FINAL REPORT

January 2021

NeuConnect Interconnector:

Contribution of NeuConnect to UK, German and European Net Zero objectives

Executive Summary

In common with the rest of the world, the UK, German and wider European electricity markets have entered a period of transition, with policy-makers seeking to significantly reduce carbon emissions to help address global concerns over climate change.

Governments in the UK and Germany as well as the European Commission have adopted ambitious targets to achieve 'Net Zero' carbon emissions by 2050 – as part of this, further investment in energy transmission infrastructure is often cited as a crucial element to support the Net Zero transition, while also helping to improve security of supply in a cost-efficient way.

Against this backdrop, NeuConnect is a proposed 1.4 GW interconnector that will connect the electricity networks of Great Britain ("GB") and Germany. By creating the first direct link between two of Europe's largest energy markets, NeuConnect is expected to play a significant role in enabling the UK and Europe to reach their Net Zero targets.

In this report, the energy teams of FTI Consulting and Compass Lexecon ("FTI-CL Energy") assess the contribution of NeuConnect to UK, German and European decarbonisation objectives. The headline results of our modelling show that NeuConnect will help to deliver:

16 $MtCO_2$ net reduction in carbon emissions over 25 years	Equivalent to **removing 400,000 cars** off the road, or **planting 28 million trees**, in a year
82% fall in carbon emissions between 2030 and 2050	Greater **integration of renewables** in UK and Germany and **improved security of supply**

The rest of this report sets out the results, the methodology and the modelling used, in more detail.

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Europe's "Net Zero" ambitions are driving significant decarbonisation efforts

Governments throughout Europe (including in the UK) are pursuing ambitious decarbonisation policies, with the aim of achieving Net Zero emissions by 2050.

In June 2019, the UK Government introduced legislation that requires it "to bring all greenhouse gas emissions to net zero by 2050" (often referred to as the "Net Zero Target").[1] Similarly, in September 2019, the German Government committed *"to pursue the long-term goal of greenhouse gas neutrality by 2050"*.[2]

In December 2019, the EC published the European Green Deal, an ambitious plan to transform the European Union ("EU") into a *"resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use"*.[3]

As the UK and Europe progress on the path towards these targets, there will be a greater need for transmission infrastructure to convey power from where it is generated to where it is consumed, to ensure costs are efficient and a reliable supply of electricity is maintained at all times. Indeed, the EC explains that *"a net-zero greenhouse gas emissions economy will be achieved only with an adequate and smart infrastructure ensuring optimal interconnection and sectoral integration across Europe"*.[4]

There are multiple technical, economic and political challenges in reaching the Net Zero objectives, and these are likely to have been further exacerbated by the ongoing Covid-19 pandemic. As consumers are facing increasing financial strain and uncertainties, the increased pressure on consumer finances, concerns over a fragile economy and the significant cost of decarbonisation, together mean it is now even more vital that the Net Zero target is delivered as cost-efficiently as possible.

The role of electricity interconnectors

Electricity interconnectors are transmission links that enable electricity to flow between different geographical and price regions. They have long been recognised for bringing multiple and significant benefits to consumers. Interconnection capacity between GB and mainland Europe is expected to lead to "a decrease in emissions in GB and EU", in addition to "less curtailment of renewable energy sources" and "a reduction in total power market cost." [5]

Interconnectors generate these benefits through three key mechanisms: enabling renewable resources to be shared across a wider geographical footprint, reducing carbon emissions (by enabling renewable generation exports from one region to displace thermal generation in another region), and enhancing the security of supply in the connected regions.

Sharing of renewable resources

Interconnectors help support the integration of renewables in the UK and European energy systems they connect, by allowing low carbon electricity to be shared across wider geographical footprints. This benefit arises partly because the output from intermittent renewable generation is not entirely correlated between countries and partly because the peak demand in the two countries is typically not fully coincident, due to the time zone difference.[6]

Crucially, since wind conditions often differ between regions in the same time period, this tends to lead to frequent periods of low wind (and high wholesale prices) in one region and simultaneous periods of high wind (and low wholesale prices) in another region. Interconnecting two such regions facilitates a flow of low-cost renewable electricity between regions depending on the prevailing weather conditions (e.g. when one region is windier than the other). That is, with an interconnector, the production of low-cost renewable energy in one country can potentially be exported to benefit its neighbours.

This in turn reduces the likelihood that renewable generation plants in the exporting region generate "excess" power (which would otherwise go unused), thus enabling them to displace thermal generation in the importing region. Overall, this increases the total renewables share of electricity generation across both regions.

Lower carbon emissions

In periods when renewable output is lower (for example, when wind speeds are low), an interconnector allows a given region to make use of cheaper renewable sources in a neighbouring region to meet demand, rather than relying on its domestic (and potentially carbon-intensive) thermal generation.

This displacement of thermal generation in favour of renewable generation is the key mechanism through which interconnectors contribute to the reduction in carbon emissions.

1 BEIS (2019), UK becomes first major economy to pass net zero emissions law (link).
2 Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2019), Federal Climate Change Act (link).
3 EC, European Green Deal, December 2019 (link).
4 European Commission (2018), A clean planet for all (link).
5 Aurora (2020), The impact of interconnectors on decarbonization (link). See also Ofgem (2014), Electricity Interconnectors factsheet (link).
6 Our analysis indicates that over a typical climate year, the German and GB peak daily demand only coincides for 43 hours per year, or in just 12% of days.

