Scottish & Southern Electricity Networks

TRANSMISSION

North of Scotland Future Energy Scenarios

May 2022

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This publication

The Great Britain (GB) energy landscape continues to undergo change with the growth of renewable energy generation continuing at pace.

To be able to meet customers' future needs over the next decade and beyond, we must understand which technologies are likely to impact generation and demand profiles. This publication sets out our view of a range of potential generation and demand scenarios in the north of Scotland out to 2050 and incorporates new elements such as rail, hydrogen and the ability to determine if and when the scenarios achieve net zero.

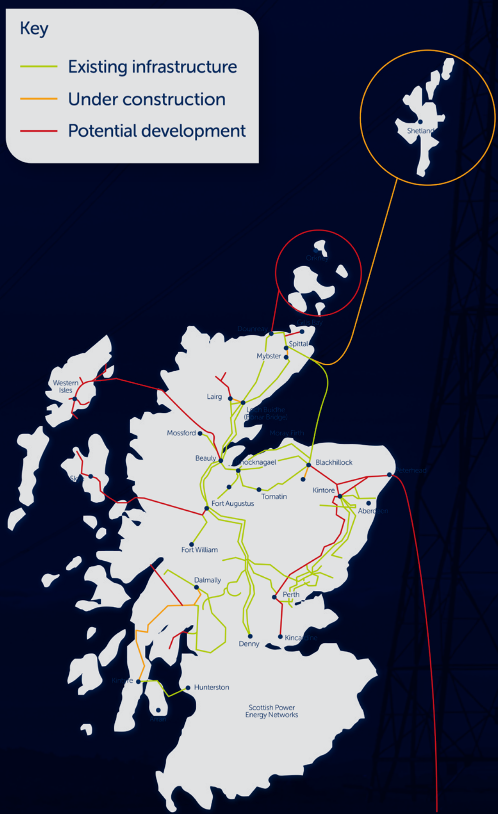
Additionally, we have also included a section around storage and the role it could play in the north of Scotland due to an increase in the number of battery and pumped storage connection applications we have received.

About us

We are Scottish Hydro Electric Transmission (SSEN Transmission), part of the SSE Group, responsible for the electricity transmission network in the north of Scotland. We operate under the name of Scottish and Southern Electricity Networks, together with our sister companies, Scottish Hydro Electric Power Distribution (SHEPD) and Southern Electric Power Distribution (SEPD), who operate the lower voltage distribution networks in the north of Scotland and central southern England.

As the Transmission Owner (TO) we maintain and invest in the high voltage 132kV, 220kV, 275kV and 400kV electricity transmission network in the north of Scotland. Our network consists of underground and subsea cables, overhead lines on wooden poles and steel towers, and electricity substations, extending over a quarter of the UK's land mass crossing some of its most challenging terrain.

We power our communities by providing a safe and reliable supply of electricity. We do this by taking the electricity from generators and transporting it at high voltages over long distances through our transmission network for onwards distribution to homes and businesses in villages, towns and cities.



A network for net zero

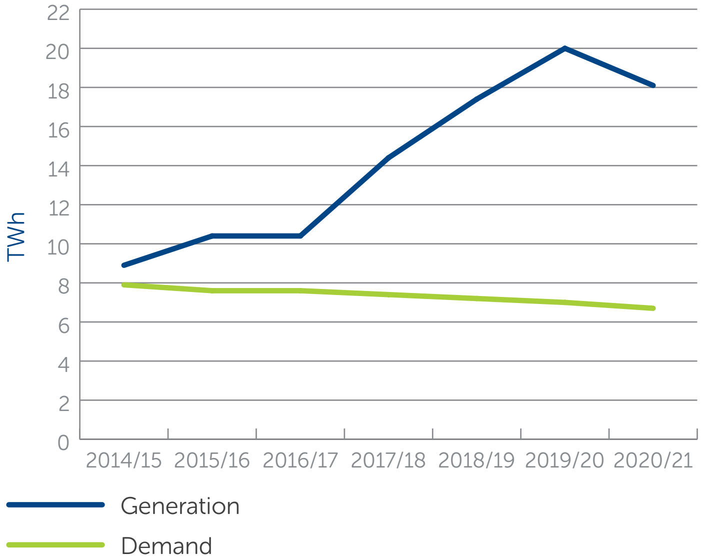
Introduction

As the electricity transmission network owner in the north of Scotland, our main focus in the last decade has been on delivering the additional capacity and connections required for increased renewable energy generation in an economic and efficient way, while ensuring reliability of supplies for our network users and consumers.

In 2020/21, the volume of electricity generated was around three times the amount consumed however electricity generated decreased slightly when compared to 2019/20 which could potentially be attributed to lower onshore wind output on the system. Demand on the network also declined from previous years. COVID-19 lockdowns during 2020/21 may have contributed to the decrease as well as the general decline seen due to efficiency improvements in homes and appliances.

As more renewables connect to the network, we may begin to see more volatility in generation output due to the intermittency of renewable generation. With that in mind we need to be mindful of how the energy system could develop in the future which will influence what network developments are required in the north of Scotland.

Historic view of electricity generated and demand in the north of Scotland



The need for localised scenarios

Every year the GB Electricity System Operator, National Grid, produces their Future Energy Scenarios (FES) which identify a range of four credible energy scenarios for the next 30 years and beyond. These consider how much energy GB might need and where it could come from.

At a macro level, the FES are a powerful tool as they capture a range of potential national political, economic, social and technological possibilities.

However, the application of the FES assumptions on a regional level is limited. In the north of Scotland, our Energy Trends papers have identified developments that have not always matched the prevailing GB trends. Therefore, additional granularity provided through localised future energy scenarios for the north of Scotland would best represent energy users' needs.

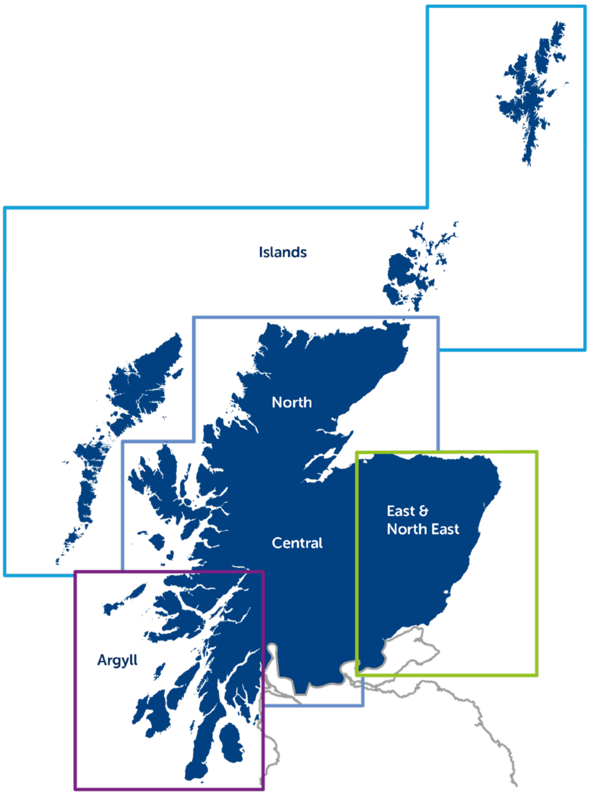
As we consider whole system planning as a fundamental element in planning our network developments, thought must also be given to changes in other areas of the energy system such as heat, transport (including rail) and hydrogen.

Changes made to this update

In our 2021 update to our North of Scotland Future Energy Scenarios, we extended the time horizon of our scenarios from 2030 to 2050 which allowed us to model how changes in the energy landscape could impact the transmission network in the longer term. Whilst this was very helpful in providing a longer term view out to 2050, we needed to increase the scope of our modelling.

In this update, we have made changes and additions to our modelling which will provide richer analysis; firstly, we changed the way in which we report generation and demand based on the regional approach shown in the map. Secondly, we added additional technologies such as gas boilers, hydrogen boilers, hydrogen powered vehicles and rail to our analysis.

Finally, as a result of the additions we made to the various technologies used in our modelling, we have been able to model the emissions of each technology and in turn determine if and when the scenarios achieve net zero.



Government targets

UK and Scottish Government targets and ambitions have been used to set the policy framework and envelope of our scenarios.

