Electricity markets in the UK, Ireland and continental Europe are physically linked by ‘interconnector’ cables. These benefit energy system operators and consumers by reducing prices. They can also help integrate renewable electricity and ensure security of supply. This note discusses these benefits, proposals for future increases in interconnection and the potential effects of Brexit.

Box 1. Electricity Markets in the UK, Ireland and Europe

**GB and Northern Ireland**
The transmission system in the UK is operated as two distinct networks and markets. The GB network and market covers England, Scotland and Wales, and National Grid is the GB system operator (SO). The Northern Ireland (NI) and Republic of Ireland (RoI) networks have operated as the Single Electricity Market (SEM) since 2007. This will become the ‘Integrated SEM’ (I-SEM) in 2018.

**The EU Internal Energy Market (IEM)**
The UK is currently a member of the EU-wide Internal Energy Market (IEM) for gas and electricity, which has been developed via a number of EU legislative packages since 1996. It promotes energy market competition, security of supply and consumer cost reduction by encouraging integration (via interconnection) across the individual markets of all EU member states (MS), and some non-MS.

**Overview**
- The UK currently imports around 6% of its electricity from northwest Europe. Imports are expected to increase significantly. Interconnector capacity will double by the early 2020s, and may double again by 2030.
- Access to cheaper electricity from abroad has reduced the price of UK electricity to date. Interconnection causes prices in connected markets to converge.
- Interconnectors reduce the need to curtail intermittent generation, reducing the cost of renewables to the electricity system.
- Imports can improve energy security by providing access to a wider market.
- EU regulations and bodies currently govern trade across interconnectors. If the UK leaves the EU Internal Energy Market, trade may become less efficient and more costly.

As the UK is a member of the EU Internal Energy Market (IEM) (Box 1), interconnectors are currently regulated in accordance with EU law. It is possible that the UK could leave the IEM as part of the EU withdrawal process. Doing so is likely to make electricity trading less efficient, increasing operator and consumer costs.

**Current and Future Interconnection Capacity**
The GB electricity system is currently connected with northwest Europe via 3 gigawatts (GW) of interconnector capacity (approximately equivalent to the power output of three large gas power plants): 2GW with France and 1GW with the Netherlands. There is 1GW between the GB and SEM markets. An additional 4.4GW of capacity is under construction (linking GB with Norway, France, and Belgium), due for completion by 2022. A further 9.5GW of projects have sought regulatory approval. The UK Government demand, and this is expected to increase in future as a number of interconnector projects are under development.

Trade also occurs between GB and the Irish Single Electricity Market (SEM) (Box 1) via interconnectors. Government and industry experts agree that increasing levels of interconnection across the UK can benefit consumers, markets and systems in the UK and EU.

The US Government have sought regulatory approval for new interconnector projects.
Box 2. Balancing the Grid Across Different Timescale
Electricity supply and demand needs to be balanced every second. Slight mismatches cause the network’s frequency (a physical property of the electrical flow) to fluctuate around its target value of 50 Hertz (Hz). The SO must keep these variations within tight limits to avoid damage to the network. There are a number of mechanisms for ensuring balanced supply and demand:

- In the wholesale market, electricity generators and interconnector users sell power to retail suppliers. Using forecasts of demand and supply, power is sold from between an hour and a day ahead of delivery (in the ‘intra-day’ market), to between 24 and 48 hours (‘day-ahead’ market) and between a day and one or more years (‘forward’ market).
- The Balancing Mechanism is the tool that the SO uses to make up for mismatches in the wholesale market up to an hour before power is delivered. Among other ancillary services, the SO relies on ‘frequency response’ services, where relevant technologies quickly adjust their power output to manage short-term frequency changes. Relevant technologies include interconnectors and battery electricity storage, among others. A trial frequency response service has been trialled on the GB-Netherlands interconnector.
- The Capacity Market pays generators and interconnectors to be available in the event of an unexpected shortage of supply at four hours’ notice. Auctions take place annually for capacity potentially needed four years ahead of time. In the 2016 auction for capacity in 2020-21, interconnectors accounted for 4.5% of successful bids.

A second interconnector obtained planning approval in 2018. There are no interconnectors between the SEM and other EU Member States (MS), though a France-Roi interconnector has been proposed, and feasibility studies are underway.

Trading Electricity Using Interconnectors
The difference in electricity prices between interconnected wholesale markets (Box 2) determines the direction and quantity of trade. Electricity normally flows from the market with lower prices to the market with higher prices. Interconnector operators earn revenue from ‘arbitrage’, or buying and selling across this price difference. They may also earn supplementary revenue from Capacity Market payments and contracts for ancillary services (Box 2).