Enhancing security of supply

One of the key challenges in the transition to a low carbon energy system is the need to maintain energy security. That is, ensuring access to sufficient sources of electricity to meet customer demand in all time periods. With the growing penetration of intermittent generation, the energy system needs to become more flexible in order to be able to manage increasingly volatile supply and demand balance.

Interconnectors, among other sources of flexibility, help alleviate this challenge by both increasing and diversifying the electricity sources a given energy system is reliant on.

By interlinking neighbouring regions, interconnectors provide each region with access to additional energy resources (often with a different generation mix), which is particularly valuable during times when it is facing "system stress".

Additionally, HVDC interconnectors equipped with Voltage Source Converters ("VSC") can also improve security of supply by providing specialised 'balancing services' to system operators ("SOs") to support the stability of the energy system. These are known as ancillary services and are likely to become more critical as intermittent renewable generation increases, and the associated system volatility requires increasing volumes of flexibility.

FTI-CL assessment of NeuConnect's contribution to decarbonisation objectives

In the context of the transition towards Net Zero by 2050, the energy teams of FTI Consulting and Compass Lexecon ("FTI-CL Energy") have been commissioned by NeuConnect to examine and quantify the contribution of the NeuConnect interconnector to the UK's, Germany's and wider European decarbonisation targets.

To estimate the impact of NeuConnect on the UK's, Germany's and wider European decarbonisation ambitions, we have used our in-house power market dispatch model, driven by the Plexos® Market Simulation Software, calibrated with a detailed representation of power markets throughout the European continent.

For a given set of assumptions (such as gas and carbon prices, and expected levels of demand), our power market model forecasts the optimal evolution of electricity generation capacity throughout Europe, and the optimal dispatch of that generation capacity. We model every five years from 2030 to 2050, on an hourly basis, to examine NeuConnect's contribution to the Net Zero objectives.

In our analysis we have assumed the ambitious decarbonisation pursued by governments in the UK, Germany, and the rest of Europe will share some critical features across all countries. First, we assume high emission sectors of the economy, such as heating and transport, will electrify rapidly, notably through the use of heat pumps and electric vehicles, which is expected to drive strong growth in the demand for electricity. Indeed, we expect the demand for electricity in Europe to grow from around 3,000 TWh per annum in 2030 to around 6,000 TWh per annum by 2050, and is broadly in line with external forecasts that assume a strong decarbonisation agenda.

We also assume carbon prices will function as a key policy tool to drive decarbonisation, rising to as much as €150 per tCO2 by 2050. Finally, we expect a strong need for renewable generation capacity to grow over time in order to meet that growing electricity demand. We assume the primary sources of renewable generation will continue to be offshore wind, onshore wind and solar. In GB,[7] we assume, by 2050, the generation capacities of these technologies will grow to 87 GW (offshore wind), 31 GW (onshore wind) and 58 GW (solar). In Germany we assume the capacities of these technologies will grow to 71 GW, 156 GW and 198 GW respectively. Together, our assumptions define a 'Policy Scenario', which we use to assess the impact of NeuConnect on the decarbonisation objectives of the UK, Germany and wider Europe. A full description of our modelling assumptions can be found in the Appendix below.

Structure of this report

In the remainder of this report, we discuss:

— how NeuConnect facilitates additional renewable generation;

— the reduction in carbon emissions due to NeuConnect under the Policy Scenario;

— the sensitivity of NeuConnect's impact on carbon emissions to an accelerated UK decarbonisation agenda;

— how NeuConnect helps to improve the use of renewable capacity; and

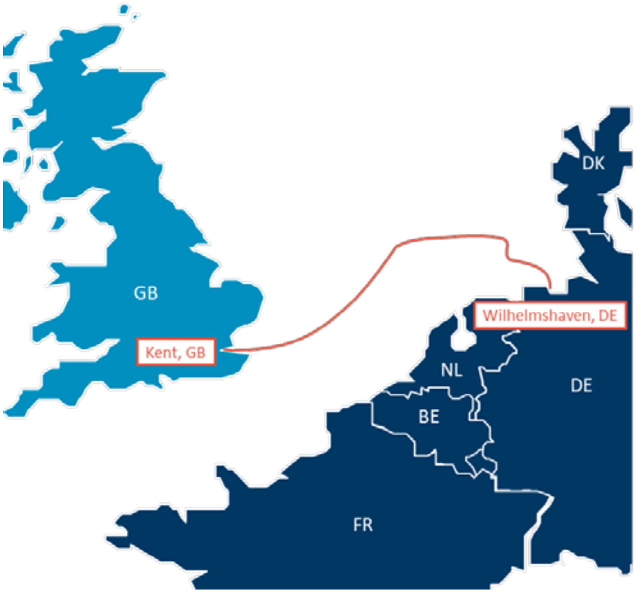
— NeuConnect's contribution to the security of supply.

7 In this report, we use *'UK'* to refer to policies set by the Government of the United Kingdom of Great Britain and Northern Ireland. We use *'GB'* to refer to assumptions and modelling results specific to the energy network of Great Britain. The energy networks of Northern Ireland and the Republic of Ireland are fully integrated as part of the Integrated Single Electricity Market.

NeuConnect facilitates additional renewable generation

NeuConnect is a proposed 1.4GW HVDC electricity interconnector, planned to connect Kent in the South-East of GB to Wilhelmshaven in the North of Germany. NeuConnect is planned to be the first interconnector between these countries.