Our two net zero scenarios, The Green Economy and The Green Society, are designed to contribute towards achieving each government's respective targets. Examples of government targets and ambitions used to inform our scenario envelopes are shown below:

- The UK Government has set out a commitment that by 2030, 95% of British electricity could be low-carbon; and by 2035, we will have decarbonised our electricity system, subject to security of supply.
- In the UK Government's Energy Security Strategy, it confirmed that it aims to deliver 50GW of offshore wind, including 5GW of floating offshore wind by 2030.
- The Scottish Government's ambition to see the development of between 11 and 16GW of renewable capacity up to 2032, which includes between 8 and 11GW of offshore wind capacity by 2030.
- The Scottish Government's draft target sets out that an additional 8-12GW of onshore wind be installed in Scotland by 2030.
- The Scottish Government's introduction of a standard requiring all new homes consented from 2024 to use zero emission heating systems.
- The Scottish Government's target that Scotland's rail services will be decarbonised by 2035.
- The UK Government's Energy Security Strategy set out an aim to double the low carbon hydrogen production capacity to 10GW by 2030, with at least half of this coming from green hydrogen.

OUR SCENARIOS

THE GREEN ECONOMY

THE GREEN SOCIETY

THE DECELERATED TRANSITION

Our scenarios

Scenarios	Key details in new scenarios
The Green Economy	Scottish consumers and businesses are supportive of achieving net zero carbon emissions, increasing their use of renewables and engaging with the energy sector at local levels. The focus is on achieving net zero through two main routes; capital investment in renewable generation projects and decarbonising heat, transport and I&C through the increasing use of hydrogen and electrification. Net zero achieved in 2045. **Net annual emissions of -0.31 MtCO2e by 2050.**
The Green Society	Scottish consumers and businesses engage directly with the energy industry by investing in micro-generation and renewable heating technologies, allowing them to contribute to achieving net zero carbon emissions. The focus is on achieving net zero through the electrification of heat, transport and I&C and investment in both large-scale and community renewable projects. Net zero achieved in 2044. **Net annual emissions of -0.56 MtCO2e by 2050.**
The Decelerated Transition	Scottish consumers and businesses are less inclined to engage with the energy industry so fewer invest in micro-generation but local planning policy encourages uptake in renewable heating technologies. There is low uptake in domestic and community-based generation whilst increases are seen in large-scale renewables. Decarbonisation is a secondary consideration for Scottish consumers and businesses, with the 2050 net zero target not being achieved. **Residual annual emissions of 1.81 MtCO2e by 2050.**

The Green Economy

Scottish consumers and businesses are supportive of achieving net zero carbon emissions, increasing their use of renewables and engaging with the energy sector at local levels. Targets set by both the Scottish and UK governments provide a focused decarbonisation pathway in which the UK government seeks to achieve net zero emissions by 2050, as legislated in June 2019. Net zero is achieved by 2045, ahead of the UK government target.

Intent on reaching the challenging decarbonisation and enabling the green recovery, government looks to support large-scale and community energy supply to maximise the use of renewable energy resources and balance local and national demand.

The economy is performing well, and investment in the energy sector remains high. Targeted support schemes lead to high capital investment in large scale projects across the north of Scotland.

Policy is in place to stimulate development of low carbon energy technologies. Significant policy support for offshore wind and carbon capture & storage (CCS) is in place which are seen as key technologies in achieving net zero carbon emissions. Biomass CCS plays a prominent role in the energy mix from the early 2030s, contributing greatly to decarbonising the power sector.

Established technologies, such as onshore wind and solar, benefit from the ability to compete for government subsidy, favourable Scottish planning policy, technology development and economies of scale, allowing projects to be developed with and without government subsidy.

Interconnection within GB and with foreign countries plays a role in managing the system, which will allow for the export of large-scale renewable generation from the North and balancing through imports.

Scottish consumers invest in microgeneration and low carbon heating technologies to bring down cost of their energy bills through participation in demand side response.

Consumers use a mix of heating technologies; in rural areas where there is excess renewable generation, consumers utilise electric storage heaters, hybrid heat pumps and heat pumps; in more urban areas, natural gas boilers are used initially however as we progress towards 2050, more and more consumers invest in hydrogen boilers.

Many consumers and businesses switch from fossil fuel cars to electric cars as they look to mitigate their impact on the environment and make best use of their additional behind the meter generation. In more urban areas, autonomous vehicles play a role and result in fewer cars on the roads.

Local authority led infrastructure development makes charging away from home easier with fast chargers in towns and cities and on key tourist routes in the north of Scotland.

All forms of hydrogen vehicles are deployed across the North of Scotland. However, hydrogen cars are only rolled out in local authorities where refuelling infrastructure is expected to be sufficient.

The Green Society

Scottish consumers and businesses engage directly with the energy industry by investing in micro-generation and renewable heating technologies, allowing them to contribute to achieving net zero carbon emissions. Net zero is achieved by 2044, ahead of the targets set by both the Scottish and UK governments.

The economy is growing, with high investment taking place in large-scale and community renewable projects. Government policy provides opportunity for growth in community based renewable projects whilst support remains for large-scale renewable projects.

Renewable technologies have reduced in cost to such an extent that some large onshore and offshore wind projects are developed without the need for subsidy support.

Small scale energy resources such as local and community wind, solar and storage projects are supported through favourable Scottish planning policy, and beneficial connection and charging arrangements.

Biomass CCS plays a prominent role in the energy mix from the mid 2030s, contributing greatly to decarbonising the power sector. Interconnection provide flexibility for bulk flows, but with more decentralised generation on the distribution network, additional flexibility is provided at a local level by distributed energy resources.

Scottish consumers invest in microgeneration and low carbon heating technologies to bring down cost of their energy bills through participation in demand side response.

In communities where there are large amounts of excess local generation such as the Scottish Islands and more remote rural areas, consumers utilise electric heating in the form of storage heaters, heat pumps and hybrid heat pumps.

Where access to excess generation is limited, a range of combined heat and power (CHP) and district heat networks are used. In more urban areas, natural gas boilers are gradually replaced by some hydrogen boilers.

Scottish consumers and businesses invest in electric cars. Less autonomous cars operate in urban areas resulting in higher numbers of electric vehicles being present on our roads.

Consumers prefer to charge their electric vehicles at home, benefitting from vehicle to grid services, with fast chargers being located in cities, on the motorways and on key tourist routes in the north of Scotland.

Uptake of hydrogen powered vehicles (vans, buses and coaches, and trucks) occurs across the north of Scotland.

The Decelerated Transition

Scottish consumers and businesses are less inclined to engage with the energy industry so fewer invest in micro-generation but local planning policy encourages uptake in renewable heating technologies. There is low uptake in domestic and community-based generation whilst increases are seen in large-scale renewables. Decarbonisation is a secondary consideration for Scottish consumers and businesses, with the 2050 net zero target not being achieved.

Economic growth plateaus however investment in the sector continues.

Government policy focuses on less established technologies such as offshore wind, floating offshore wind and CCS. More established technologies such as onshore wind and solar are developed subsidy free.

Large scale onshore wind and solar projects are developed in the limited locations where subsidy free development is viable in the north of Scotland.

A reduction in the number of new renewable projects across GB increases the need for interconnection in the north of Scotland in order to meet demand in other areas of GB.

The removal of some subsidy costs lowers the cost of energy bills so fewer consumers and businesses see little need to engage with the energy industry and invest in microgeneration.

There is limited financial incentivisation from government to encourage consumers to move towards greener sources of energy, but planning policy encourages the deployment of low carbon heating solutions, such as heat pumps and hybrid heat pumps in off-gas areas. In urban areas, efficient natural gas boilers continue to be used and remain the heating technology of choice.

Electric vehicle uptake takes place due to the government ban on petrol and diesel cars. There is little reduction in the number of electric vehicles on the road as autonomous vehicle uptake is negligible.

Charging electric vehicles at home remains the method of choice however charging away from the home is made easier through investment in transport hubs primarily located in towns and cities. Uptake of hydrogen powered vehicles is only considered for heavy hydrogen vehicles within the Aberdeen City and Aberdeenshire regions.

Electricity supply

The generation mix of the GB electricity system is continuing to shift towards renewable sources as there is increased focus on achieving net zero. Further decarbonisation will be required across all sectors to meet climate change targets, and electricity will play a large part in this. As we look forward to 2050, transformational growth in generation is required if we are to achieve net zero carbon emissions.

Below is an overview of how generation develops in our three scenarios;

The Green Economy

Within this scenario, policy support favours renewable energy generation allowing generation capacity to grow from 8,009MW in 2020 to 51,558MW in 2050. By 2050, offshore wind has the largest share of generation capacity in 2050 at 22,043MW due to successful outcomes from ScotWind leasing rounds. Onshore wind follows with 12,485MW connected to the network by 2050. Pumped hydro will reach 4,446MW with Hydro (river run) reaching 1,621MW by 2050. Solar and Interconnection capacity rises to 3,902MW and 1,400MW respectively by 2050. Carbon capture and storage (CCS) will play a key role in achieving net zero carbon emissions with a 1,200MW Biomass CCS (BECCS) plant coming online in 2033. A hydrogen powered generation plant connects in 2030 with a capacity of 1,180MW. 2,360MW of Battery storage and 247MW of Tidal will be connected by 2050 as well as 673MW of Waste and Other generation.. 2029 represents the first year where all generation connected to the transmission network will come from renewable sources.

