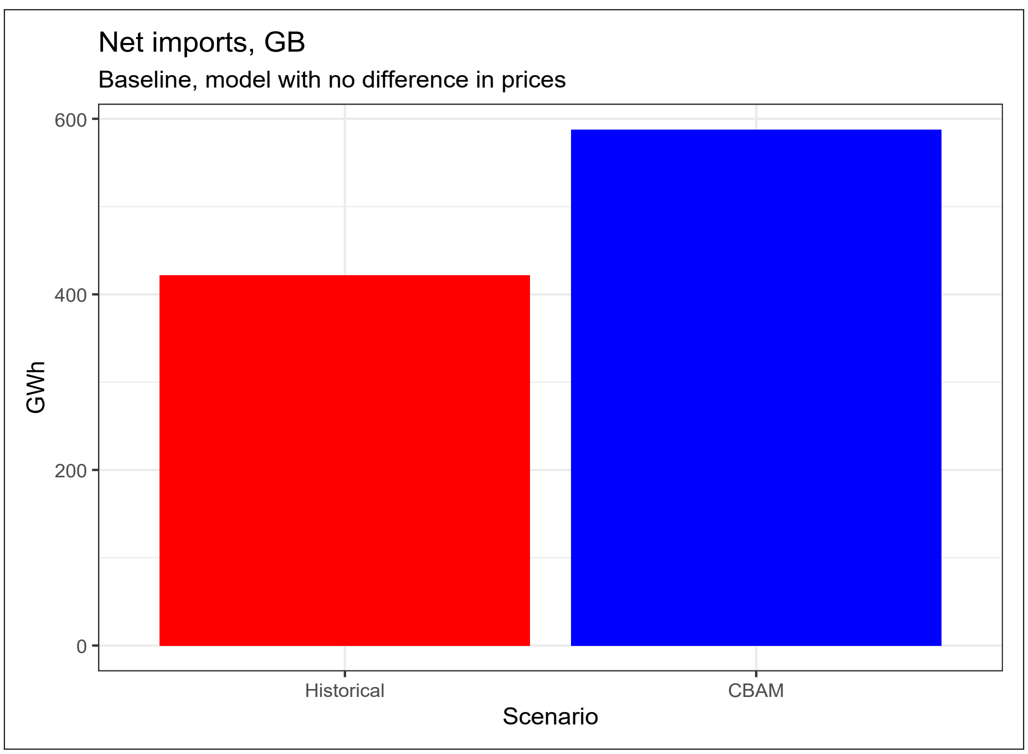

Figure 6: Scenario analysis of the CBAM's impact in 2023. Due to the temporal characteristics of the ARIMAX model, both the historical scenario and the projected CBAM scenario are filtered through the baseline model, which assumes no differences in electricity prices.

By combining the CBAM obligation and CBAM adjustment with the sensitivity of net exports, we can simulate the overall impact for the year 2023, assuming CBAM had been active during that period. This exercise illustrates that the introduction of CBAM will result in a daily net export reduction of approximately 0.45 GWh, amounting to a total of 164 GWh over the course of 2023, as depicted in Figure 6. Assuming an average annual electricity consumption of 3 MWh per household, this could potentially impact the equivalent amount of electricity used by a city the size of Lancaster (around 52,000 inhabitants)[7].

5 Policy implications

The simulation of the impact of the EU CBAM on GB's electricity flow highlights its potential to undermine UK renewable energy exports and, by extension, the future deployment of additional UK renewable capacity. This is a critical issue, as reduced export opportunities could dampen investment in renewable projects, slowing the UK's progress toward its clean energy goals. Therefore, strategic policy measures are needed to mitigate these impacts and ensure the UK's transition to a net-zero economy remains on track.

One obvious solution is for the UK to link its ETS to the EU's ETS. Logistically, this is feasible, as the UK and EU ETS systems have remained nearly identical. Additionally, non-EU members such as Iceland, Liechtenstein, Norway, and Switzerland already participate in the EU ETS, demonstrating that participation from outside the EU is possible.

Linking the UK ETS with the EU ETS would grant the UK "*virtual exemptions*" for electricity exports to the EU. Carbon prices in both regions would converge, creating uniform carbon costs. This would effectively eliminate, or significantly reduce, the costs associated with CBAM obligations for UK exporters.

Alternatively, the UK Government and the European Commission could collaborate to develop and implement their respective CBAM policies, focusing on exempting electricity trades from CBAMs on a reciprocal basis. This means both the UK and EU countries would agree not to impose CBAMs on electricity traded between them, benefiting from reciprocal price differentials and cleaner electricity production.

[7] Calculating the CBAM obligation based on the average annual carbon intensity of energy production in the UK for 2023, this reduction equates to nearly 178 GW per year.

Appendix

GB's electricity generation mix

GB's reliance on coal generation has steadily decreased, while gas generation has remained constant, and wind and solar generation have grown significantly, as illustrated in Figure 7.