Figure 1: Proposed NeuConnect Interconnector

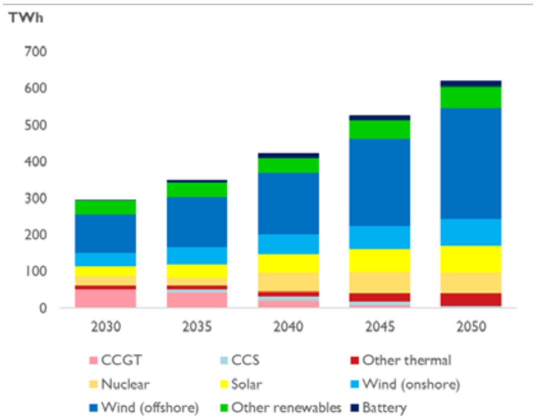


Source: FTI-CL analysis

The fundamental economic rationale behind the development of the interconnector is that, by connecting the complementary generation mixes of GB and Germany, NeuConnect would help optimise the dispatch of power in both countries. Thus, the interconnector would allow both countries to make use of cheaper (and less carbon intensive) sources of generation to meet their combined electricity demand.

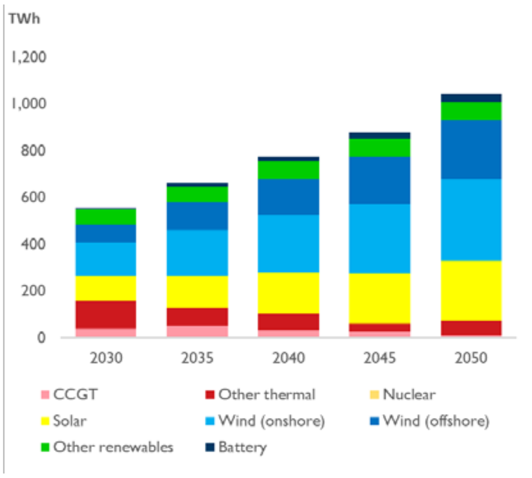
This is indeed the case, based on our power market modelling analysis. Figures 2 and 3 below illustrate the expected generation from different sources in both GB and Germany between 2030 and 2050, as forecasted through our power market analysis. This indicates that GB and German generation mixes are complementary in the sense that offshore wind generation forms a large proportion of total GB electricity generated, while German electricity generation relies more on onshore renewables such as onshore wind and solar. Geographically, seasonally and on an intra-day basis, the output from different types of renewables is reasonably uncorrelated. This means that, with NeuConnect, both GB and Germany will be able to make use of the other's renewable generation to meet demand.

Figure 2: GB generation outlook (TWh)



Source: FTI-CL analysis

Figure 3: Germany generation outlook (TWh)



Source: FTI-CL analysis

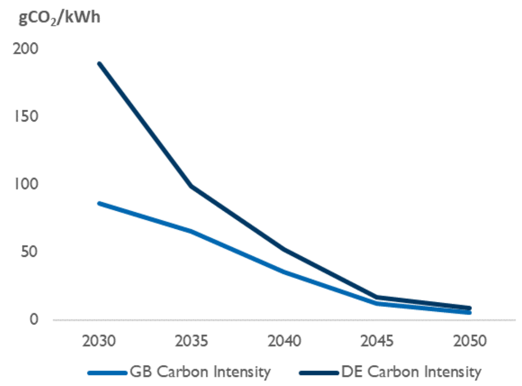
As shown in Figures 2 and 3 above, throughout the modelled period, the share of renewable generation (as a proportion of total electricity generated) is greater in Germany than in GB. Even by 2050, German renewables account for 90% of total generation, while in GB this remains somewhat lower at 82%. This is primarily due to the continued use of nuclear capacity in GB, which serves as a baseload source of electricity. By contrast, Germany has committed to decommissioning all nuclear power plants by 2022.

In earlier years (between 2030 and 2035), the share of GB renewable generation as a proportion of total electricity produced is expected to be significant, between 70% and 74%. In addition, some of GB demand is met through German renewable generation, which is exported to GB through NeuConnect. In the scenario with NeuConnect, our modelling indicates that Germany produces around 400 GWh of additional renewable electricity in 2030, and an additional 1,200 GWh in 2035, compared to the scenario without NeuConnect.

In later years (between 2040 and 2050), the share of renewable generation is expected to have grown further. Indeed, by 2050, over 80% of the total electricity generated in both countries is estimated to come from renewable sources. This is, in part, a result of our assumptions on the trajectory of carbon prices (which rise from €47/tCO_2 in 2030 to €150/tCO_2 in 2050) that arise as a result of implementation of Net Zero policies. This changes the merit order of generation technologies in favour of low carbon renewables, which therefore end up representing a growing share of total supply in both GB and Germany.

The increase in renewable generation manifests itself in a significant fall of the average carbon intensity of both GB and German generation over the modelling period. In GB, the average carbon intensity of electricity generation falls from 86gCO_2/kWh in 2030 to 6gCO_2/kWh in 2050. In Germany, this falls from 189gCO_2/kWh to 9gCO_2/kWh over the same period, as illustrated in Figure 4 below.