The Green Society

This scenario sees the largest growth in generation capacity, reaching 48,961MW in 2050 from 8,009MW in 2020. Offshore wind represents the technology with the largest share of generation capacity at 23,043MW followed by Onshore wind at 12,499MW. Pumped hydro will reach 2,646MW followed by Hydro (river run) reaching 1,779MW by 2050. Solar capacity reaches 3,274MW by 2050 whilst Interconnection capacity grows to 1,400MW. By 2050, a 1,200MW BECCS plant is in operation which connects in 2035. 577MW of Waste and Other generation capacity, 2,265MW of Battery storage and 277MW of Tidal will be connected by 2050. All generation connected to the transmission network from 2030 onwards will come from renewable sources.

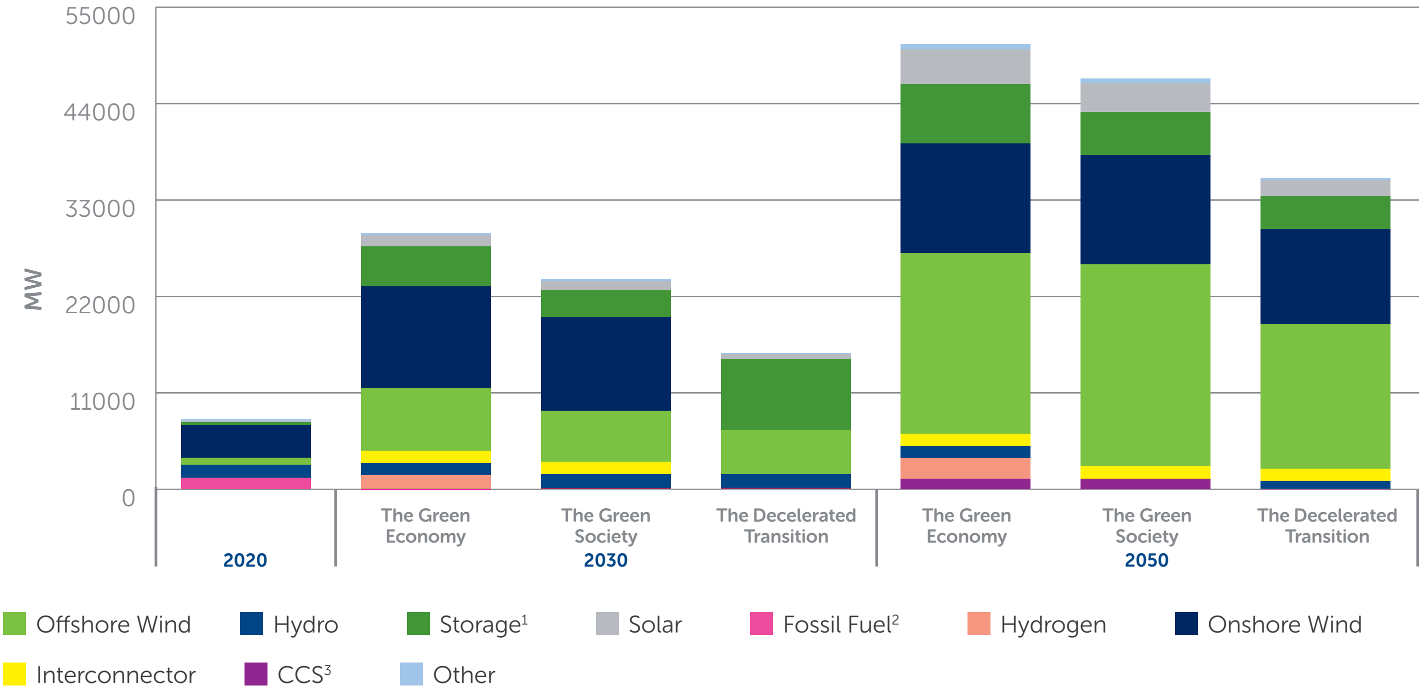
The Decelerated Transition

Within this scenario, fewer renewable energy generation projects come forward when compared to the other scenarios, resulting in the generation capacity installed on the network reaching 37,371MW by 2050. Offshore wind has the largest share of generation capacity at 16,543MW. Onshore wind follows with 10,776MW on the network in 2050. By 2050, Pumped hydro will reach 1,962MW of generation capacity on the network with Hydro (river run) increasing to 1,560MW. Interconnection capacity reaches 1,400MW by 2050 whilst Solar and Waste & Other generation capacity increases to 1,780MW and 289MW respectively. 1,845MW of Battery storage and 267MW of Tidal will be connected by 2050. A Gas CCS plant with a generation capacity of 900MW connects in 2037. However, due to the use of Gas CCS, the generation connected to the transmission network will not reach 100% renewable generation by 2050.

Annual installed generation capacity by scenario

Annual generation output by scenario

Annual installed generation capacity by scenario



Evolution of renewable generation on the transmission network

2029

In **The Green Economy**, all generation connected to the transmission network from 2029 onwards will come from renewable sources.

2030

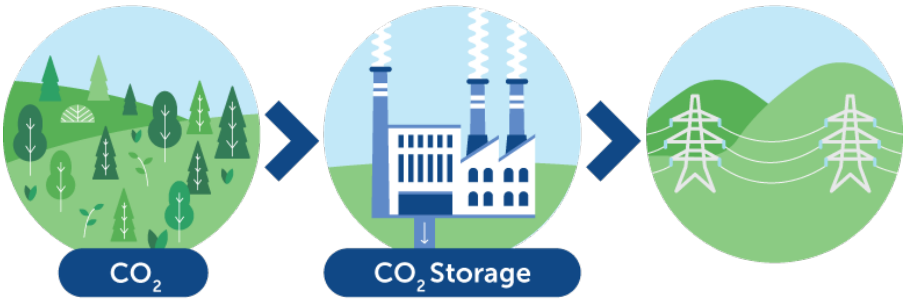
In **The Green Society**, 100% of generation connected to the transmission network from 2030 onwards will come from renewables.

In **The Decelerated Transition**, due to the use of Gas CCS, the generation connected to the transmission network will not reach 100% renewable generation by 2050.

[1]Includes Battery Storage and Pumped Storage.
[2]Includes CCGT, Diesel, OCGT and Gas Reciprocating Engine
[3]Includes BECCS and Gas CCS

Technology Spotlight: Bioenergy with Carbon Capture and Storage (BECCS)

BECCS systems remove carbon from the atmosphere by firstly using biomass to generate bioenergy. The CO_2 emissions produced during the bioenergy conversion are then captured and transported to permanent underground storage facilities. The later part of the process is also known independently as carbon capture and storage (CCS) and can be used with other fuel sources such as Gas. In regards to the technology, bioenergy is already commonly used across the UK, with Drax Power Station being a prime example but the CCS aspect of the process has not yet been deployed on a large scale.



BECCS has an important role to play in reaching net zero emissions. Decarbonisation will be required across all sectors to reach net zero, however some may struggle to do so more than others, such as transport and I&C. BECCS technology provides an opportunity for a potentially cost-effective way for additional emissions to be taken out of the environment and help reach negative emissions. However, having several different processes raises uncertainties with the emissions created as a result of each stage, and therefore questions the ability of negative emissions. Emissions will also be a by-product of the substantial level of investment in infrastructure that will be required for large scale deployment of BECCS.

The Bioenergy Update published by the Scottish Government in March 2021 outlines the future role for bioenergy as well as the factors to consider when deploying Negative Emission Technologies (NETs), such as BECCS. The report states that before 2030, it does not expect NETs to be playing a substantial role in helping reach emission reduction targets. The timeline for BECCS in our scenarios is in line with this expectation. The Green Economy and The Green Society see a 1,200MW BECCS scheme connect in 2033 and 2035 respectively, but do not see any additional growth as we progress towards 2050. In the Decelerated Transition scenario, BECCS does not play a role as Gas CCS is included within the scenario.

Whilst BECCS has the potential to play a significant role in achieving net zero, more work is required to determine what policy and/or support schemes may be required to facilitate development and deployment. The Scottish Government are currently working towards publishing a Bioenergy Action Plan in 2023.

Technology Spotlight: Storage

It is important to highlight the role energy storage will play in the future transmission network where almost all of the generation connected to the network will come from renewable sources. It will be critical in balancing the supply and demand of electricity, especially with the intermittency of supply and reduced system stability associated with renewables.

