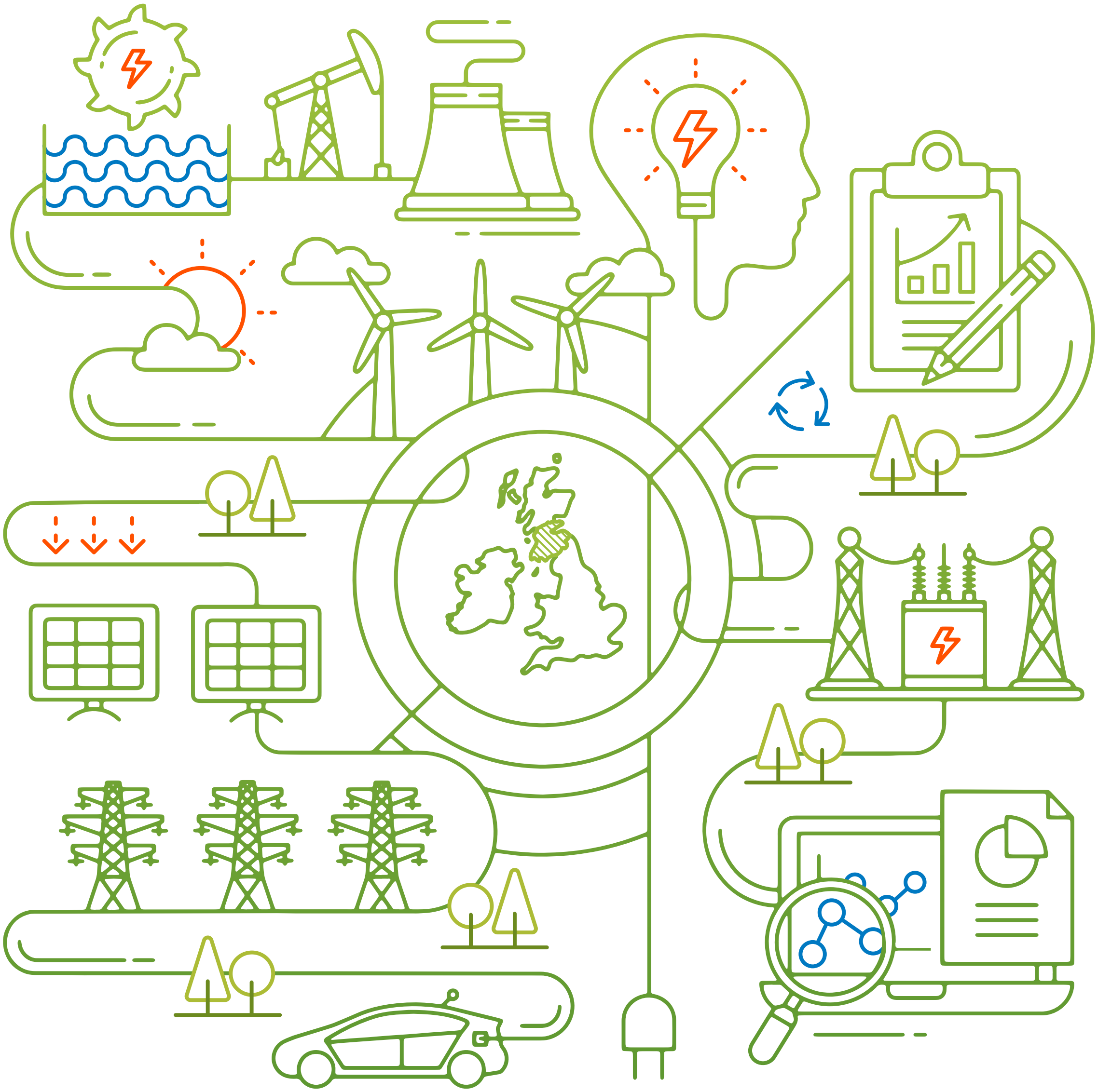
SP Transmission
Historical Energy Trends



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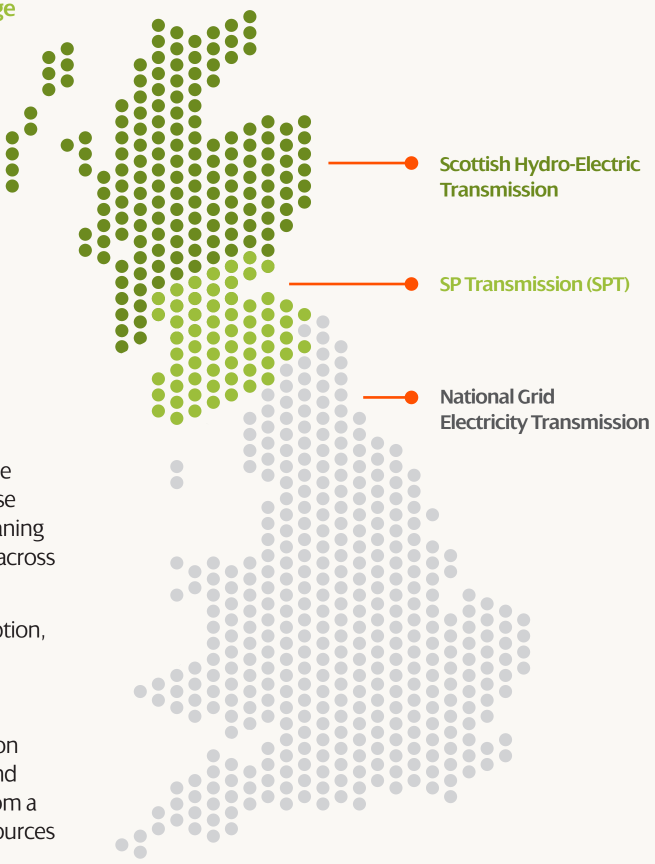
Introduction

Since 2010, there has been a significant change in the usage of energy across the United Kingdom, and this is anticipated to continue. Government targets surrounding the reduction of emissions is one of the biggest catalysts for these changes.

The EU's Renewable Energy Directive (RED), set in 2009, meant the UK government set a sustainability target of 15% for the UK's energy consumption to come from renewables by 2020. Similarly, the Scottish Government created a target of renewable sources to generate the equivalent of 100 per cent of Scotland's gross annual electricity consumption by 2020.

It could be said that such targets have shifted the way energy is generated and how consumers use their energy in order to meet these targets, meaning new energy consumption trends are emerging across the current decade.

This report examines trends in energy consumption, focusing on electricity generation and transfers covering the period 2010-2017, drawing out conclusions that may need to be addressed as part of our RIIO-T2 price control. This will focus on SP Transmission's (SPT) license area of central and southern Scotland. The data has been drawn from a number of in-house sources, as well as public sources to better inform the analysis.



2 Glossary

Transmission Network – Is the network utilised for the bulk transfer of electrical energy across large distances. As well as large customers this also supplies energy to the Distribution network via Grid Supply Points.

Distribution Network – Is the network utilised for the delivery of electrical energy to end users.

Scottish Power Transmission (SPT) – The Transmission Network Owner for central and southern Scotland, own the transmission network at 132kV, 275kV and 400kV

Scottish Power Distribution (SPD) – The Distribution Network Owner for central and southern Scotland, own the distribution network at 33kV, 11kV and LV into the home.

Grid Supply Point (GSP) – the point at which the Transmission System is connected to the Distribution System.