Figure 4: Average carbon intensity of GB and German generation (gCO_2/kWh)



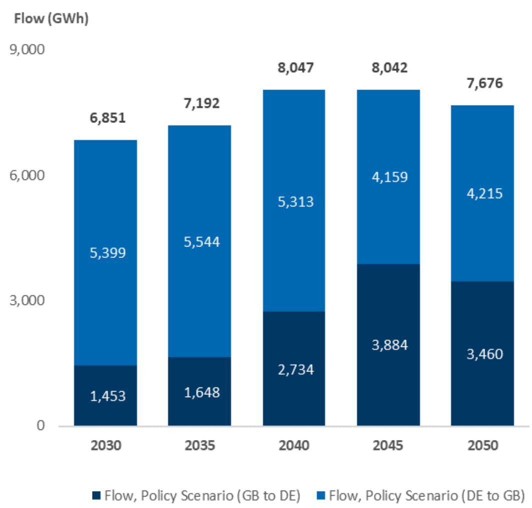
Source: FTI-CL analysis

Underlying this fall in the carbon intensity of GB and German generation is a sustained decline in the use of thermal carbon-intensive generation in the scenario with NeuConnect (compared to the scenario without NeuConnect). Carbon emissions in Europe as a whole (including GB and Germany), are expected to fall from around 353MtCO_2 in 2030 to around 65MtCO_2 by 2050, a decline of around 82%.

One of the key benefits of NeuConnect in the long term (and particularly from 2040 onwards) is that it supports the Net Zero objectives by allowing renewable generation in either GB or Germany to be shared between both countries. When renewable generation is higher in one country, for example when wind speeds are high in GB but lower in Germany, the power generated by offshore windfarms in GB can be exported via NeuConnect and contribute to meeting German power demand, and vice versa at times when wind speeds are high in Germany but lower in GB.

The impact of the sharing of renewable generation described above can be seen in the flows across NeuConnect, shown in Figure 5 below.

Figure 5: NeuConnect flows (GWh)



Source: FTI-CL analysis

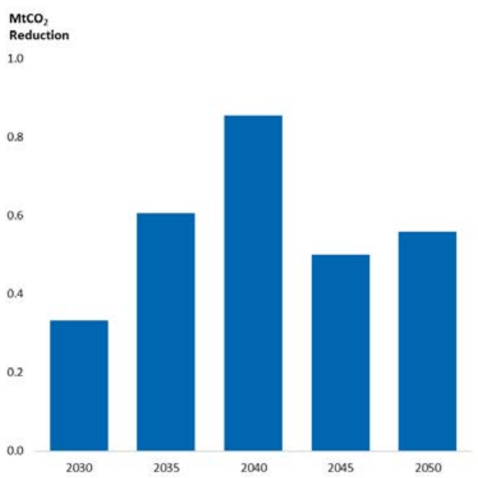
In the earlier years (2030-2040), the majority of the flows on NeuConnect are from Germany to GB, partly because a portion of German renewable generation can be exported to displace GB's thermal generation. This pattern changes in the later years: by 2045 and 2050, the penetration of renewables in both Germany and GB is very high, and NeuConnect is increasingly used as a tool to balance the intermittent generation both countries. This means that when it is relatively windy in Germany, NeuConnect tends to be used to export power towards GB, and vice versa when it is relatively windy in GB. This leads to flows on NeuConnect being more or less evenly balanced in the two directions, as the weather conditions (e.g. wind speeds) vary naturally over the course of the year.

NeuConnect contributes to an EU-wide net reduction in carbon emissions

By facilitating the flow of renewable generation, which typically has low marginal cost and low carbon emissions, NeuConnect allows thermal generation in both countries to be displaced by renewables generation. For example, in the absence of NeuConnect, when wind speeds are low in GB, it is more likely that a significant volume of carbon-intensive thermal generation (such as gas) would be needed to meet GB demand. However, with NeuConnect, a greater share of GB demand can instead be met through electricity imports from Germany, reducing the need to make use of GB's thermal generation, and therefore reducing GB emissions.

By forecasting the hourly output of all generators in each modelled year and multiplying this by their emission factors, our power market model estimates total carbon emissions of the electricity markets in Europe (including GB and Germany) on an hourly basis. We compare this to a similar analysis performed assuming NeuConnect is not constructed. This allows us to calculate, for each modelled hour and in each modelled year, the total impact of NeuConnect on carbon emissions, as shown in Figure 6 below.

Figure 6: Net effect of NeuConnect on Europe-wide (incl. GB) emissions, Policy Scenario ($MtCO_2$)



Source: FTI-CL analysis

As shown in Figure 6 above, NeuConnect reduces Europe-wide emissions in each of the modelled years, from 2030 through to 2050.

To calculate the annual impact of NeuConnect on carbon emissions over a 25-year period, we interpolate between each of the modelled years.[8] Using this approach, our modelling shows that NeuConnect reduces Europe-wide emissions (including GB) by a total of 16 $MtCO_2$ over its first 25 years of operation. This is equivalent to removing around 400,000 cars from the road, or planting 28 million trees, in a year.[9]

ENTSO-E Carbon Impact Assessment

The benefits of interconnectors in reducing carbon emissions are widely recognised and assessed by European authorities. For example, as part of its Ten-Year Network Development Plan ("TYNDP"), the European Network of Transmission System Operators ("ENTSO-E"), conducts a cost-benefit assessment ("CBA") of proposed interconnector investments in Europe,[10] but only up to 2030. This includes an assessment of the carbon impacts of proposed interconnector investments, such as NeuConnect. As part of its most recent TYNDP 2020, ENTSO-E estimated that NeuConnect would lead to a net reduction of Europe-wide (including GB) carbon emissions of between 0.3 $MtCO_2$ – 0.4 $MtCO_2$ in 2030.[11] This is similar to FTI-CL's estimate of a 0.3 $MtCO_2$ reduction in 2030 due to NeuConnect, although ENTSO-E's estimates include additional changes in emissions (e.g. due to changes in network losses), which we have not quantified.[12] Differences between ENTSO-E's and FTI-CL's estimates are primarily driven by this difference in methodology, and by ENTSO-E's differing input assumptions.