Storage technologies, such as battery energy storage systems (BESS) and pumped storage, allow electricity to be stored for use in periods of high demand or low supply. As well as being a quick responding energy reserve, storage can also reduce consumer costs by storing low-cost electricity and exporting it during peak periods, where the cost is typically higher. Electricity storage, particularly pumped storage, can also assist in restarting the grid if a black out was to occur therefore improving the reliability of the transmission network. Storage technologies are an alternative to peaking power plants and demand side response to help address imbalances between energy demand and energy production, thereby enabling better utilisation of renewable electricity from intermittent power sources such as wind, tidal and solar power. Storage providers can participate in a range of Balancing & Ancillary services offered by NGESO in order to provide operational services to the network. These can include maintaining grid frequency, providing rapid and reliable delivery of power by increasing output from generation or reducing demand consumption and providing black start capability in the unlikely event of a total blackout.

A trend of co-locating storage is emerging. Co-locating renewable generation with behind-the-meter storage allows a generator to store renewable electricity when generation is high and export the stored electricity to the grid when generation is low.

The role storage plays in each scenario is outlined below.

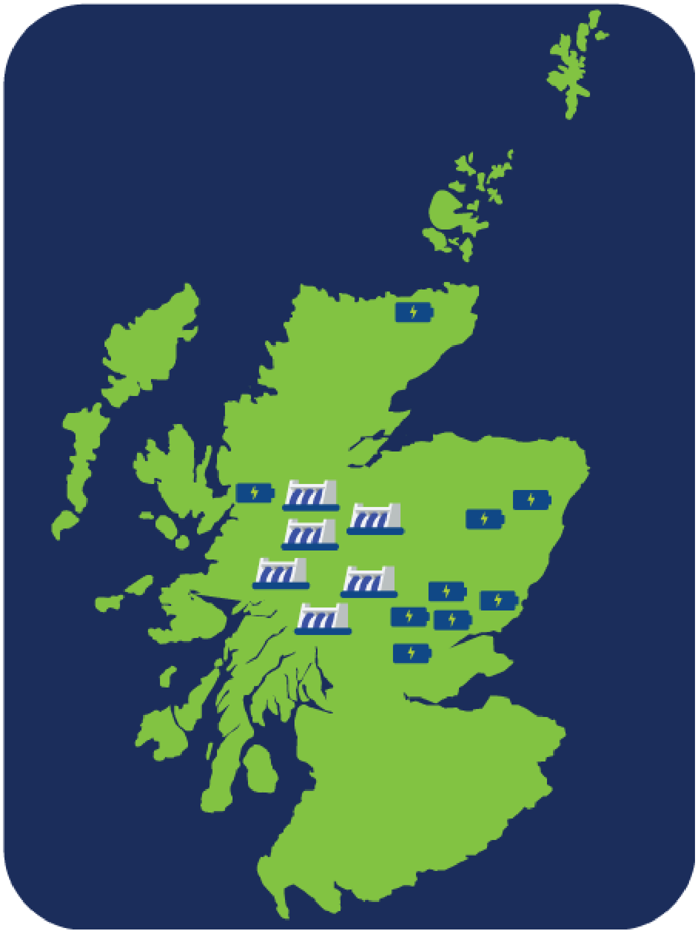
Battery Storage

Battery storage facilities are mostly found in the East & North East region, as can be seen on the map.

The Green Economy scenario has 16MW of battery storage connected in 2020 which grows to 1,968MW by 2030 and reaches 2,360MW in 2050. The Green Society scenario follows a similar trend with 16MW of battery storage generation capacity in 2020, increasing to 1,344MW in 2030. This continues to increase to reach 2,265MW in 2050. The Decelerated Transition will only see 684MW of battery storage connected by 2030 but grows significantly to 1,845MW of battery storage connected by 2050.

Pumped Storage Hydro

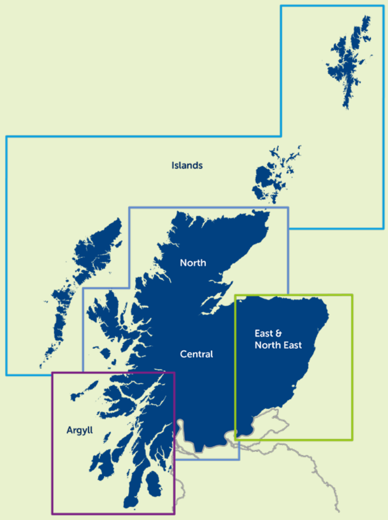
Each scenario has 300MW of pumped storage generation capacity connected in 2020 from Foyers. In The Green Economy this increases to 2,646MW in 2030 and rises further to reach its maximum capacity of 4,446MW by 2032. The Green Society and The Decelerated Transition do not see as much growth in pumped storage capacity by 2050 when compared to The Green Economy. The Green Society reaches 2,646MW by 2050 whilst by 2050, The Decelerated Transition only reaches 1,962MW. Pumped storage hydro schemes have a lengthy construction period, often between 5 to 8 years for larger projects, hence the large growth in the 2030s.



Installed generation capacity by region in 2050

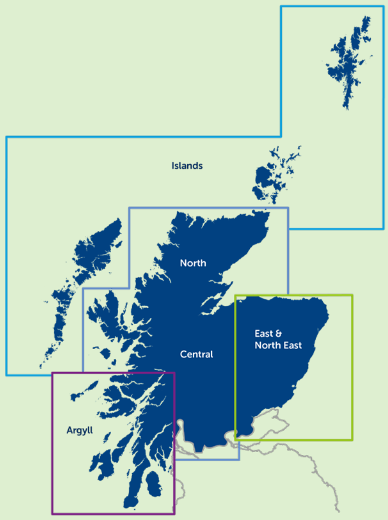
THE GREEN ECONOMY

Region	By 2050
Argyll	4,377MW
Central	8,255MW
East & North East	26,338MW
North	11,309MW
Islands	1,280MW



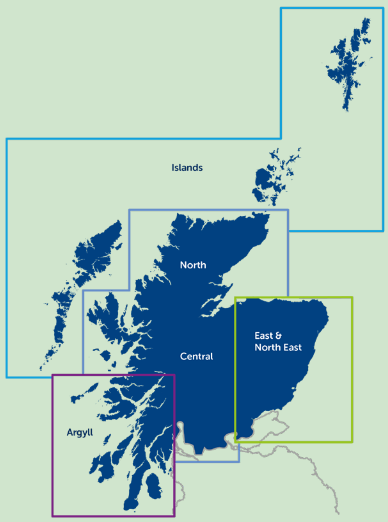
THE GREEN SOCIETY

Region	By 2050
Argyll	3,426MW
Central	7,290MW
East & North East	24,789MW
North	12,175MW
Islands	1,280MW



THE DECELERATED TRANSITION

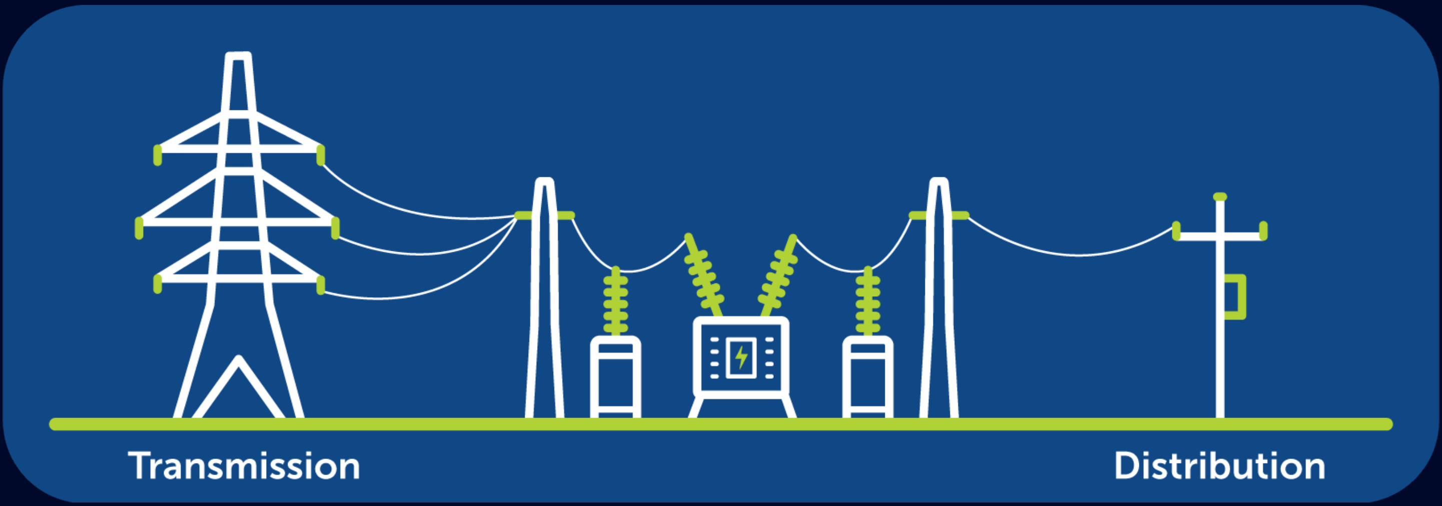
Region	By 2050
Argyll	3,021MW
Central	5,670MW
East & North East	18,676MW
North	8,725MW
Islands	1,280MW