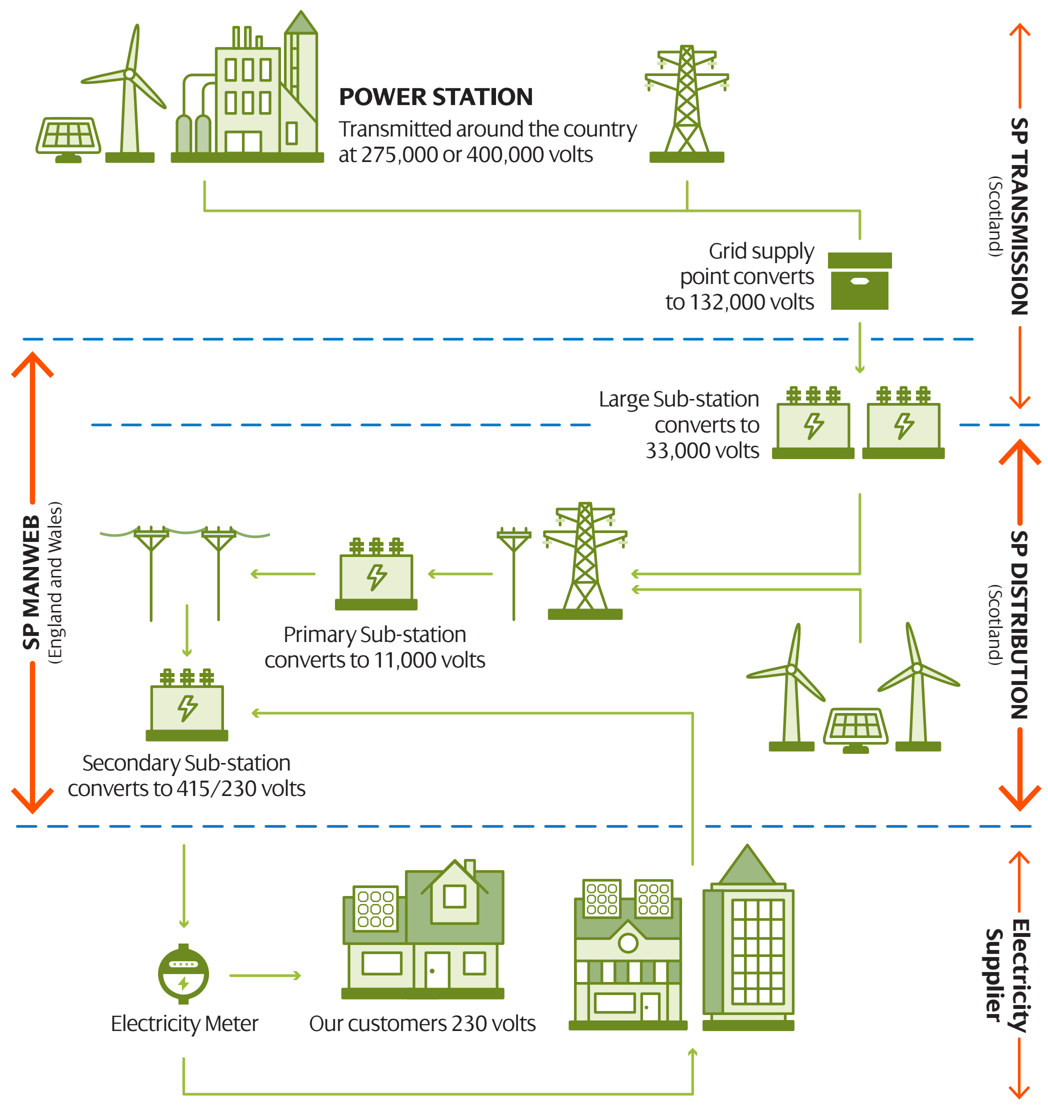
Distributed Generation/Embedded Generation – generation connected to the Distribution Network as opposed to the Transmission Networks. In this document this covers all generation connected at Distribution regardless of size.

FiT – Feed-in Tariff is the Government scheme design to encourage the update of small scale renewable low carbon technology.

Micro Generation – Small scale generation utilised most often at domestic level e.g. rooftop solar PV.

kW/kWh – kiloWatt is the unit of power required to operate a certain demand, kiloWatt hour is the energy supplied in an hour to that demand e.g. tumble drier requires 2.4kW to operate, if this runs for 1 hour it has consumed 2.4kWhs.

Real Power/Reactive Power – Real power is that which is used to undertake useful work from the electricity network. Reactive power is required for the network to function but cannot be utilised in the same way as Real power.



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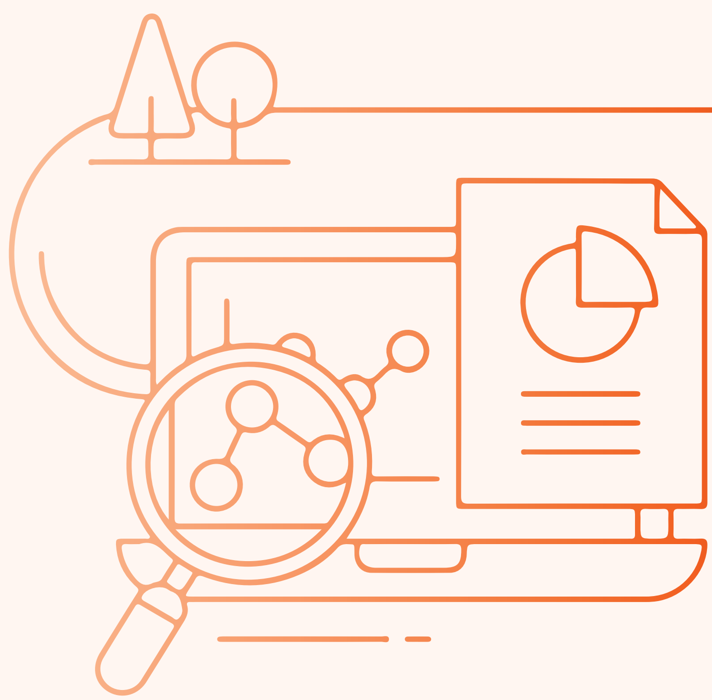
Key Findings from the period 2010-2017



Electricity Generation
-2200 MW
Transmission Connected
-
Closure of coal plants slightly offset by increase in wind generation

Electricity Generation
+1400 MW
Distribution Connected
-
Exponential increase in embedded wind generation

Electricity Generation
70%
of GSPs with Embedded Generation
-
Potentially exporting to the Transmission network

Electricity Generation
30%
of total generation connected to Distribution
-
3x greater than in 2010

Electricity Transmission
>260 days
Importing from SHETL each year
-
Hydro & wind generation in the north meeting demand in the south

Electricity Transmission
>331 days
Exporting to NGET each year
-
Generation in Scotland exceeds Scottish demand

Electricity Consumption
-6.4%
Typical Domestic Demand
-
Energy efficient technologies installed within homes

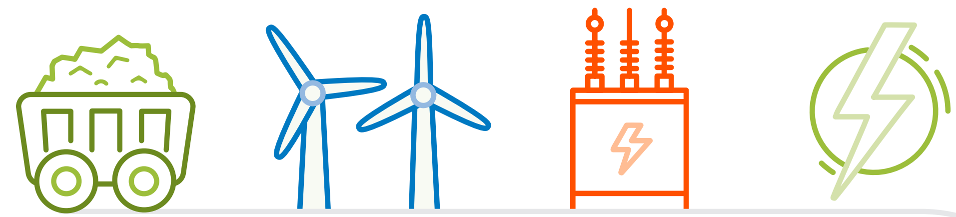
Electricity Consumption
-16.6%
Typical Industrial/ Commercial Demand
-
Improved processes on-site generation and changing customer demographic

Electricity Consumption
2.13m
Customers connected through through SPD
-
0.79% increase since 2010

Electricity Vehicles
>5000 EVs
in Central & Southern Scotland
-
This is 73% of the total number of EVs in Scotland

4
Electricity Generation

Electricity is generated in a number of different ways. Fossil fuels, renewables, nuclear and interconnection with mainland Europe all provide sources of power, but this isn't always in the location that it is required which is the role of the transmission network to get it to the demand. In order to ensure a reliable supply across the country, the transmission network plays a vital role in moving power around and to facilitate the energy market.