8 Our modelling covers a period of 21 years, from 2030 to 2050. To estimate this over a 25-year period, which is the standard regulatory period for interconnectors in GB, we have sought to estimate the total carbon impact over the same 25-year period. To do so, we extend our modelling results backwards for four additional years. We assume the carbon impact of NeuConnect between in each of those years is equal to the average carbon impact over each of the five modelled years.

9 Based on the per annum ratio of emissions and impact on car volume as assessed by National Grid, Power of Now Carbon Dashboard (link), and the per annum absorption of emissions as calculated by the European Environment Agency (link)

10 The TYNDP is a bi-annual publication the collates and assesses proposed electricity infrastructure developments.

11 TYNDP 2020 NeuConnect project sheet (link)

12 We compare the methodology and the assumptions behind FTI-CL's and ENTSO-E's modelling in the appendix.

Sensitivity of NeuConnect's carbon impact to an accelerated GB decarbonisation agenda

The estimated impact of NeuConnect on Europe-wide (including GB) carbon emissions is strongly driven by the energy sector policies that will be pursued by individual governments over the next 30 years. Underlying our Policy Scenario are climate and decarbonisation policies that the UK, German and European governments have elected to pursue, but these policies are, of course, subject to change.

Indeed, at the time of writing this report, the UK Government has announced plans for a Green Industrial Revolution, with ambitious targets in respect of renewable and low carbon technologies set out in its "Ten Point Plan".[13] The Energy White Paper accompanying the Ten Point Plan is supportive of GB interconnection capacity, and explains that *"a higher level of interconnector capacity could decrease cumulative emissions in Great Britain by up to 99MtCO_2e by 2050."*[14]

The targets in the Ten Point Plan are generally focused on the medium-term future (that is, the 2030s) rather than the 2050 long term horizon. In general, they represent an acceleration of the GB decarbonisation agenda relative to the Policy Scenario discussed above.

We have assessed the Europe-wide carbon impact of NeuConnect under an accelerated decarbonisation pathway in GB, represented by this Ten Point Plan, under a 'UK Political Ambition Scenario', as a sensitivity on the Policy Scenario.

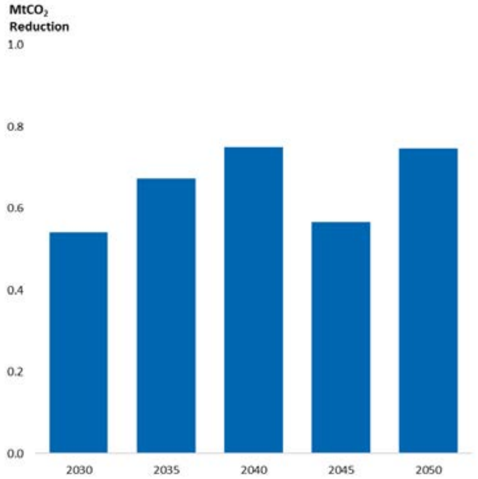
Most of the assumptions in the UK Political Ambition Scenario are the same as those of the Policy Scenario, but we have made certain adjustments to reflect the Ten Point Plan. Firstly, we assume a higher level of GB electricity demand under the UK Political Ambition Scenario, due accelerated targets for the development of low carbon hydrogen (5GW capacity by 2030), and a greater level of electrification of transport. Secondly, we assume higher GB offshore wind capacity under the UK Political Ambition Scenario, due to more ambitious offshore wind targets (40GW capacity by 2030). Finally, we assume an accelerated development of GB nuclear capacity under the UK Political Ambition Scenario (Hinkley Point C commissioned in mid-2020s). A full description of our modelling assumptions can be found in the Appendix below.

Using the above adjustments, we estimate the total carbon emissions of the European electricity markets (including GB) under the UK Political Ambition Scenario. We compare this to a similar analysis performed assuming NeuConnect is not constructed, with the difference being the total impact of NeuConnect on carbon emissions, as shown in Figure 7 below. Under the UK Political Ambition Scenario, NeuConnect reduces Europe-wide emissions (including GB) in each of the modelled years.

Similarly to the Policy Scenario, we interpolate between each of the modelled years to calculate the impact of NeuConnect on carbon emissions over a 25-year period. Our modelling shows that, under the UK Political Ambition Scenario, NeuConnect reduces Europe-wide emissions (including GB) by a total of 17 MtCO_2 over its first 25 years of operation.

The accelerated decarbonisation agenda under the UK Political Ambition Scenario therefore represents a slight upside in respect of NeuConnect's carbon impact, relative to our assessment of 16MtCO_2 under the Policy Scenario.

Figure 7: Net effect of NeuConnect on Europe-wide (incl. GB) emissions, UK Political Ambition Scenario (MtCO_2)



Source: FTI-CL analysis

13 UK Government Press Release 'PM outlines his Ten Point Plan for a Green Industrial Revolution for 250,000 jobs' (link).