Summary of generation capacity in our scenarios

	THE GREEN ECONOMY	THE GREEN SOCIETY	THE DECELERATED TRANSITION
Connected capacity 2021	9,430MW	8,163MW	8,142MW
Connected capacity in 2026	15,542MW	13,266MW	11,291MW
Connected capacity in 2030	30,779MW	24,327MW	14,593MW
Connected capacity in 2040	49,531MW	47,075MW	36,668MW
Connected capacity in 2050	51,558MW	48,961MW	37,371MW

Connected capacity in 2050 by connection type



THE GREEN ECONOMY		THE GREEN SOCIETY		THE DECELERATED TRANSITION	
40,104MW at Transmission	11,454MW at Distribution	38,149MW at Transmission	10,812MW at Distribution	30,079MW at Transmission	7,292MW at Distribution

Electricity Demand

As we strive to achieve net zero carbon emissions, the power sector is not the only sector that will need to decarbonise. Heat, transport and I&C will also have to decarbonise. Our 'Getting to Net Zero: The critical contribution from electricity generated in the north of Scotland' paper, published in late 2021, identified the vital role that electricity created in our network in the north of Scotland will play in replacing existing fossil fuels to decarbonise the heat, transport and I&C sectors.

Our analysis is particularly focused on the electrical impact of increased demand on the network in the north of Scotland. This section will provide an overview of how demand changes out to 2050 and what factors we have modelled that impact demand growth on our network.

Further to this, we have included annual energy demand (TWh), which covers all fuel types, for the first time in our analysis. This will be used for our carbon calculations to determine if and when the scenarios achieve net zero.

Summary of electricity demand in our scenarios

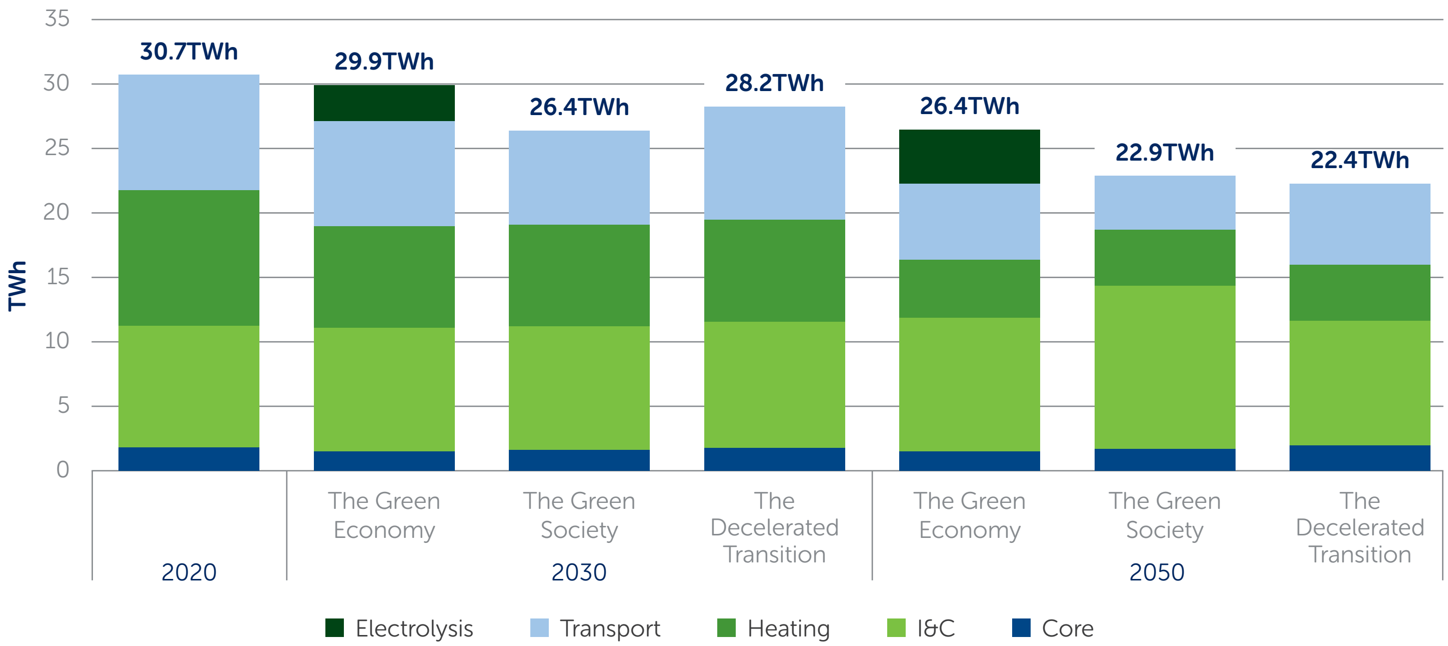
	THE GREEN ECONOMY	THE GREEN SOCIETY	THE DECELERATED TRANSITION
Total electricity demand in 2020 at winter peak	1,534MW	1,534MW	1,534MW
Total electricity demand in 2050 at winter peak	2,867MW	2,520MW	2,089MW
Which is made up of;			
Residential demand in 2050 at winter peak	467MW	397MW	606MW
Industrial & commercial demand in 2050 at winter peak	695MW	861MW	706MW
Electric vehicle demand in 2050 at winter peak	337MW	378MW	396MW
Heat demand in 2050 at winter peak	312MW	596MW	166MW
Rail demand in 2050 at winter peak	140MW	140MW	140MW
D-connected electrolysis in 2050 at winter peak	108MW	94MW	1.4MW
T-connected electrolysis in 2050 at winter peak	753MW	0MW	20MW
T-direct connected demand in 2050 at winter peak	55MW	54MW	54MW

From our three scenarios, The Green Economy sees the largest increase in electricity demand at winter peak. By 2030, demand in The Green Economy reaches 1,793MW as a result of increases in rail, heating and EV demand. By 2050, winter peak demand increases to 2,867MW which is attributed to I&C, EV, rail and electrolysis demand.

The Green Society has the second largest growth in electricity demand at winter peak, rising to 1,741MW by 2030 as a result of rail, heating and EV demand. By 2050, demand reaches 2,520MW. Additional demand comes from I&C, heating and rail demand.

The Decelerated Transition shows the lowest increase in electricity demand at winter peak, reaching 1,737MW by 2030 and 2,089MW by 2050. Lower levels of heating, EV and electrolysis demand results in lower overall levels of demand when compared to the other scenarios.

Annual end consumer energy demand by sector



The chart above details the total annual end consumer energy demand by sector. This includes use of electricity, gas, hydrogen and diesel / petrol. It is important to state why it shows a different trend when compared to peak demand. Our scenarios show that winter peak demand increases in all scenarios by 2050 due to deployment of low carbon technologies such as heat pumps and EVs (which are more efficient than their fossil fuel counterparts) however the chart above shows that annual energy demand decreases over time. The drop in energy consumption as fossil fuels are phased out is much greater in each sector than the increase in energy consumption due to electrification, so whilst this process will cause peak demand increases, annual energy consumption still reduces considerably as we progress towards 2050.

Energy demand in 2020 was 30.7TWh in the north of Scotland, made up of energy demand from the residential (core), I&C, heating, transport and electrolysis sectors.

From our three scenarios, The Green Economy sees the smallest decrease in energy demand by 2050, decreasing by 14% to 26.4TWh. The decrease is not as significant when compared to the other scenarios due to increased energy demand from the use of hydrogen in the heating, transport and electrolysis sectors.

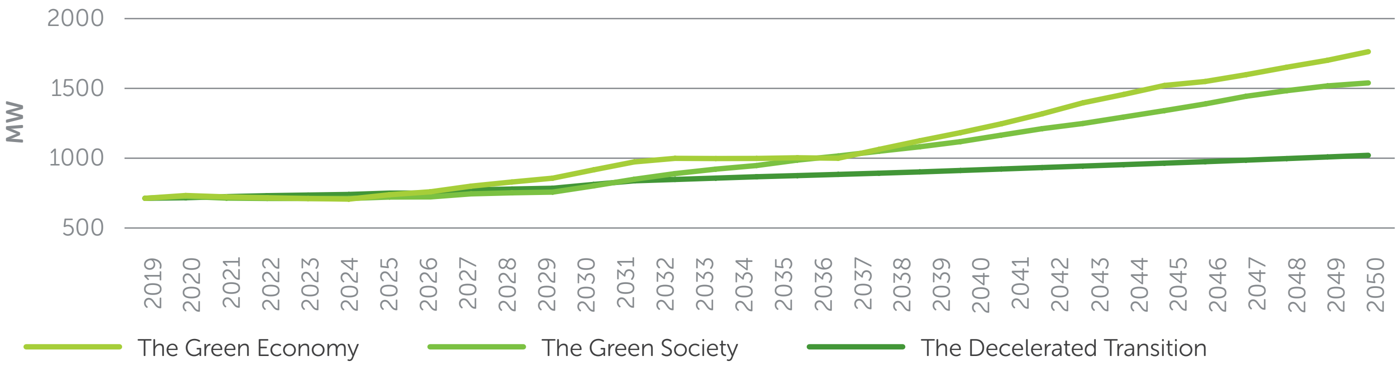
The Green Society has the second largest decrease in energy demand, decreasing to 22.9TWh by 2050. Even with increased levels of electrification in the heating, transport and I&C sectors, overall energy demand decreases as a result of reduced fossil fuel use across the various sectors.