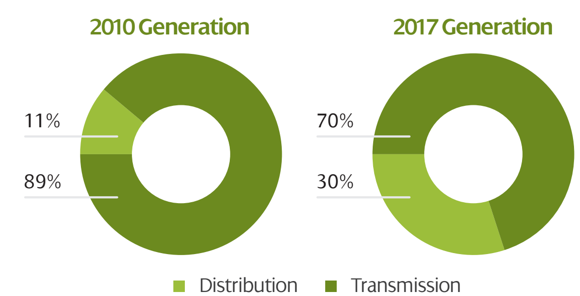
Electricity Generation	Electricity Generation	Electricity Generation	Electricity Generation
-2200 MW	+1400 MW	70%	30%
Transmission Connected	Distribution Connected	of GSPs with Embedded Generation	of total generation connected to Distribution
Closure of coal plants slightly offset by increase in wind generation	Exponential increase in embedded wind generation	Potentially exporting to the Transmission network	3x greater than in 2010

4.1 **Total** Connected

As of 2017, there is approximately 7,500 MW of connected generation in central and southern Scotland most of this is connected to the SP Transmission network. There is approximately twice as much generation in our network area as there is demand from customers. With such a large volume of renewable generation on the network, high amounts of generation are important to allow for times when the wind doesn't blow or there is less such to power renewables.

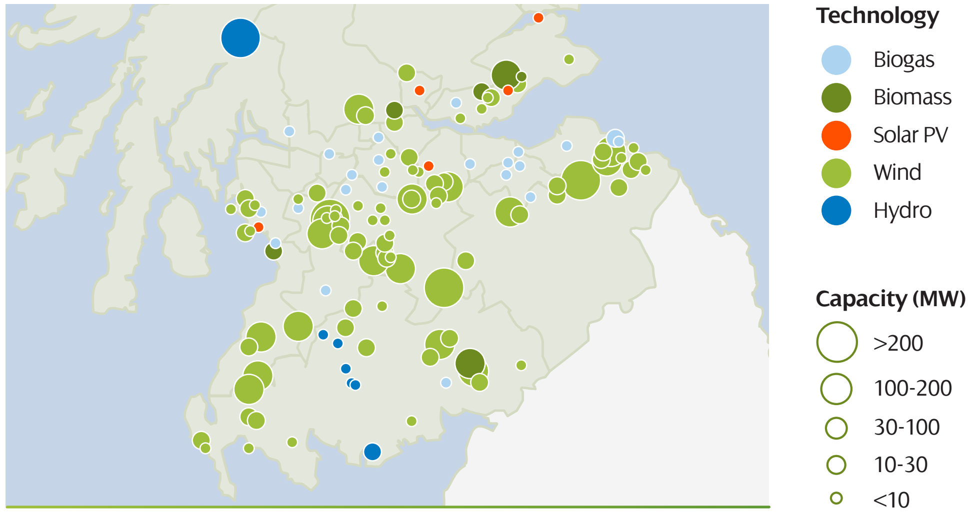
There has been a ~500MW reduction in connected generation sincesince 2010 due to the decommissioning of fossil fuel powered generators. This capacity has been replaced with onshore small scale wind generation connecting into our Distribution network. This has resulted in a 20% increase in generation connected to the Distribution network.

Figure 1 | Generation split



Overall, there is 5,000 MW of renewable generation connected within the SPT licence area. This is 13 % of the total UK renewable capacity [1]. If all of this generation operated at the same time this would be enough to power the 2.43 million [2] households in Scotland with capacity to export to the rest of the UK. The location of this generation is shown in Figure 2 (next page).

Figure 2 | Geographic location of renewable generation connected to the SP Transmission network



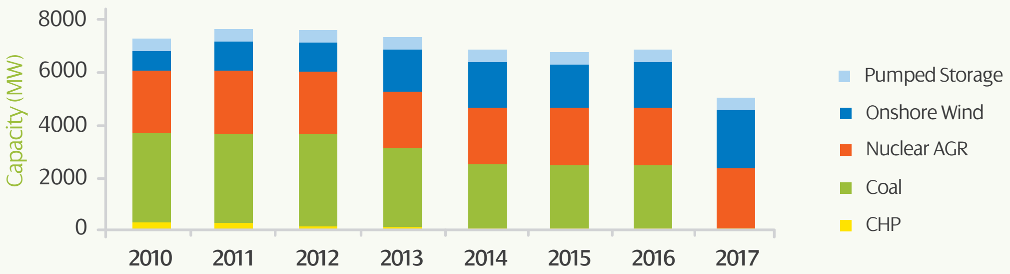
4.2 **Transmission** Connected

The generation portfolio in central and southern Scotland has undergone a number of significant changes in the past 7 years, notably; the closure of the coal power stations, Cockenzie and Longannet in 2013 and 2016 respectively. The timeline below shows the capacity amount of energy being connected and removed from the network in the past 7 years.

2010	7,100MW of generation was connected to the transmission network.
2013	Cockenzie power plant closes, removing 1,200 MW of generation.
2016	Longannet power station closes, removing 2,400 MW of generation.
2010 - 2017	3,600 MW loss offset by 1,400 MW increase in onshore wind.
Now	4,900MW connected.

That is a **31% reduction since the beginning of 2010**. Figure 3 shows how the generation mix has altered.

Figure 3 | Transmission Connected Generation 2010 - 2017

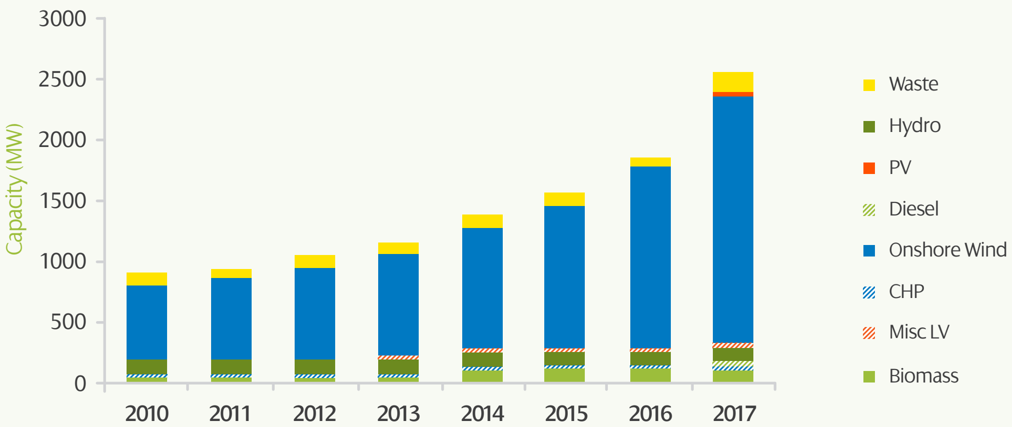


4.3 **Distribution** Connected

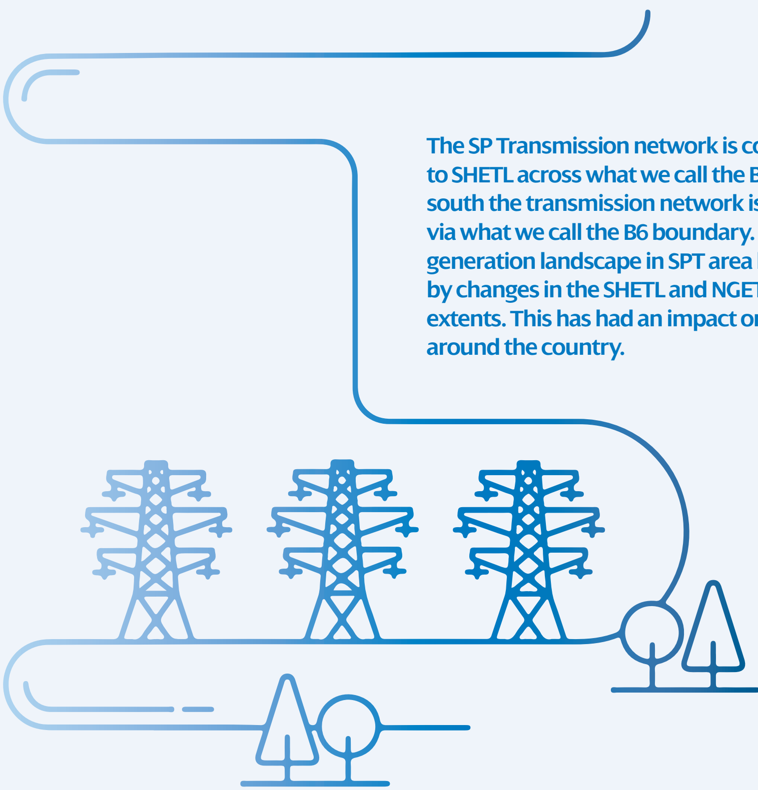
The generation capacity connected to the distribution network has increased significantly. Overall, embedded generation has increased from 900 MW in 2010 to 2500 MW in 2017. This does not include approximately 200 MW small scale generation behind the meter which is connected to the SPD network.