14 UK Government (2020) Energy White Paper: Powering our Net Zero Future (link).

NeuConnect allows Germany to make better use of its growing renewable capacity

During some periods, non-dispatchable resources (e.g. intermittent generators such as wind and solar) may generate electricity that cannot be used to meet demand on the system, either due to insufficient demand or due to transmission constraints. When this occurs, SOs may take action to prevent such resources from dispatching their output onto the network, in order to balance the overall system demand and supply. This is known as 'curtailment'. When such curtailment of renewable generators occurs, it reduces the volume of low-carbon electricity that is being dispatched on the system, and this remains unused.

By allowing a portion of domestic renewable generation to be exported, NeuConnect reduces the curtailment of renewable generation in Germany in each modelled year, as shown in Table 1 below.[15]

Table 1: Curtailment of German renewable generation (TWh)

	2030	2035	2040	2045	2050
Without NeuConnect	11.3	26.2	51.7	61.7	65.6
With NeuConnect	10.9	25.1	49.5	59.2	63.4
Additional renewables generation	⬆ **0.4**	⬆ **1.1**	⬆ **2.2**	⬆ **2.5**	⬆ **2.2**

Source: FTI-CL analysis

The reduction in the curtailment of German renewables represents an improvement in the utilisation of renewable generation sources, which therefore contribute more to the Net Zero transition.[16]

Enhancing security of supply

NeuConnect enhances the energy security of both GB and Germany by providing both countries with potential access to the other country's generation capacity, and by potentially providing SOs with services required to balance the system, known as ancillary services.

The provision of capacity is particularly crucial during periods of so-called "system stress", when there may be insufficient generation available in either GB or Germany to meet its own electricity demand. This risk is becoming particularly acute as ageing thermal plants in both countries close in the coming years and are progressively displaced with intermittent renewables.

In GB, the contribution of interconnectors to the security of supply is currently explicitly recognised through their direct participation in the GB Capacity Market ("GB CM").[17] The GB CM was developed in 2014 as a mechanism to remunerate energy developers for investments that help meet future GB capacity requirements. Successful generators and interconnectors in the GB CM commit to make their capacity available in the GB market during periods of system stress.[18]

Only a portion of the capacity of each resource is remunerated through the CM, to reflect the likelihood that the resource is expected to be able to contribute to mitigating the system stress event (this is known as 'de-rating').

We have estimated a de-rating factor of 70% for the NeuConnect interconnector, based on a recent report[19] by the National Grid Electricity System Operator ("NG ESO").[20] This makes NeuConnect a reliable contributor to GB system security.[21]

15 Our power market model does not take into account internal congestion in either GB or Germany. Doing so would likely further increase the benefit of in respect of lower curtailment of German renewable generation.

16 Wind generation in Northern Germany is typically constrained due to transmission congestion between the North and South of Germany. German TSOs estimate around 465 GWh of previously curtailed wind energy could be exported by NeuConnect. See German TSOs, NEP 2030, pg. 586 (link). To approximate this effect in our power market model, we assume that, without NeuConnect, maximum wind generation in Germany is constrained by 1,400MW (the capacity of NeuConnect). This has a relatively limited quantitative effect on our model results, as the volume of additional curtailment assumed is small relative to the total amount of electricity generated in Germany.

17 This is not the case in Germany, where strategic reserve payments are available to out-of-market participants only.

18 At the time of writing, the Agency for the Cooperation of Energy Regulators ("ACER") is consulting on a framework for allowing direct foreign generation participation in European CMs. Under this framework, interconnectors such as NeuConnect would no longer be able to bid into CMs directly, but would instead sell CM 'access tickets', which would give foreign generators in Germany the right to make use of NeuConnect to participate in the GB CM. However, the recent EU-UK Trade and Cooperation Agreement suggests this framework will not apply to the GB CM. See EU-UK Trade and Cooperation Agreement, Article ENER.6 (link). It is likely the current adjustment to interconnector capacity based on a measure of the interconnector's contribution to a given country's security of supply (the de-rating factor) will remain in place.

19 National Grid ESO (2020), 2020 Interconnector De-Rating Analysis (link).

20 NG ESO calculated a de-rating factor of 83% for Germany, which represents the proportion of the time during which generation capacity in Germany is estimated to be able to contribute to GB system security. However, this estimate does not take into account the technical availability of the interconnector, so the interconnector-specific de-rating factors in the NG ESO report have been adjusted downwards relative to the country-level de-rating factor. NG ESO did not explicitly estimate the impact of the technical availability of NeuConnect, but for other GB interconnectors, these downward adjustments to de-rating factors for technical availability were typically in the range of 3 to 20 percentage points, at an average of 13 percentage points (when compared to the average of country-level de-rating factors taken over the scenarios tested by NG ESO). Applying this average downward adjustment (of minus 13 percentage points) to the German country-level de-rating factor of 83% gives a de-rating factor of 70% for NeuConnect.

21 A de-rating factor of 70% would be comparable to that of other French interconnectors (between 69% to 75%) and is higher than Belgian (68%) and Danish (52%) interconnectors. See National Grid ESO (2020), 2020 Interconnector De-Rating Analysis (link).

Additionally, with both GB and Germany progressing towards Net Zero by 2050, a higher penetration of renewables is likely to increase the pressure on the electricity grid by, for example, causing larger or more frequent disturbances to frequency, or by reducing inertia. This is likely to increase the need for SOs to procure ancillary services to ensure that the system operates in a stable and secure manner. Interconnectors can play an important role in this kind of system balancing by providing a range of services to the SOs, such as frequency response, black start or reactive power. By expanding the potential options open to the SO and therefore increasing competition in the provision of these services this in turn, is likely to exert downward pressure on the overall cost the SOs pay for ancillary services necessary to maintain system stability and security which are ultimately borne by electricity consumers.