The price of wholesale electricity is usually higher in GB than in north-west Europe, hence GB usually imports from France and the Netherlands. Exports and imports between GB and the SEM are more even. Price differences between wholesale markets occur because of differences in:
- Electricity generation mix. A market’s dominant form of generation will affect its average price over the long term, as generation technologies have different operation, maintenance and fuel costs. For example, the substantial nuclear capacity in France has a lower running cost than the UK’s dominant gas capacity.
- Weather patterns. High levels of wind power can lead to rapid changes in power output as weather systems move and develop. This can cause short-term price differences across geographically disperse markets.
- Energy and climate policies. Generators must pay for each tonne of carbon dioxide (CO₂) they emit. This is known as a ‘carbon price’, and it increases the average wholesale price in most markets. As a result of government policy, the GB carbon price is significantly higher than in the rest of the EU. This has been a key factor in recent price differences.
- Other policies. GB generators pay ‘balancing and transmission charges’ to the SO to cover the costs of operating the network. Generators in some European countries do not pay these to their respective SOs.
- Different demand patterns. Periods of high electricity demand increase prices, and low demand decreases prices. Demand usually follows a similar pattern over consecutive days within a country. However, time differences and different working patterns can cause peaks in demand, and hence prices, to occur at different times across countries.
- Exchange rates. Fluctuations in currency values affect the price of traded electricity. The 2016 drop in Sterling relative to the Euro increased the price of imported electricity in the GB market.

As a result of these, cost-benefit analyses of future interconnector projects are sensitive to assumptions about how these factors will develop in future. UK generators have expressed concern that certain policies and market incentives disadvantage domestic generation compared to that abroad.

Effects of Interconnection
New interconnector cables can accommodate changes in the amount of power flowing across them at very short timescales. This provides interconnected markets with a ‘flexible’ source of electricity, which can help ensure security of electricity supply cost-effectively, while reducing CO₂ emissions. Some proposed interconnector projects are more likely to provide these benefits than others.

Converging Wholesale Electricity Prices
Interconnection can be a cost-efficient method of providing electricity, as it can offset the need to build generating capacity and provides access to different sources of electricity from abroad. The link between wholesale markets causes prices in each to converge: they reduce in the importing market and increase in the exporting market. To date, GB has been a net importer, which has reduced prices. Because wholesale costs comprise a significant portion of consumer electricity bills (approximately a third in 2016), interconnection has reduced costs for consumers.

Stakeholders widely agree that some additional interconnection would further decrease prices, because of the prevailing higher GB wholesale price.
2014, National Grid estimated that each 1GW of new interconnection capacity to continental Europe could reduce GB wholesale prices by 1-2%. However, there are limits to achievable savings, as price reductions diminish with each additional interconnector to the same market. If prices converge sufficiently (through increased interconnection or other factors), GB may export more frequently, increasing prices for British consumers.

**Security of Electricity Supply**

Interconnection can contribute to security of electricity across a range of timescales. Imports that are driven by long-term average price differences (such as differences in carbon prices) can help to meet total annual electricity demand. Interconnectors can also address risks to security of supply across shorter timescales (such as from changes in wind output). National Grid’s 2017 *Future Energy Scenarios* project that interconnection will be increasingly important for grid balancing as future demand is supplied by more intermittent renewables.

**Meeting Overall Electricity Demand**

Increased access to sources of electricity generation from abroad could help meet future annual electricity demand. The Department of Business, Energy and Industrial Strategy (BEIS) projected in January 2018 that imports could become the UK’s second largest source of electricity (around a fifth of supply) by 2025. Increased imports would help to offset closures of UK nuclear plants due for retirement, and the Government’s planned phase-out of coal power by 2025.

**Managing Variability in Electricity Demand**

Interconnectors’ flexibility makes them useful for balancing short-term supply and demand on the grid (Box 2). If demand suddenly increases, or supply is constrained (for example if a large generator or transmission line fails), power can be quickly imported from abroad. Conversely, if there is an excess of supply (for example on a sunny and windy day, when renewable output is high whilst demand is low), exporting power reduces the need to curtail renewable generation (see Integrating renewable electricity).

However, trade is governed by market processes, and this arrangement can result in power flowing abroad during peaks in GB demand if supply becomes constrained overseas. For example, when a number of French nuclear reactors unexpectedly closed in winter 2016, GB became a net exporter to France for a number of months despite high GB demand. This temporarily increases the GB wholesale price, but helps ensure security of supply across the wider European energy system.

**Integrating Renewable Electricity Generation**

The EU Renewable Energy Directive sets a target for the UK to produce 15% of its energy from renewable sources by 2020. Interconnection can reduce carbon dioxide (CO₂) emissions from electricity systems by making the most efficient use of intermittent renewable electricity.

A wide geographic distribution of interconnected wind power can smooth variations in supply as weather systems develop across countries. Wind power generation in GB and the SEM has increased significantly in recent years, and in future there may be more frequent periods where the supply of renewable generated electricity is greater than demand. Without sufficient electricity storage or interconnection to move the power where it is needed, the excess electricity must be ‘curtailed’, or wasted. Curtailment increases the cost of electricity as the SO must compensate curtailed generators for lost revenue.