Between 2010 and 2017, we have seen the same amount of capacity connected that could power 1 million homes in central and southern Scotland. In 2016-17 SPD connected 850 MW of wind generation. In comparison to this, 180MW of new biomass, CHP and PV connected between 2010 and 2017. This is shown in Figure 4, where the exponential growth in wind generation capacity since 2010 is clearly visible.

Figure 4 | Distribution Connected Generation 2010 - 2017 (Small & Large Embedded)

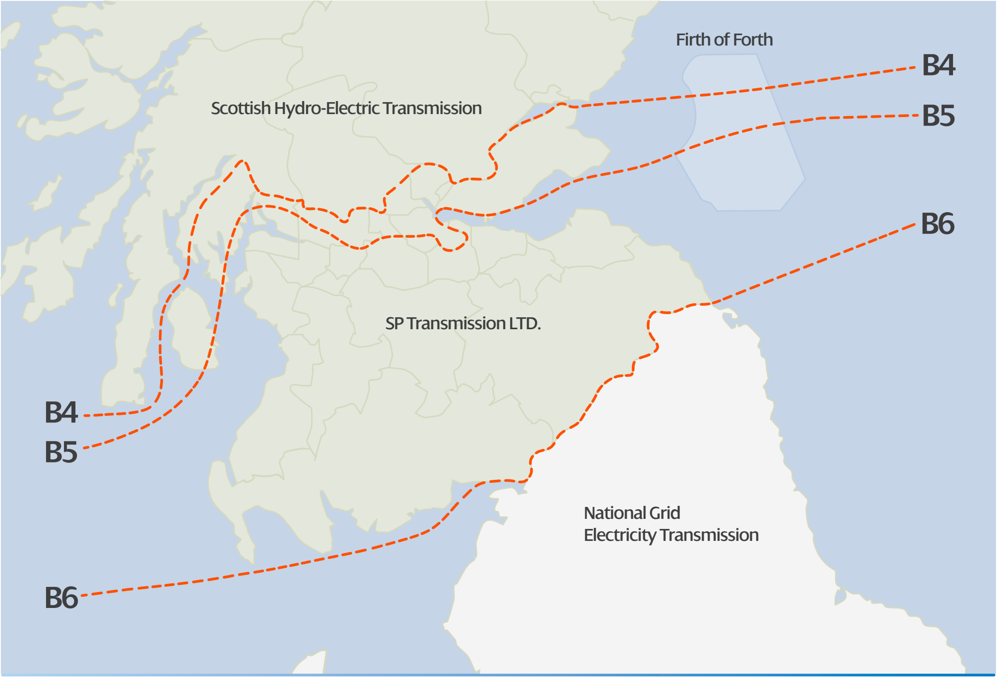


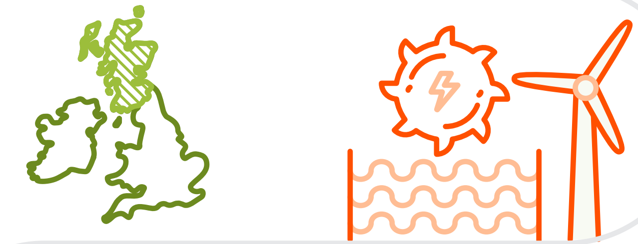
5 Electricity Transmission



The SP Transmission network is connected to the north to SHETL across what we call the B4 boundary. To the south the transmission network is connected to NGET via what we call the B6 boundary. The changes to the generation landscape in SPT area have been matched by changes in the SHETL and NGET areas to different extents. This has had an impact on the flow of power around the country.

Figure 5 | SPT associated boundaries [3]





Electricity Transmission

>331 days

Exporting to NGET each year

Generation in Scotland exceeds Scottish demand

Electricity Transmission

>260 days

Importing from SHETL each year

Hydro & wind generation in the north meeting demand in the south

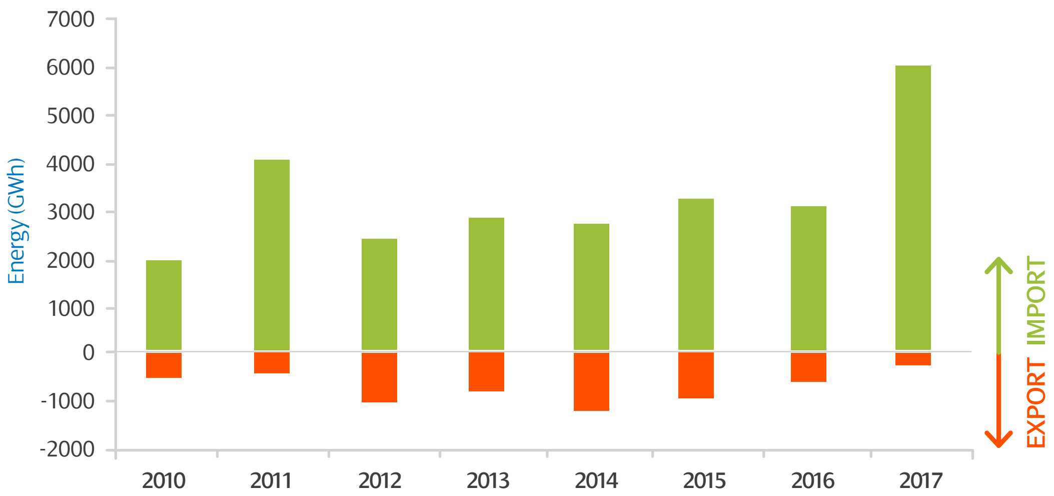
5.1 **B4** Boundary

The B4 boundary separates the section of the transmission network owned by SPT and SHETL. SPT have consistently imported more electricity from SHETL each year than exported. This power flow trend is reflected in the total amount of energy transferred across the boundary each year as shown in Figure 6. As of 2017 we have imported twice as much energy than in 2016 and 2,000GWhs more than the previous peak in 2011, this is equivalent to the energy consumption of 530,000 homes.

The transfer capacity has changed not only as a result of more generation, but also as a result of network upgrades such as Beauley - Denny and Kintyre - Hunterston

Note: in all diagrams below +ve indicates an Import into the SPT network and –ve indicates an Export from the SPT network.

Figure 6 | Energy transferred across the B4 Boundary



5.2 **B6** Boundary

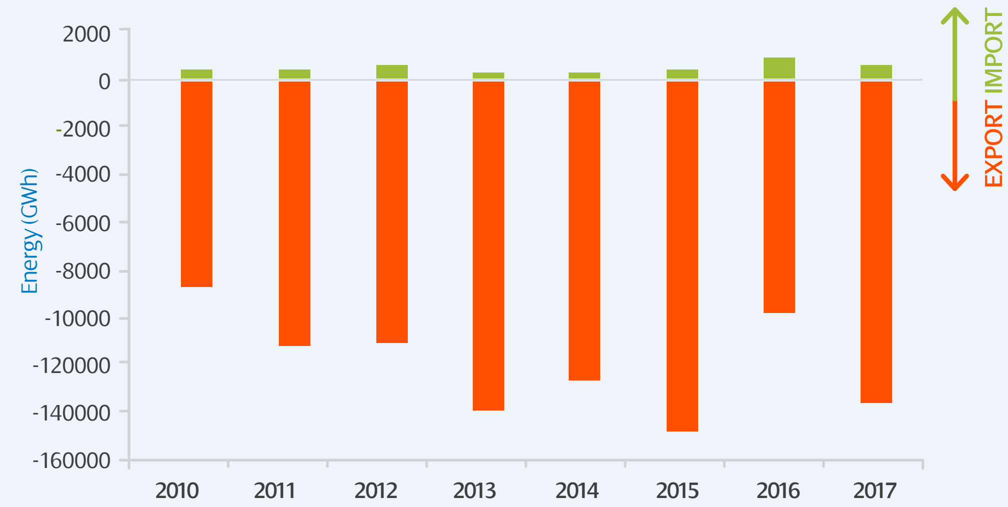
The B6 boundary follows the border between Scotland and England and separates the areas of the transmission network owned by SPT and National Grid Electricity Transmission (NGET). This boundary includes 400 kV and 132 kV lines connected to the Harker, Stella West and Blyth substations in the north of England as shown above in Figure 5. As of 2017, power also crosses this boundary through the HVDC Western Link between Hunterston and Deeside providing export capacity for up to 20% of Scotland's renewable generation capacity.