Indeed, Ofgem recognises that HVDC interconnectors equipped with voltage source converters ("VSC") such as NeuConnect, are *"capable of facilitating the delivery of ancillary services"*. Specifically, Ofgem expects NeuConnect (along with other VSC equipped interconnectors assessed by Ofgem) will *"potentially generate considerable consumer benefit from the provision of Frequency Response services"*.[22]

22 Ofgem (2017), Cap and floor regime: Initial Project Assessment of the GridLink, NeuConnect and NorthConnect Interconnectors (link).

Appendix: Summary of modelling methodology and assumptions

NeuConnect contributes to European decarbonisation objectives by enabling electricity to be transported between GB and Germany and thus to optimise the use of resources over a larger geographical footprint.

This appendix presents the key assumptions behind the modelling results presented in this report.

Modelling tool and overall approach

To estimate the impact of NeuConnect, we have used FTI-CL's in-house European power market dispatch model, which runs on the commercial modelling platform Plexos® using data and assumptions constructed by FTI-CL Energy.

The model covers the bulk of the European power market and evaluated the supply potential in each price zone based on individual plants and their characteristics. The analysis also takes into account cross-border transmission (interconnectors) and unit-commitment plant constraints.

In this analysis, we have modelled five spot years (every five years from 2030 to 2050), to estimate the impact of NeuConnect on the European power market.

Key assumptions

There are five key sets of assumptions underpinning our modelling in the Policy Scenario: NeuConnect's physical characteristics, commodity prices, demand levels, renewable and nuclear generation capacity and the development of other interconnectors. Each is considered below in turn.

1. NeuConnect's physical characteristics

The technical characteristics of NeuConnect we have assumed are that the NeuConnect interconnector will be commissioned in 2026 as a HVDC cable, have a capacity of 1,400MW, and have a technical loss factor of 3.9%.

2. Commodity prices

Gas prices, having recovered from a short downturn due to Covid-19, are assumed to rebound in the short-term. In the longer-term, prices converge to World Energy Outlook's New Policies Scenario, and reaches around €25/MWh by 2050.

CO_2 prices are assumed to steadily increase over the modelling horizon as a result of overlapping European and national policies to decarbonise their economies, with EU ETS prices reaching €47/tCO_2 in 2030 and €150/tCO_2 by 2050. The GB Carbon Price Floor is assumed to be removed in 2031, as the EU carbon prices catch up to the level of the GB prices.

3. Demand levels

Annual demand is assumed to continue growing significantly over time, with the electrification of transport, heat and industry, driven by European decarbonisation objectives.

4. Renewable and nuclear generation capacity

In GB, we assume significant growth in renewable capacity:

- Offshore wind capacity is assumed to grow from 30GW in 2030 to 75GW by 2050.
- Onshore wind capacity is assumed to grow from 20GW in 2030 to 25GW by 2050.
- Solar capacity is assumed to grow from 23GW to 52GW by 2050.

We also assume the commissioning of new-build nuclear plants in GB are significantly delayed from their scheduled start dates, due to the historical delays and difficulties with constructing new nuclear plants. We assume GB nuclear capacity will be around 4GW in 2030, falling to 3GW in 2035 as older plants (such as Torness and Heysham 2) are decommissioned, then rising to 10GW by 2050.

In **Germany**, we likewise assume significant growth in renewable capacity:

- Offshore wind capacity is assumed to grow from 20GW in 2030 to 63GW by 2050.
- Onshore wind capacity is assumed to grow from 67GW in 2030 to 140GW by 2050.
- Solar capacity is assumed to grow from 90GW to 168GW by 2050.

The German government has committed (and agreed with industry) to decommission all nuclear power plants by 2022, following the disaster at the Japanese Fukushima nuclear power plant in 2011. At present the licences of all nuclear power plants still operational expire in or before 2022. Our assumptions reflect this and feature no Germany nuclear capacity throughout the modelling period.

5. Other interconnectors

The development of additional interconnection capacity in Europe throughout the modelling period is likely to interact closely with the contribution of NeuConnect to European Net Zero objectives. In our modelling, we have developed assumptions for the GB and German cross-border capacity based on information published by developers and by relevant authorities (e.g. transmission operators). The assumptions have also been informed by our and NeuConnect's understanding of the challenges faced by specific links in progressing their development.

GB cross-border capacity:

In GB, the total volume of cross-border transmission capacity is assumed to grow more than three-fold from 5GW in 2020 to 13GW in 2030 and 16GW in 2050. The majority of this capacity (around 10GW by 2050) is connecting GB to continental Europe (France, Belgium, Netherlands and Netherlands), but 4GW is assumed to connect to Norway and Ireland by 2050.

German cross-border capacity:

In Germany, the total volume of cross-border transmission capacity is assumed to almost double between 2020 and 2050.

We assume German import capacity will grow from around 21GW in 2020 to around 37GW by 2030 and 39GW by 2050. We also assume German export capacity will almost double from around 22GW in 2020 to around 40GW by 2030 and 43GW by 2050.

The majority of these connections will be towards Austria, France, Netherlands, Denmark and Switzerland, at around 5-8GW each (both import and export capacity), with smaller volumes towards Belgium, Poland, Sweden, Czech Republic and Norway, at around 1-3 GW each.