Interconnection to markets with significant hydropower reserves, such as Norway, has been highlighted as particularly valuable for integrating wind power in GB. Some hydropower facilities can store excess renewable electricity by pumping water uphill, which can later be released to generate electricity when demand is high.

**Governance of Interconnectors**

Interconnectors between the UK and continental Europe are developed, owned and operated by private companies or national SOs. They are regulated by Ofgem and the relevant national regulatory agency of the connected country. BEIS liaises with foreign governments on interconnector issues.

**Capacity Market Governance**

BEIS sets ‘de-rating factors’ for each interconnector, which determine how much of its capacity can participate in the Capacity Market (Box 2). These are based on forecasts of how much an interconnector can be relied upon during a supply shortage. They take account of the technical reliability of the interconnector cable, market price differences and the typical amount of spare generating capacity in the respective market.

**Investment in Interconnector Projects**

Current interconnectors in GB are ‘merchant operators’, earning the majority of revenue available from arbitrage. The high cost of subsea cables and risk of changes in price differences between markets has in the past deterred investment in new projects. To reduce risk and encourage increased investment, in 2014 Ofgem introduced the option of ‘cap and floor’ regulation for interconnectors (Box 3).

Most GB projects under development will be cap and floor regulated.

**Box 3. The Cap and Floor Regulatory Regime**

Cap and floor interconnector regulation is designed to reduce the risk that interconnector operators will be unable to earn revenue in future, while reducing risk for consumers. The regulation places a ‘floor’ on an operator’s revenue. If the operator’s combined revenue from arbitrage, the Capacity Market and ancillary services is below the floor, National Grid will top them up to this level. This is passed through to consumers via network charges. Conversely, if interconnectors’ revenues exceed the cap, they must return the surplus to National Grid, which passes this back to consumers through reduced network charges.
European Governance

The UK and RoI are members of the IEM (Box 4). The EC has a target for IEM members to have interconnection capacity equal to 10% of their generating capacity by 2020.92 Completing all GB projects currently proposed or under development would meet this target.8

There are a number of EU regulations that manage cross-border electricity networks and provide the legal basis for the IEM and ACER (Box 4).17,18,20 The European Network Codes (ENCs) are EU Regulations that govern technical aspects of energy trading and pricing.21 ENC facilitate efficient trading, including management of ‘market coupling’ mechanisms (Box 5). Along with the European Commission, ACER and ENTSO-E are the EU bodies responsible for drafting and implementing ENC for electricity.

Potential Effects of Leaving the EU

Although the effects of Brexit on electricity trade are highly dependent on future UK-EU energy relationships, it is widely agreed that trade is likely to continue post-Brexit.5,22,24,47,83 If the UK is no longer part of the IEM, it will continue to be able to access it.84 However, if the GB market becomes less integrated with the IEM, trade could become less efficient and more costly because of changes to market coupling arrangements (Box 5) and regulatory divergence. Interconnectors may also lose access to some EU project development funds which have benefited previous projects. A majority of contributors to a 2017 EU Energy & Environment Sub-Committee inquiry across the energy sector advocated retaining the UK’s IEM membership.85

Future Investment in Interconnector Projects

Stakeholders agree that the investment case for new interconnectors will remain while there is a clear price difference between UK and European wholesale markets. However, in the short term uncertainty around the future regulation of interconnectors increases investment risk and the cost of finance.83,88 Leaving the IEM would cause UK projects to lose access to EU ‘Connecting Europe Facility’ (CEF) funding.88 The CEF provides selected European infrastructure projects with early funding, though this amount tends to be small compared to total project costs. The CEF has allocated €73m to seven UK interconnector projects since 2013.47,93,95 Some of this funding has yet to be provided, though the UK Government has guaranteed most CEF funding until the EU withdrawal date.91

Operation of Interconnectors

The extent of Brexit’s effect on electricity trade depends upon the extent to which the UK continues to participate in the IEM. Retaining full membership would be unlikely to adversely affect trade.5,88 The UK would need to conform to, and automatically adopt in future, relevant EU regulations and standards such as energy and environmental legislation, state aid and competition rules.88 This arrangement is in place with EEA members such as Norway.5 In such circumstances, National Grid would retain membership of ENTSO-E and Ofgem might remain in ACER (possibly as a non-voting observer).81 However, both would lose influence in shaping ENC.

If the UK leaves the IEM with no replacement arrangements it is unlikely that tariffs would be applied to electricity trade as there are no tariffs on electricity under WTO rules.92,93 However, GB interconnectors could be excluded from current and future market coupling mechanisms.5,85,94 This would make day-ahead markets less efficient and more costly. They may also be excluded from cross-border balancing mechanisms (Box 2)93,94 Research commissioned by National Grid in 2016 suggested that the combined effects of the above could cost the GB system £260m annually.94 Operators face greater complexity if regulations diverge, leading to increased operational costs.11 Ofgem would cease to be a member of ACER.5,88,95

Endnotes

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