From 2010 to 2017, SPT exported on average 50 times more energy to the NGET network than was imported, as shown in Figure 7.

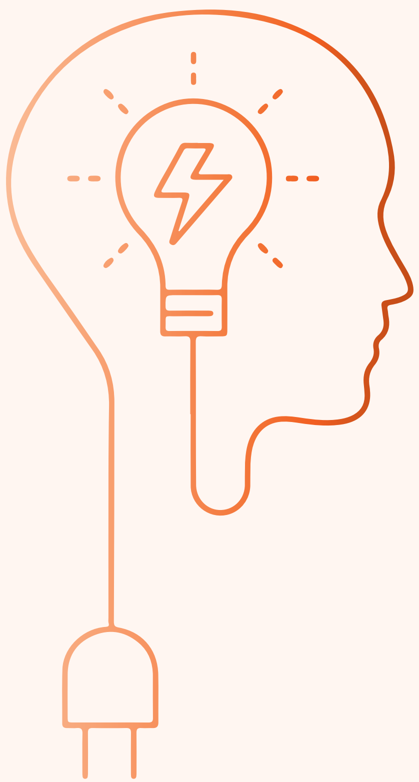
As with B4, some of this change has been facilitated by network upgrades, B6 is currently one of the most congested parts of the network and projects such as western HVDC link will help to alleviate this.

Note: in all diagrams below +ve indicates an Import into the SPT network and –ve indicates an Export from the SPT network.

Figure 7 | Annual Energy Transfer across the B6 Boundary

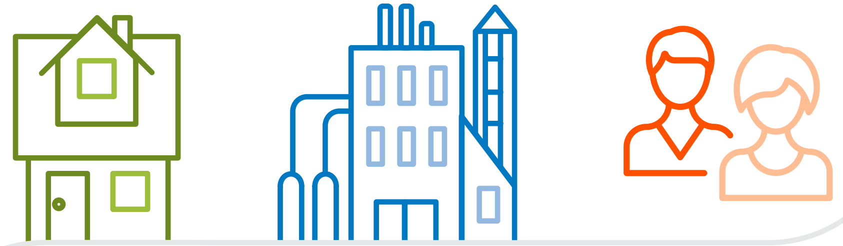


6 Consumer Trends



6.1 Electricity Consumption

A key change required in order to meet government mandated targets on decarbonising our energy mix is changing how we consume electricity. This is only likely to change further as electric vehicles become more prevalent. Our changing consumption trends are highlighted in the following sections.



Electricity Consumption
-6.4%
Typical Domestic Demand
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Energy efficient technologies installed within homes

Electricity Consumption
-16.6%
Typical Industrial/ Commercial Demand
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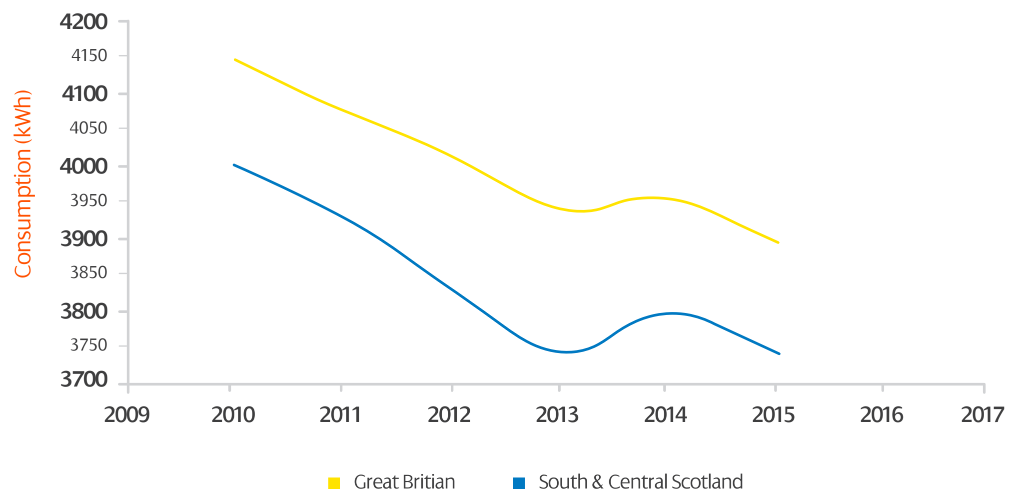
Improved processes on-site generation and changing customer demographic

Electricity Consumption
2.13m
Customers connected through through SPD
-
0.79% increase since 2010

6.2 Domestic

Between 2010 and 2015, the average domestic property in central and southern Scotland used slightly less electricity than the average household in Great Britain as a whole. The average consumption in central and southern Scotland fell 6.4% between 2010 and 2015 from 4000 kWh to 3740 kWh. This is equivalent to on average every household in central and southern Scotland getting rid of an LCD TV.

Figure 8 | Average Residential Electricity Consumption [4]



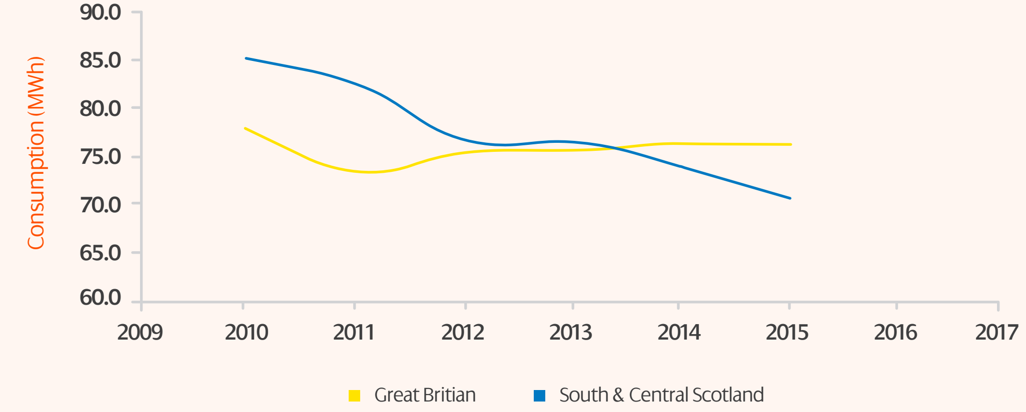
A significant amount of this reduction can be attributed to improved appliance efficiencies and the contribution of small scale domestic generation such as rooftop solar PV panels. When generating, PV panels will reduce a property's demand from the electricity network, in some cases even supplying power back to the grid.

Across the SP Transmission network area the typical domestic properties in Dumfries and Galloway have the highest average demand which is around 13% more than the rest of central and southern Scotland. This could be attributed to the rural nature of many properties in Dumfries and Galloway, resulting in fewer houses connected directly to the gas network and having to rely on electric heating. This region also has a lower proportion of multi occupancy buildings which generally have a lower demand.

6.3 **Industrial** & Commercial

The average industrial and commercial (I&C) supply has seen a net decrease in consumption between 2010 and 2015 in central and southern Scotland. However, this decline has not been as linear as domestic properties. Despite the net decrease, the average consumption in Great Britain has seen growth since its lowest point in 2011. This is illustrated in Figure 9.