The Decelerated Transition shows the highest decrease in energy demand, decreasing by 27% to 22.4TWh by 2050. The deployment of EVs displaces fossil fuel powered cars which is the largest contributor to the decrease in energy demand.

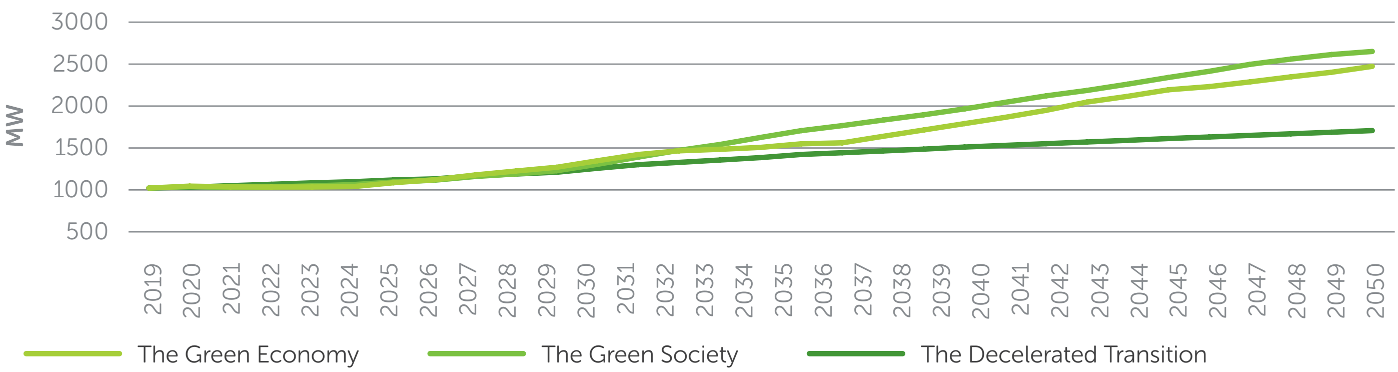
Total electricity demand in our scenarios

Total electricity demand at Winter Peak

Total electricity demand at Summer AM



Total electricity demand at Summer PM

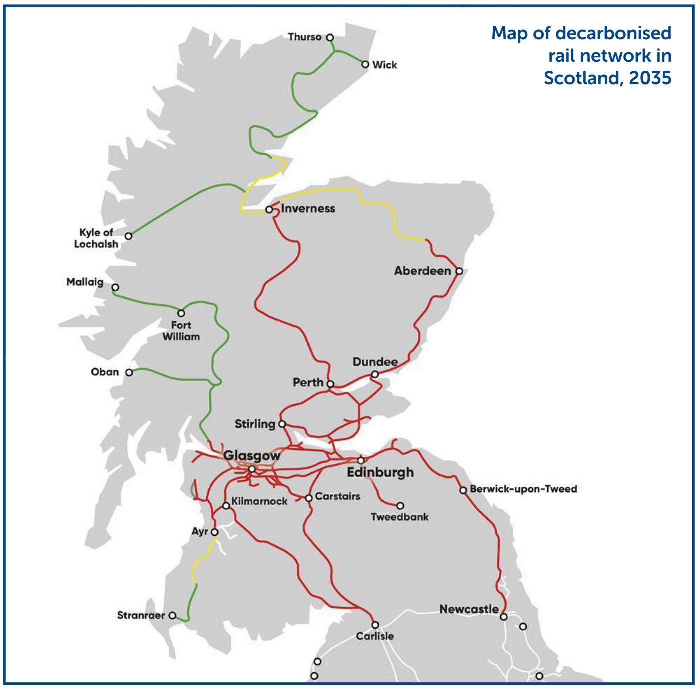


Demand spotlight: Rail

As we strive to achieve net zero carbon emissions, the power sector is not the only sector that will need to decarbonise. The rail sector has been identified by the Scottish Government as a sector where change is needed. Transport Scotland outlined that Scotland's rail services would be decarbonised by 2035. A large extent of the rail network in the central belt of Scotland has been electrified. The remaining parts of the network that require to be electrified are in the Borders and in our area in the north of Scotland.

The map to the right shows different routes where various solutions will be used to decarbonise the rail network. The routes outlined in red are where electrification will take place, routes shown in yellow will employ a temporary solution before electrification takes place and the routes in green will utilise alternative solutions which we have assumed to be either battery or hydrogen.

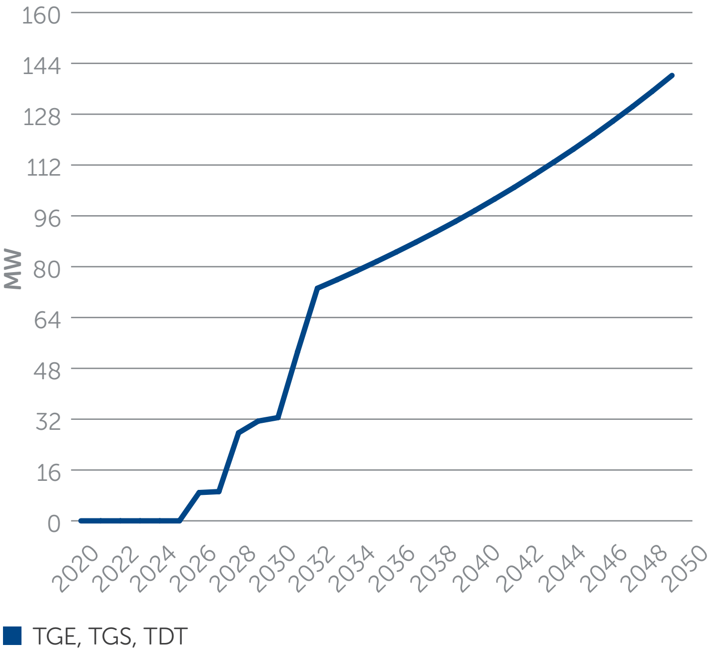
Utilising information about the efficiency of different fuel types, battery train charging times, and the annual growth rate of rail infrastructure in rural and urban regions, our modelling has been able to show how rail electricity demand could increase in the future. Across our three scenarios, the modelling shows that rail electricity demand could reach 140MW at Winter Peak by 2050.



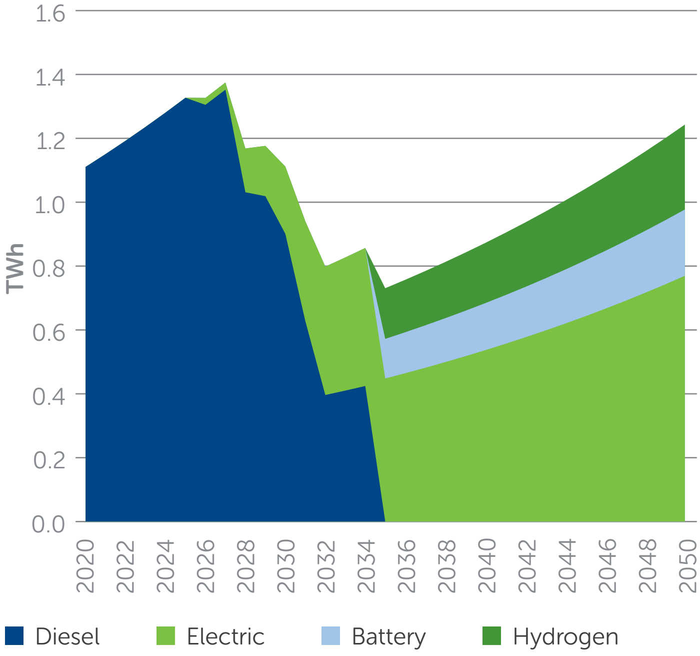
Map of decarbonised rail network in Scotland, 2035

Additionally, our modelling allows us to detail the annual rail demand by fuel type. Diesel demand peaks at 1.35TWh in 2027 before declining to 0TWh in 2035 due to other fuel types coming online. Electric demand begins around 2026 based on assumptions around when the decarbonisation plan may commence. Hydrogen and battery solutions come online in 2035 as these are likely to take longer to deploy at scale when compared to the electrification of routes.

