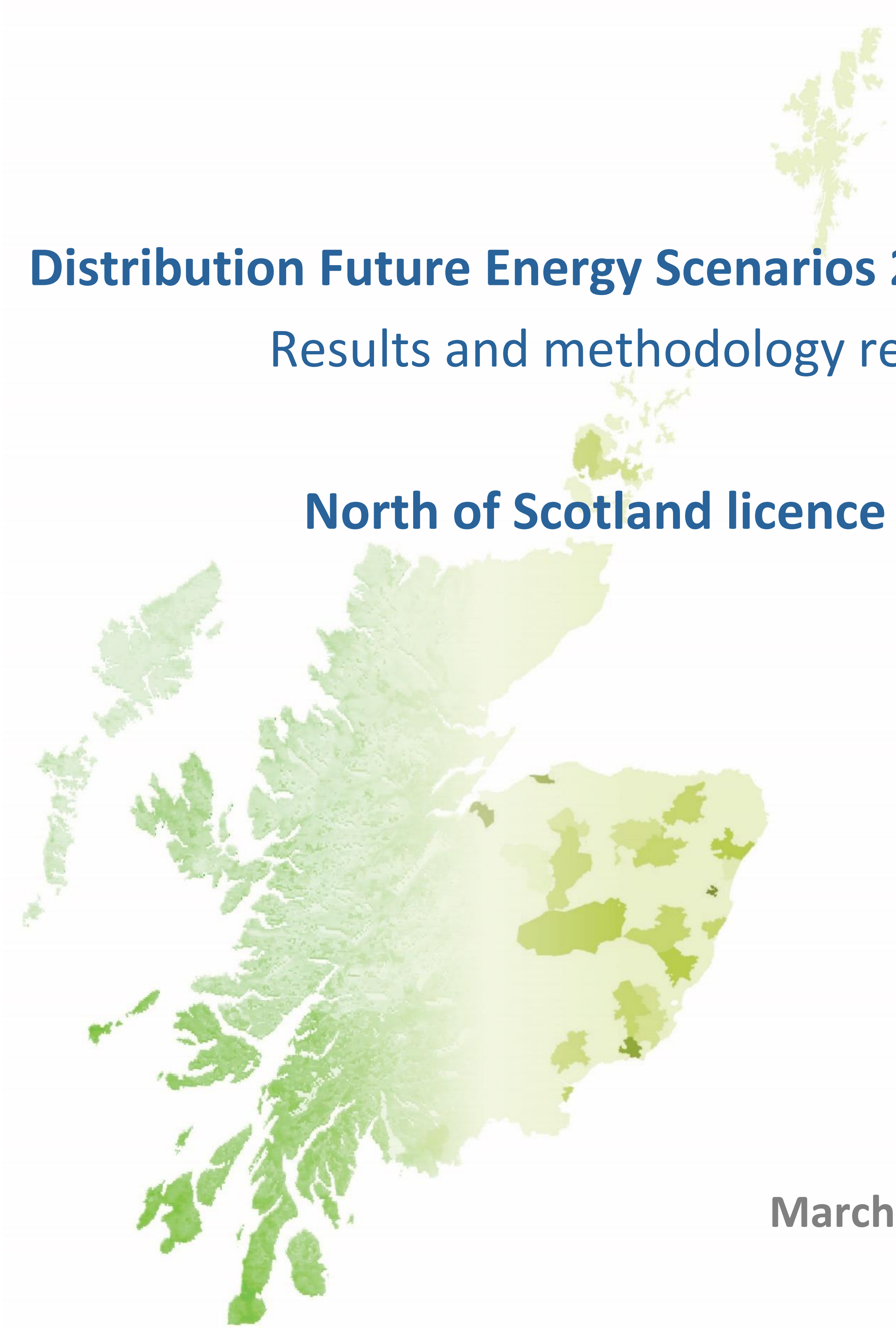
Distribution Future Energy Scenarios 2021

Results and methodology report



North of Scotland licence area

March 2022

regen
transforming energy

Scottish & Southern
Electricity Networks

This report was produced for	Scottish and Southern Electricity Networks (SSEN)
Issue date	4th March 2022
Version	Final version for publication
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Foreword

Scottish and Southern Electricity Networks (SSEN) Distribution is the electricity distribution arm of the FTSE-50 energy company, SSE. We serve over 3.8 million customers across the diverse and unique geographies of the north of Scotland and central southern England.

Our role has never been more important. The communities we serve depend on us to deliver a safe, reliable supply of electricity to their homes and businesses so they can thrive today and we are also working to deliver the infrastructure to create a net zero tomorrow. That means readying our network for the uptake in low carbon technologies such as electric vehicles, heat pumps and local renewables, which will need smart connections to be able to interact with the grid.

We welcome the UK and Scottish Governments' commitments to this transition, including their targets to decarbonise by 2050 and 2045 respectively and to ban the technologies that are now most responsible for the UK's contribution to climate change, namely petrol and diesel vehicles and boilers powered by fossil fuels. These targets improve clarity to the market and consumers and allow SSEN to plan for the anticipated three-fold increase in electricity demand that these technologies will bring.