Figure 9 | Average Industrial & Commercial Electricity Consumption [4]



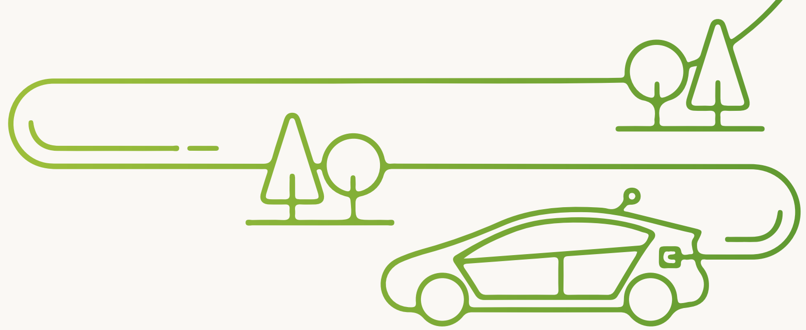
I&C consumption can be dominated by a small number of major energy users such as large factories, steel making plant and other heavy manufacturing. The closure of these major users or investment in new equipment to improve efficiency will have a notable impact. The overall decrease in industrial and commercial electricity demand could be a result of large sites installing on site generation to meet their energy needs and reduce reliance on the grid as well as closures of sites. Ultimately, the average values consider a wide variety of business types from large factories to local shops so actual consumption will be highly variable and some areas of industry will be more sensitive to economic factors than domestic consumption.

7

Electric Vehicles (EVs)

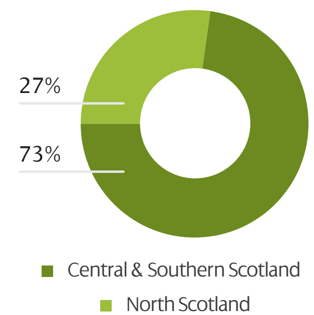
Widespread adoption of electric vehicles is expected to provide a significant challenge to the electricity industry due to the large increase in demand and potential for new technologies and markets.

The Sottish Government has set a target to phase out new petrol and diesel cars by 2032, along with the UK Governments similar ambition for 2040 across the country.



There are currently 6,958 EVs registered in Scotland, as of Q4 2017 Figure 10 shows how the EVs are split between the north of Scotland and central and southern Scotland. This is broadly in line with the population split between the two areas

Figure 10 | EVs in Scotland [5]



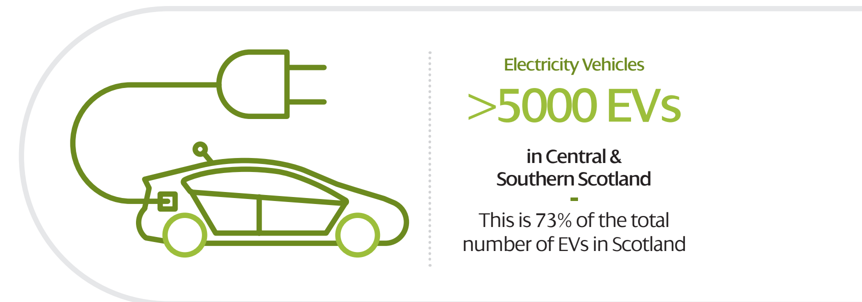
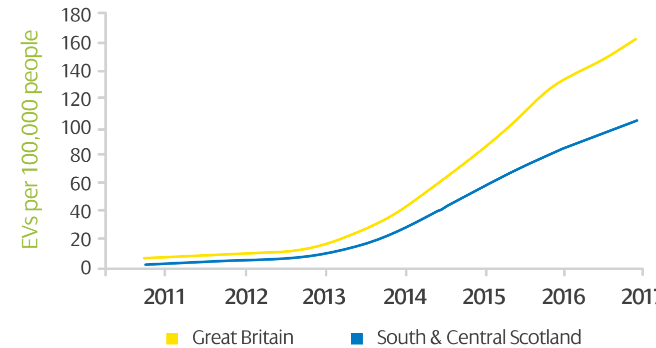


Figure 11 | EVs registered



The number of EVs in central and southern Scotland increased from 59 in 2011 to 5,010 by Q4 2017. Meanwhile, the number of EVs in all of Great Britain rose from 2301 to 127,202 during the same time period. Figure 11 shows how quickly EVs have been adopted in Great Britain compared to central and southern Scotland.

When accounting for the difference in population, the total number of EVs registered in central and southern Scotland closely followed the number of registered EVs in all of Great Britain. However since 2014, the rate of EV adoption has increased quicker across the UK than in southern & central Scotland.

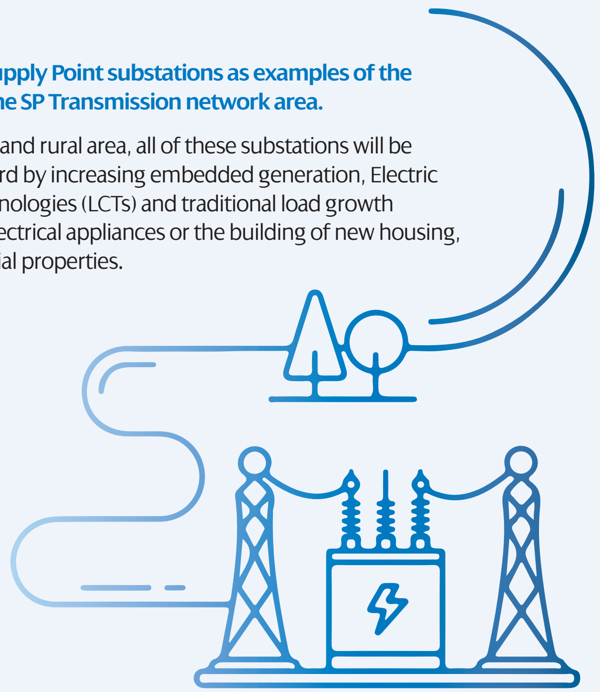
London and South East England account for almost a third of all registered EVs in 2017. These are highly populous areas of the country so it should be expected that EVs are more prevalent in these areas. This trend is also true in central and southern Scotland, where EVs are predominantly found in Renfrewshire, Edinburgh and Stirling.

8

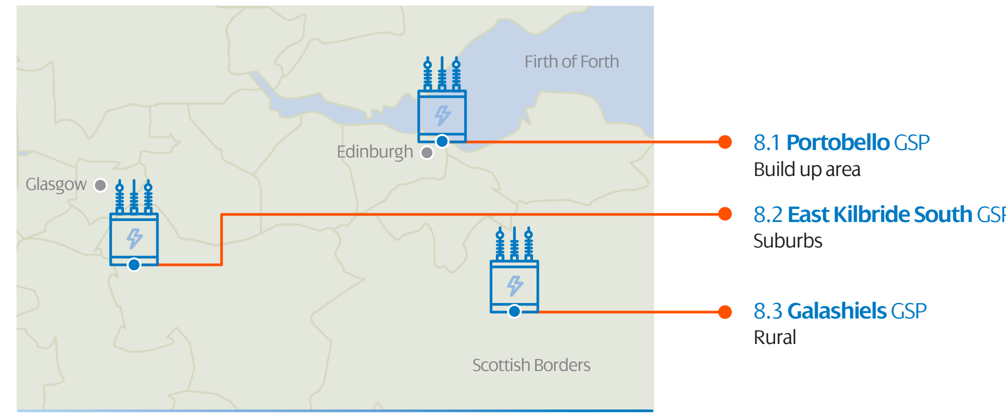
Grid Supply Point: Case Studies

We have selected three Grid Supply Point substations as examples of the typical substations fed from the SP Transmission network area.

These cover a city centre, urban and rural area, all of these substations will be affected differently going forward by increasing embedded generation, Electric Vehicles (EVs), Low Carbon Technologies (LCTs) and traditional load growth associated with an increase in electrical appliances or the building of new housing, industrial centres and commercial properties.