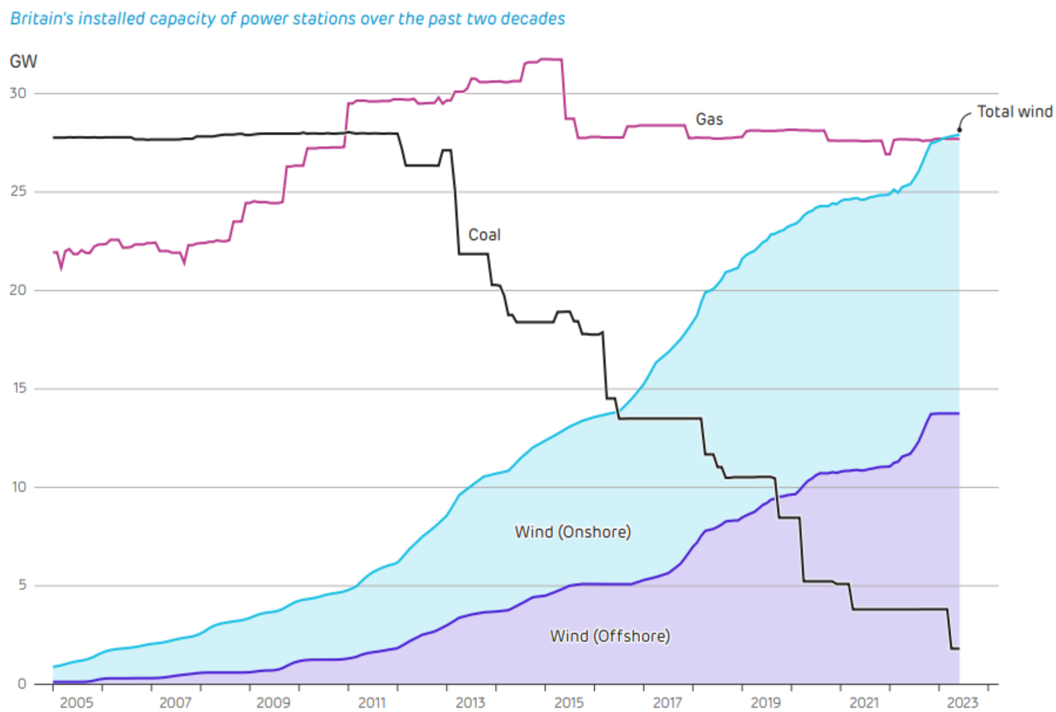

Figure 7: Britain's installed capacity of power stations, Drax Electric Insights Quarterly – Q2 2023.

Sensitivity of GB's net export to electricity price difference

We collected electricity prices in GB, France, Belgium, Denmark, Netherlands, and Ireland from January 1, 2022, to December 31, 2023. The EU electricity price was defined by calculating the equally weighted average of prices in France, Belgium, Denmark, Netherlands, and Ireland.

	Estimate	Std. Error	P-Value
$AR(1)$	0.379	0.071	***
$MA(1)$	-0.831	0.045	***
$\log(P_{GB}/P_{EU})$	17.040	4.820	***
Number of observations: 520			

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table 1: ARIMAX model. The dependent variable is Great Britain's net imports and the exogenous variable is the differences in log-scale between electricity prices in Great Britain and European Union countries (France, Belgium, Denmark, Netherlands, and Ireland).

Next, we used an ARIMAX model to describe GB's net export of electricity to the EU as a function of the price difference between GB and EU electricity prices[8]. Table 1 reports the estimated coefficients, offering insights into the relationship between price differences and net electricity exports.

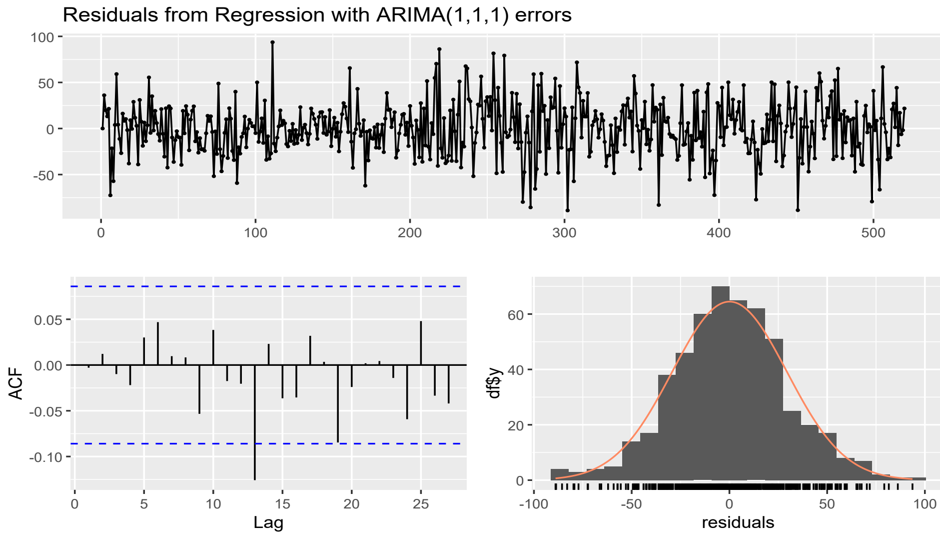

Figure 8: Residuals of the ARIMAX model. The dependent variable is Great Britain's net imports and the exogenous variable is the differences in log-scale between electricity prices in Great Britain and European Union countries (France, Belgium, Denmark, Netherlands, and Ireland).

The residuals from the model, plotted in Figure 8, help us assess the accuracy and reliability of the model's predictions.

Despite the time dimension, price differences positively affect the dependent variable – when electricity prices in EU countries are higher relative to those in GB, GB's net imports decrease. The residuals follow a normal distribution, show no autocorrelation, and exhibit homoscedasticity, supporting the model's validity.

Limitations and future directions

Given the limited data available on the Electricity Map platform, the analysis relies on net exports as the dependent variable. However, focusing specifically on GB exports could yield more accurate results. Moreover, the ARIMAX model used captures only linear effects of exogenous variables; future research should explore non-linear models as potential alternatives.

[8]The model estimation was performed using the `auto.arima` function, which automatically selects the best-fitting ARIMAX model based on the data.