6. UK Political Ambition Scenario

NeuConnect's physical characteristics under the UK Political Ambition Scenario are assumed to be identical to those under the Policy Scenario. Similarly to the Policy Scenario, the key sets of assumptions underpinning our UK Political Ambition Scenario are: commodity prices, demand levels, renewable and nuclear generation capacity and the development of other interconnectors. Each is described below in turn.

Commodity prices under the UK Political Ambition Scenario are assumed to be equivalent to those of the Policy Scenario.

The Ten Point Plan targets a total of 5GW of industrial hydrogen production by 2030, which is reflected as a source of electricity demand in our modelling. The Ten Point Plan also commits to banning the sale of new non-electric cars and vans by 2030. Together, these result in a small increase in electricity demand in the UK Political Ambition Scenario relative to the Policy Scenario in all modelled years.

The Ten Point Plan targets 40GW of offshore wind in 2030, compared to the 30GW we assumed under the Policy Scenario. We also assume, under the UK Political Ambition Scenario, that GB offshore wind capacity grows to 93GW in 2050, compared to 87GW under the Policy Scenario.

The Ten Point Plan targets the mid-2020s for the commissioning of the Hinkley Point C nuclear power plant. Our Policy Scenario assumes the commissioning of Hinkley Point C would be delayed to the late 2030s, reflecting the historical delays and construction difficulties. The Ten Point Plan also points to the development of Small Modular Reactors ("SMRs"), but does not state whether the SMRs would be developed in addition to – or in lieu of – large-scale nuclear capacity. In our modelling we assume planned future GB nuclear plants (such as Sizewell C and Bradwell B) would be replaced by SMRs of equivalent total capacity.

Finally, we assume the development of cross-border capacity under the UK Political Ambition Scenario is equivalent to that under the Policy Scenario.

Carbon Impact Assessment – third party estimates

As discussed in the main report, the role of interconnectors in facilitating the displacement of thermal generation, and thereby contributing to a reduction in carbon emissions, is well understood. As such, other European authorities have recently estimated the impact of interconnectors on carbon emissions.

As part of its TYNDP 2020 assessment, the ENTSO-E examined the carbon impact NeuConnect (and other individual interconnectors) specifically. By contrast, the UK Government's Department for Business, Energy and Industrial Strategy ("BEIS") and its advisors have estimated the carbon impact of increasing total GB interconnection capacity with mainland Europe. In the remainder of this appendix, we compare the methodologies used by ENTSO-E and BEIS' advisors to estimate the carbon impact of interconnectors, with that used by FTI-CL in this report.

ENTSO-E (TYNDP 2020)

There are two key differences between the methodology used in ENTSO-E's carbon assessment and that used by FTI-CL in this report.

First, ENTSO-E's carbon assessment of NeuConnect is made up of two components: (i) market studies; and (ii) network studies. Market studies involve forecasting the cost optimal dispatch of generation, conditional on supply being sufficient to meet demand in each modelled timestep. This is analogous to the approach we have taken in this report. Network studies use the results of market studies as an input, and produce a representation of flows through the transmission network, given market conditions and generation output.[23] Based on these studies, ENTSO-E's estimates include variations in CO_2 emissions due to network losses. By contrast, our modelling for this report did not perform any network studies.

Second, the input assumptions underlying ENTSO-E's market studies also differ to those we have used in this report. ENTSO-E's central National Trends Scenario reflects the National Energy and Climate Plans ("NECPs") of EU Member States. Under ENTSO-E's National Trends Scenario, European Net Zero objectives are not achieved by 2050, and represents a less ambitious decarbonisation agenda than that underlying the assumptions used in this assessment.

BEIS (Energy White Paper)

Advisors to BEIS in support of the Energy White Paper have published a standalone report on the impact of GB interconnectors on decarbonisation. In contrast to FTI-CL's and NeuConnect's approach, BEIS have estimated the carbon impact of increasing total GB interconnection capacity to mainland Europe, rather than focusing on the effect of individual interconnectors.

BEIS' advisors considered using the average carbon intensity of electricity generation from the importing country, multiplied by the volume of imported electricity, to measure the volume of emissions imported via an interconnector. However, they dismissed this approach, noting the imported electricity may not necessarily be produced by low carbon generators in the exporting country – it could be the case that higher emission thermal plants instead respond to the increased demand for export. An alternative approach that focused on the marginal plant in the merit order was also considered. However, this was considered to be too focused on the carbon intensity of inputs on specific interconnectors and could not be generalised to estimate the effect of interconnectors throughout the entire European region.[24]

BEIS' advisors ultimately decided to focus on the incremental change in emissions in GB and the rest of Europe due to changes in total interconnection capacity, assuming the supply of generation is sufficient to meet electricity demand in all European price zones (including GB).[25] This is analogous to the approach taken by FTI-CL in this report, and to the 'market studies' approach used by ENTSO-E. However, one key difference is both FTI-CL's and ENTSO-E's market study approach compared total GB and European emissions with and without the NeuConnect specifically. BEIS' advisors compared total GB and European emissions with and without a number of different interconnectors (including the Netherlands, Germany, France, Denmark, and others), and thus does not identify the carbon impact of the NeuConnect interconnector specifically.

23 This allows ENTSO-E to estimate constraints in the electricity network, and therefore forecast the additional generation required to offset the effects of those constraints.

24 Aurora (2020) The impact of interconnectors on decarbonisation (link).

25 Aurora (2020) The impact of interconnectors on decarbonisation (link).

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