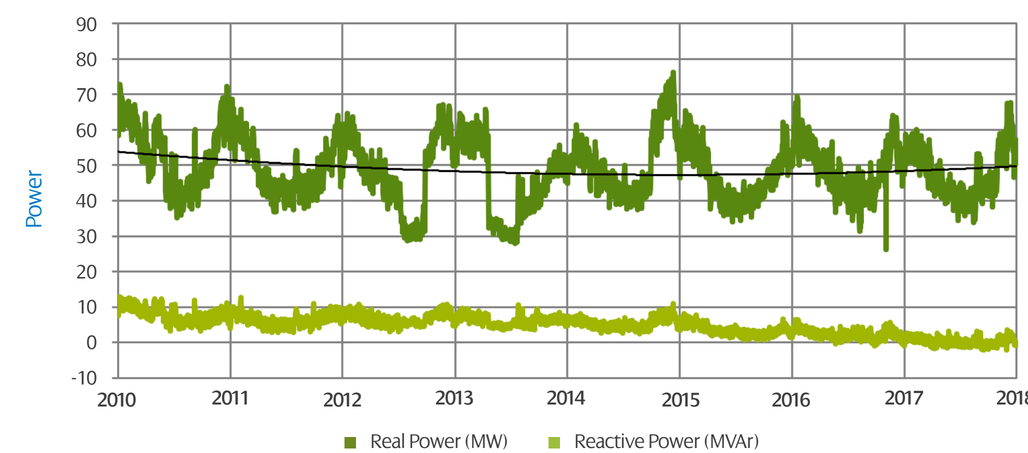
Map: GSP Case Study Substation Locations



8.1 Portobello GSP

Portobello GSP supplies electricity to in the east of Edinburgh City Centre. The area is a mix of domestic, industrial and commercial properties. Due to the city centre location of the site there is no generation of significant size connected to the local network. There is approximately 13MW of smaller generation connected across the distribution network in this area, enough to power approximately 8,500 local households. Figure 13 shows the daily average load of Portobello GSP.

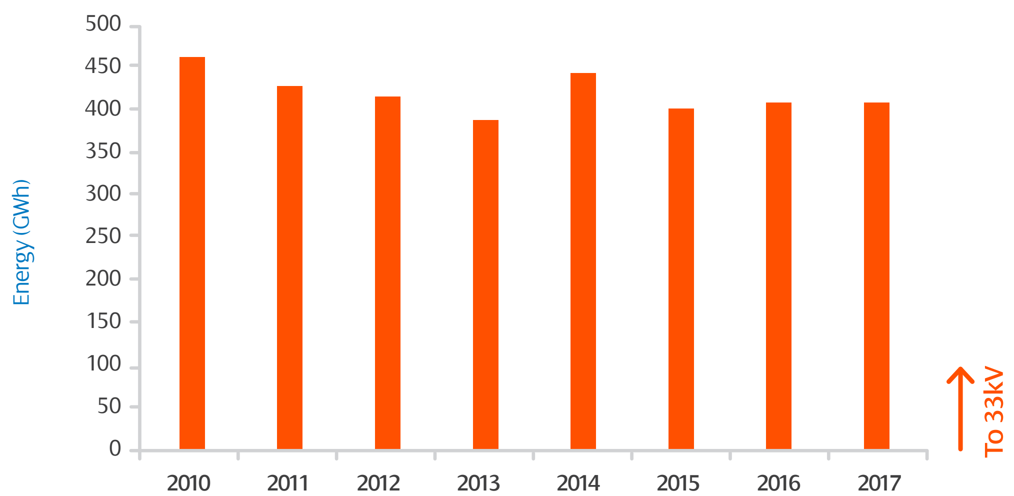
Figure 12 | Annual Portobello GSP Power Flow



The presence of generation connected into Portobello GSP has not resulted in a significant reduction in the demand profile. There has been a slight decrease in overall demand since 2010, however, this could be a result of local adoption of energy efficient appliances or technologies, as industrial and commercial sites and homeowners seeking to reduce their overall energy consumption which is consistent with the wider energy trends we see.

The total energy supplied to the local network has decreased since 2010 as shown in Figure 13.

Figure 13 | Portobello GSP Energy



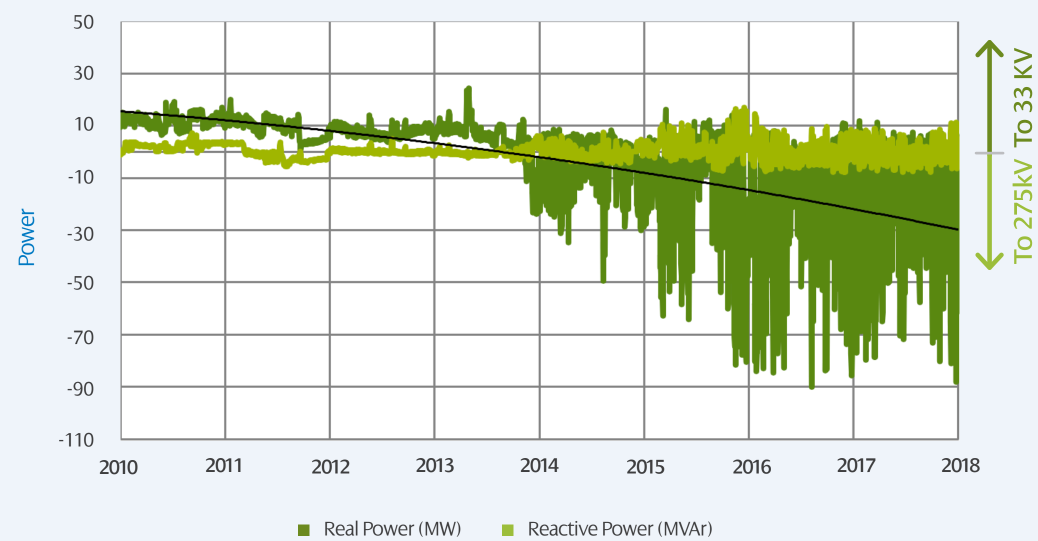
Between 2010 and 2017, the total amount of energy supplied to the local networkfell by approximately 10%. The gradual decrease reinforces the suggestion that the demand is falling as a result of more energy efficient technology. The increase in energy supplied in 2014 could be a result of network reconfiguration towards the end of the year. However, since 2015, demand has remained relatively constant at approximately 410 GWh.

While demand has remained approximately the same since 2015 and decreased overall since 2010, the city centre location of this GSP could put it at risk of supplying an increased concentration of electric vehicle charging points. This would lead to an increase in the energy demand as EVs become the norm. As this area is a mix of industrial and commercial and domestic properties, these charging points could be utilised constantly throughout the day.

8.2 East Kilbride South GSP

East Kilbride South GSP supplies a semi urban area consisting of domestic properties and an industrial estate to the north and farmland to the south. As a result of it's location, 4 large windfarms are connected to this GSP. This can cause power to flow from the distribution network to the transmission network. This is reflected in the half hourly average power flow as shown in Figure 14.

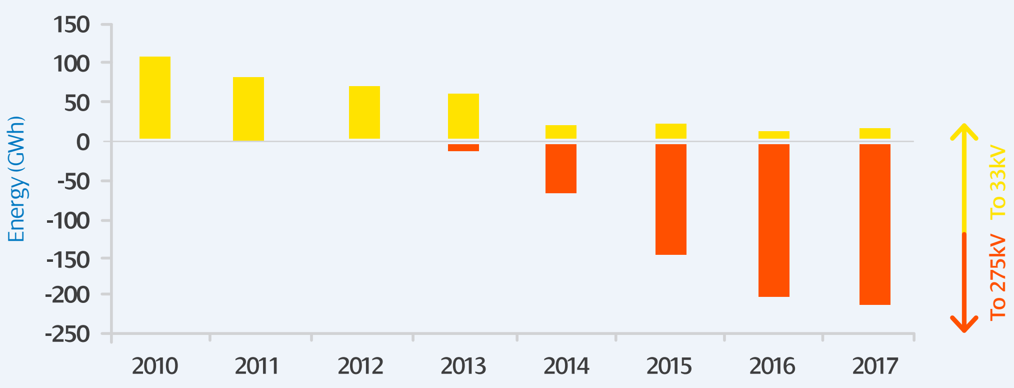
Figure 14 | East Kilbride South GSP Power Flow



The graph shows that in 2014, the transformer began exporting power to the transmission network. This aligns with the connection and commissioning of the local distributed generation sites.