Rail electricity demand at Winter Peak



Annual rail energy demand by fuel type



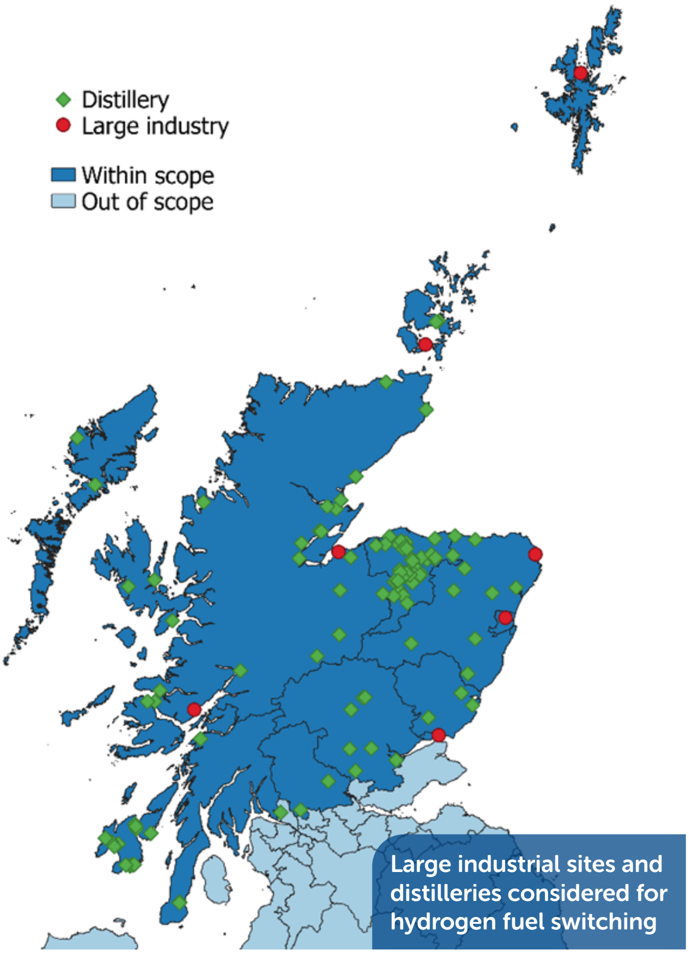
Demand spotlight: Hydrogen

Since late 2020, there has been press coverage on the potential for hydrogen to be utilised as a means to facilitate the reduction in greenhouse gas emissions. The recent UK Government Energy Security Strategy set out an aim to double the low carbon hydrogen production capacity to 10GW by 2030, with at least half of this coming from green hydrogen[1].

The development of hydrogen will be supported by a range of measures from the UK Government which has pledged £240 million towards a Net Zero Hydrogen fund, setting out of hydrogen business models and a revenue mechanism for private sector investment. The Scottish Government has committed £100 million funding to boost research, innovation development & demonstration of low cost clean hydrogen production between 2021 and 2026.

There are multiple pathways available to reach the net zero decarbonisation targets set forth by the Scottish and UK governments. Any given pathway will consist of a mixture of energy sources and technologies. Hydrogen has the potential to play a significant role in the energy transition. Below is an overview of how hydrogen is incorporated into each of our scenarios.

- **The Decelerated Transition** sees limited hydrogen deployment in the north of Scotland, with application based in the regions closest to the Acorn project in St Fergus, specifically, Aberdeen City and Aberdeenshire. Hydrogen production in this scenario is blue hydrogen[2] from the Acorn project along with green hydrogen produced from wind powered electrolysis. Hydrogen is used for decarbonisation of the highest emitting industrial sites in Aberdeen City and Aberdeenshire as well as in the transport sector for heavier types of vehicles in the region.
- **In The Green Society**, hydrogen deployment in industry and transport are expanded to the whole north of Scotland region, covering decarbonisation of large industrial sites and fuel for heavier types of vehicles (vans, buses and coaches, and trucks). Additionally, hydrogen is used for heating, through a partial conversion of the gas grid to distribute hydrogen. Hydrogen supply is predominantly blue hydrogen, produced through the Acorn project, with some green hydrogen from wind powered electrolysis. The north of Scotland becomes a net exporter of hydrogen, delivering hydrogen to the rest of Scotland for industrial use.
- **In The Green Economy**, use of hydrogen in the industry sector expands to smaller industries as well the larger industrial sites as seen in the Green Society, and hydrogen does not only supply fuel for heavy duty vehicles but also for private cars. There is also a higher deployment of hydrogen for heating, with a full conversion of the gas grid to distribute hydrogen. Hydrogen is also used in the power sector and the Peterhead Power Station[3] is converted to hydrogen. The north of Scotland becomes a net exporter of hydrogen to the rest of the UK.



Large industrial sites and distilleries considered for hydrogen fuel switching

[1] Green hydrogen is produced by using renewable energy to electrolyse water, separating the water into hydrogen and oxygen.
[2] Blue hydrogen is produced through steam methane reformation, where natural gas is reacted with steam to form hydrogen. Carbon capture and storage (CCS) is likely to be used to capture the carbon dioxide by-product from this process.
[3] Assumption made that Peterhead would be converted to hydrogen due to its proximity to the National Gas Transmission System

Co-location of hydrogen electrolysers

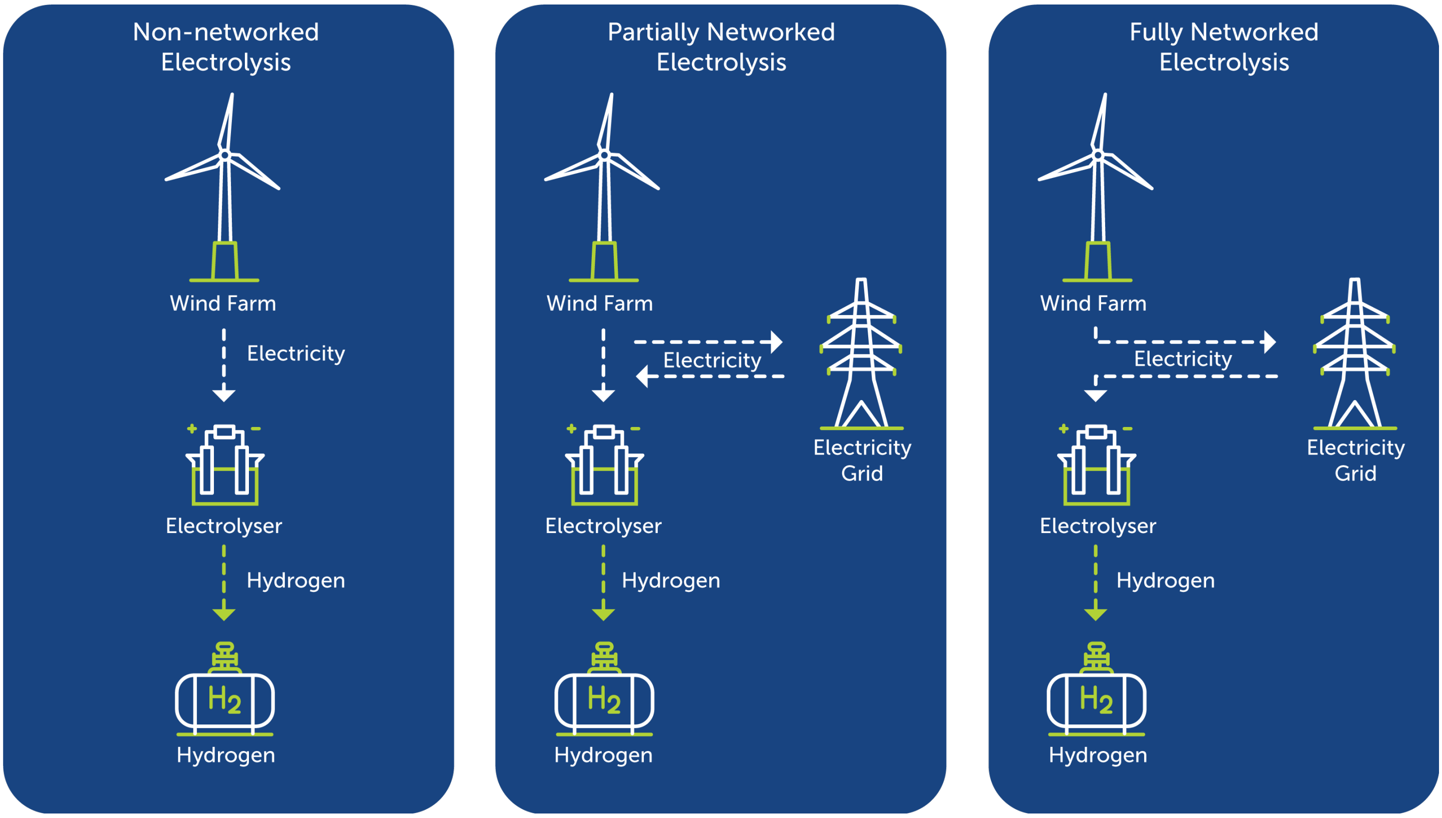
From our research, there are three potential ways that hydrogen electrolysers could be powered:

- Fully networked electrolysis
  - An electrolyser that draws all its electricity supply from the grid, with no direct connection to a renewable generator, is referred to as the fully networked case
- Non-networked electrolysis
  - This describes a case where electrolysers draw power directly from a wind farm, with no input or connection to the grid. This is sometimes referred to as the 'islanded' case, where electrolysers are co-located with wind farms.
- Partially networked electrolysis
  - This refers to electrolysers that draw the majority of their supply from wind farms but are able to draw electricity from the network when required.