The distributed generation connected has caused a large volume of energy to be exported from the Distribution network to the Transmission network as local generation has exceeded local demand. The true magnitude of the demand is therefore hidden by the generation. Figure 15 shows the total energy supplied across the years as increasing levels of distributed generation is connected to the GSP.

Figure 15 | East Kilbride South GSP Energy



The total amount of energy supplied to East Kilbride South GSP has steadily dropped between 2010 and 2017. This is a result of both an increase in the prevalence of more energy efficient appliances and the presence of embedded generation partially meeting the local demand. This is most evident in 2013 with the GSP first exporting power to the wider transmission network. As more and more windfarms were commissioned into the GSP this has resulted in a massive increase in exported energy.

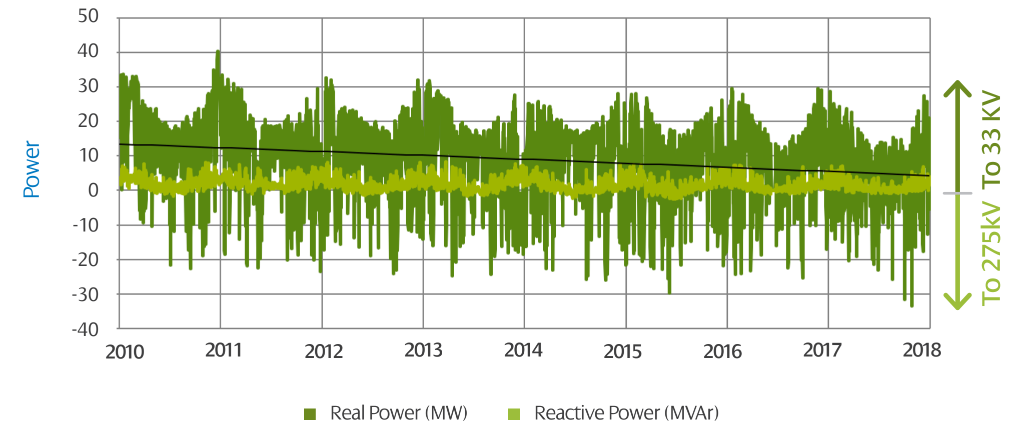
From 2013, less than 20 GWh of energy has been imported by the transformer each year to local loads, a decrease of 80 % since 2010. The energy exported to the transmission network has increased rapidly from 0 GWh to almost 200 GWh. This is enough energy to meet the needs of approximately 56,000 homes, 75% of the population of East Kilbride.

As this GSP supplies commuter areas south of Glasgow, EVs could become more popular in this area in the near future. However, unlike Portobello GSP, these EVs would be more likely to be charged overnight from a domestic property than throughout the day at a workplace charging station. This could cause a reduction in the total volume of energy exported to the transmission network or could equally cause the demand of the Distribution network to increase if the output from the embedded wind generation is low.

8.3 **Galashiels** GSP

Galashiels GSP supplies a primarily rural area in the Scottish Borders. Due to its rural location, there are 2 large wind farms connected to the GSP's distribution network. The power flow through this substation has many similarities with East Kilbride South GSP due to the generation connected to the network. The power flow is shown in Figure 16.

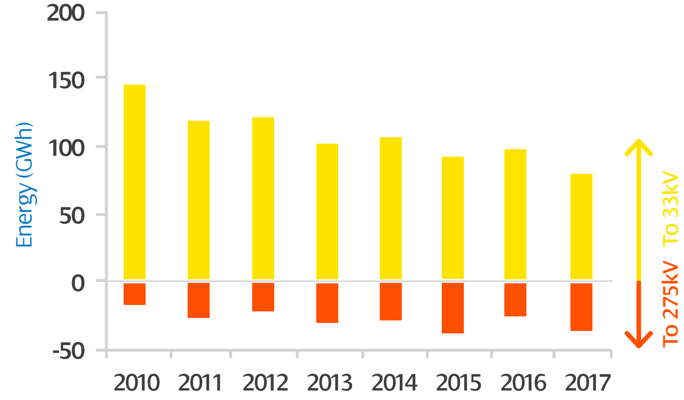
Figure 16 | Galashiels GSP Power Flow



The above graph shows that the power generally flows from the transmission network to the distribution network. However, there is not sufficient generation connected to this substation to reverse the power flow (reactive and real) for long periods of time, especially during the winter months.

The level of energy supplied by the transformers at Galashiels GSP has steadily decreased from 2010 to 2017; this could be a result of an increase in smaller scale embedded generation as well as increasing penetration of energy efficient devices and appliances.

Figure 17 | Galashiels GSP Energy



The rural location of Galashiels GSP could limit the rate of adoption of EVs due to the longer commuting distances and lower population density. Instead, any additional wind generation installed during the RIIO-T2 period could cause the GSP to begin to export more electricity to the transmission network similarly to East Kilbride South GSP depending on local network constraints.

9 Conclusion

9.1 **Transmission & Distribution** Embedded Generation

There has been a step change in the type of generation and the location of generation connecting to our network. Across both Distribution and Transmission onshore wind is now the dominant technology with a loss of dispatchable generation from the network. This raises some areas that we will require to consider in T2 such as:

- Impact of the loss of predictable dispatchable generation on Transmission network
- Incorporating increasing flexibility into the Transmission network
- Reinforcement options across GSPs now seeking to export power to the Transmission network
- Management of increasing levels of embedded generation
- Impact of generation mix on stability of network and resilience of network when recovering from major events

9.2 **Boundary** Transfer Capability

Over the last ten years we have delivered boundary transfer increases to both the B4 and B6 boundaries. The historic utilisation reinforces the trend of power to flow north to south has been consistent. Going forward we will need to consider the following areas:

- Ensuring sufficient boundary capability for existing and forecast generation
- Change in boundary use profiles as generation mix alters

9.3 **Energy Consumption** Trends

Electrical energy consumption across Domestic and Industrial & Commercial sites has been in line with the rest of the United Kingdom with a reduction in average consumption. Across both these sectors it is thought that this reduction is due to the combination of generation installed "Behind the Meter" reducing the overall seen consumption and increases in energy efficiency with modern appliances and industrial processes. The main areas we will need to consider are:

- Impact and level of the electrification of heat and industrial processes on electricity demand
- Tracking of the "True" demand and undertaking appropriate reinforcement

9.4 GSP Flexibility

We examined three GSP case studies which will all be affected differently by technology uptake, embedded generation and load growth throughout the RIIO-T2 period. We will need to consider the following areas with regards to GSPs:

- Co-ordination across both the Distribution and Transmission networks to ensure Whole System approach to reinforcement
- Impact of increasing levels of embedded generation, storage and co-ordination with future DSO worlds
- Changing nature of load and impact on power factor, flow and load profiles

9.5 Technology Uptake and Impact

Both governments have targets on the uptake of EVs associated with the reduction in carbon outputs. We have already seen a dramatic increase in EVS in our network area (~6800"% increase) which will only accelerate as we move closer to the associated deadlines. Consideration is required on both EVs and other technologies that will impact on the network:

- Impact of emerging EV flexibility markets such as vehicle2grid, smart charging , constraint management
- Electrification of rail, goods haulage, public transport and ferry services
- Uptake of domestic storage/generation
- Electrification of heat via air source/ground source heat pumps, electric boilers

10 References

[1] BEIS, Energy Trends September 2017

[2] Estimates of Households and Dwellings in Scotland 2015, Published 8th June 2016, last accessed online at www.nrscotland.gov.uk/files/statistics/household-estimates/house-est-15/15house-est.pdf

[3] National Grid, Network Options Assessment 2016/17 January 2017

[4] BEIS, Regional and local authority electricity consumption statistics: 2005 to 2015

[5] Department for Transport, Table VEH0131 - Plug-in cars and vans licensed at the end of quarter by location of registered keeper: United Kingdom

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