In order for electrolysers to be profitable in the various configurations as shown above, the electrolyser would need to be operating at a 60% load factor (based on research from Element Energy and using current market costs of electrolysers).

We believe the fully networked electrolysis case is an unrealistic one, under current market arrangements, as electrolyser facilities will most likely obtain cheaper electricity prices by making direct contracts with wind farms or other generation sites.

In the non-networked electrolysis case, electrolysers are installed close to generation sites, most likely wind farms, and are able to draw electricity straight from these sites, bypassing the grid and eliminating the impact on the network. This is most likely to be used in some of the currently planned projects, such as the Dolphyn and Surf n' Turf.



However, in the majority of cases, the partially networked electrolysis case would most likely be used, meaning that electrolysers would draw the majority of their power from wind farms but when wind resource is low, they would draw upon the grid to meet their needs intermittently.

The impact of hydrogen production is complex and subject to a high degree of uncertainty, as it will depend on how the electrolyser plants are configured and, in the case of partially networked electrolysers, how much electricity they draw from the grid. For these reasons, the role of hydrogen remains a material uncertainty in our future energy scenarios.

Net zero pathways

One of the additions we made to our modelling this year was the inclusion of emissions of the various technologies used within each scenario which allowed us to determine if and when the scenarios achieve net zero. This analysis excludes infrastructure related emissions.

In order to be able to carry out the emissions modelling, we firstly had to divide the modelling into two sections: direct emissions and indirect emissions. Fuel carbon intensities (FCI) are applied to directly emitting technologies, such as gas boilers and petrol cars, and describe how much carbon dioxide is emitted for every unit of energy consumed.

Grid carbon intensities (GCI) are applied to indirectly emitting technologies, such as electric vehicles and non-hybrid heat pumps, and describe how much carbon dioxide is emitted for every unit of electricity generated. This is dependent on the type of generation used, whether these are powered by fossil fuels such as coal and gas, or whether they use renewable resources such as wind. The GCI used for our calculations has come from the ESO to ensure consistency with our 'Getting to Net Zero' report which was published in November 2021.
The charts below show the various net zero pathways for each scenario with and without BECCS as part of the grid carbon intensity.

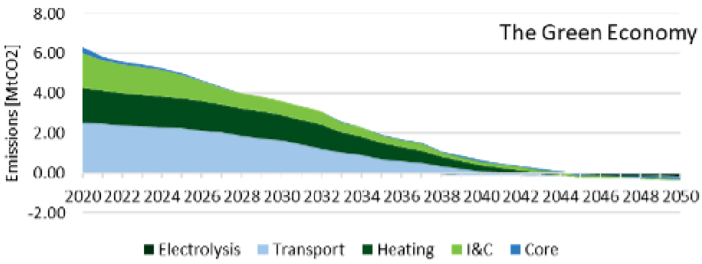
In order to achieve net zero within our scenarios, based on the various uptake rates of the different technology types, this will only occur if there are negative emissions for every unit of electricity generated. The Green Economy reaches net zero in 2045, achieving the Scottish Government target on time and resulting in net annual emissions of -0.31 MtCO2e by 2050 (i.e. the equivalent of 310 thousand tonnes of carbon dioxide are removed from the atmosphere).

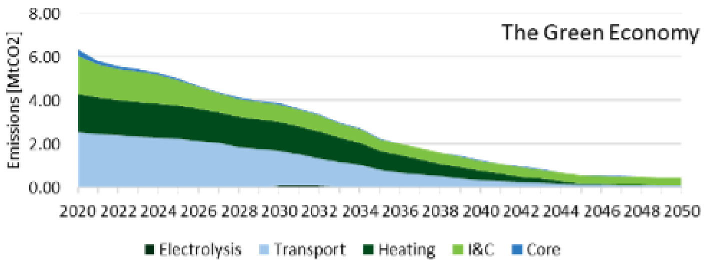
In The Green Society, the scenario achieves net zero one year earlier in 2044 and results in net annual emissions of -0.56 MtCO2e by 2050.

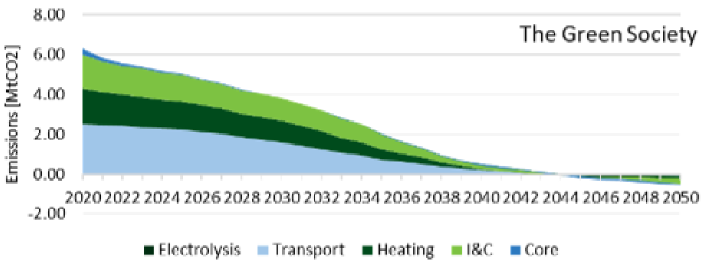
The Decelerated Transition does not meet any net zero targets with or without BECCS, reaching 1.81 MtCO2e of residual annual emissions by 2050.

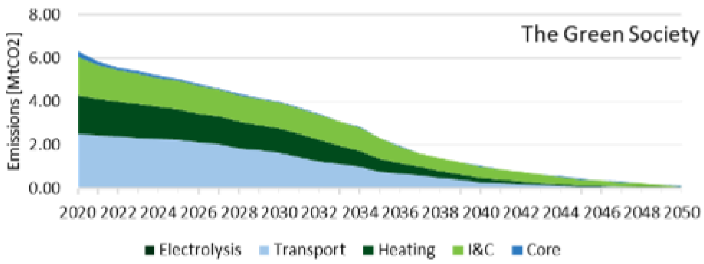
Includes BECCS

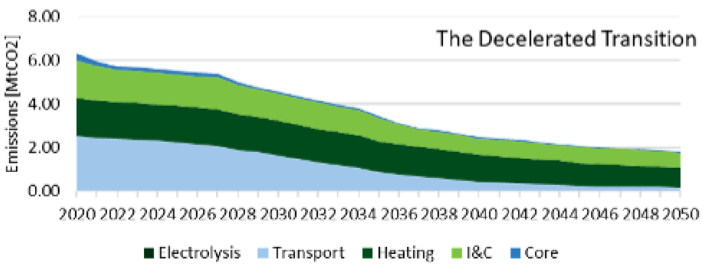
Excludes BECCS

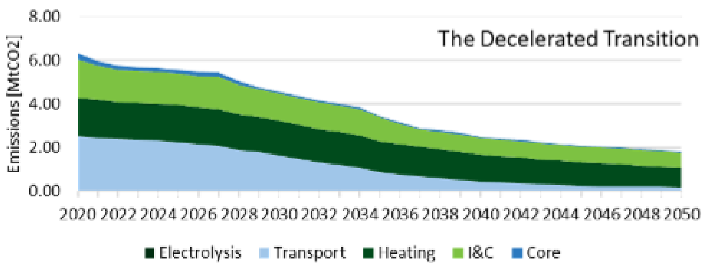












Scottish & Southern Electricity Networks

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Further analysis and engagement

There are two areas where further analysis will be undertaken in the next 12 months to identify the potential impact on the electricity network in the north of Scotland: hydrogen and onshore wind repowering.

Whilst we have carried out research into hydrogen during 2021, there is still a significant number of unknowns with regards to the deployment of the technology at scale in the north of Scotland. We will be looking to consult with developers around their hydrogen ambitions for existing or upcoming generation projects to test some of our assumptions.

For onshore wind repowering, we consulted with the developers on this topic back in 2018 however we think we may have been too early. We believe now is a good time to take another look at this topic as ROCs for some of the older sites in the north of Scotland will be ending around 2026.

We will be carrying out further stakeholder engagement, giving you the opportunity to provide information and input into the development of our North of Scotland Future Energy Scenarios.

We want to hear from you

We welcome any comments and feedback on this document.

This document and future North of Scotland Energy Scenario documents will be hosted on:
www.ssen-transmission.co.uk/information-centre/industry-and-regulation/future-energy-scenarios

If you would like to get in touch with the team to ask questions, provide feedback and comments or take part in our engagement activities then please use the following contact methods:

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