SSEN is working to anticipate the location and timing of new demand to ensure the measures are in place to flex supply and demand to balance the grid, or to reinforce the network. The work that Regen has undertaken here and for previous reports is crucial in supporting informed decision making which enables timely and cost-effective network management.

Our Business Plan, published in December 2021, draws on these DFES figures to inform our commitments over the next regulatory price control period, during which the building blocks must be put in place for net zero by 2050. We will invest nearly £4bn in our network without increasing our costs on customers' bills, which means by 2028 we will be able to facilitate 1.3 million electric vehicles and 800,000 heat pumps on our network, as well as 8GW of distributed generation and storage. This will be supported by development of new market models to allow consumers to interact with the energy system manage their own usage and costs. We are also working to empower local communities and propose mechanisms to enable strategic investment in our network.

Lastly, SSEN is committed to a fair transition that leaves nobody behind. The net zero future offers considerable opportunities but also the risk that new forms of unfairness will be embedded into the system. With the right data, forecasting, regulations, skills and investment, we can ensure a transition that is smart and fair.

I'd like to thank Regen for their work on this essential and timely report and to thank all our stakeholders, including local and regional authorities, for their ongoing engagement and contributions to our research. We look forward to continuing to work closely with them to deliver net zero.

Andrew Roper

DSO Director, Scottish and Southern Electricity Networks

Introduction

This report provides a summary of the methodology and results of the 2021 edition of the Distribution Future Energy Scenarios (DFES) for the North of Scotland electricity distribution network licence area[1], operated by Scottish and Southern Electricity Networks (SSEN).

The DFES analysis provides high granularity scenario projections for the growth (or reduction) of energy generation (low carbon and conventional), demand and storage technologies which are expected to connect to the distribution network. This analysis helps SSEN to understand how the demands on their networks are likely to change over the next decade and beyond.

The DFES forms part of a wider, integrated network planning and investment appraisal process, as outlined in Figure 1. The projection datasets allow SSEN's network planning teams to model and analyse different future load scenarios in specific geographic areas. Producing future energy scenarios is now a business as usual activity for electricity networks as part of their requirement to produce forward looking Network Development Plans. The DFES process has also directly supported the development and evidence base that has underpinned SSEN's RIIO-ED2 business plan[2] and draft determination.

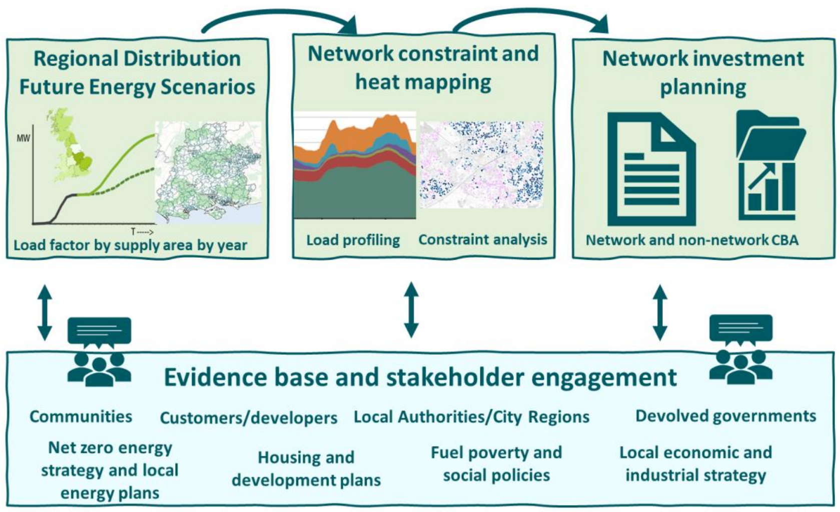


Figure 1: Wider network and investment planning process that DFES analysis feeds into

As its framework, the DFES uses four national energy scenarios, based on the National Grid ESO Future Energy Scenarios 2021 publication[3]. The DFES projections are, however, heavily influenced by input from local and regional stakeholders, including local authorities, the Scottish Government and representatives from the Scottish Islands. Regional growth factors and a detailed analysis of the pipeline of known projects within SSEN's North of Scotland licence area underpins the near-to-medium term analysis and scenario projections. The DFES seeks to provide a granular and bottom-up assessment of the impact of the net zero energy transition in specific regions.

As an annual publication, the analysis has also built on the SSEN DFES 2020 analysis[4], reconciling many of the individual technology projections against last year's results. This report provides an overview of Regen's DFES methodology, a summary of the stakeholder engagement input and some of the headline 2050 scenario projections produced for the North of Scotland licence area. The report also includes an index of individual technology summaries, showing detailed results, evidence and assumptions used.

[1] Also referred to as the Scottish Hydro Electric Power Distribution (SHEPD) licence area

[2] See SSEN *Powering Communities to Net Zero* ED2 business plan website and document: https://ssenfuture.co.uk/

[3] See FES 2021: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021

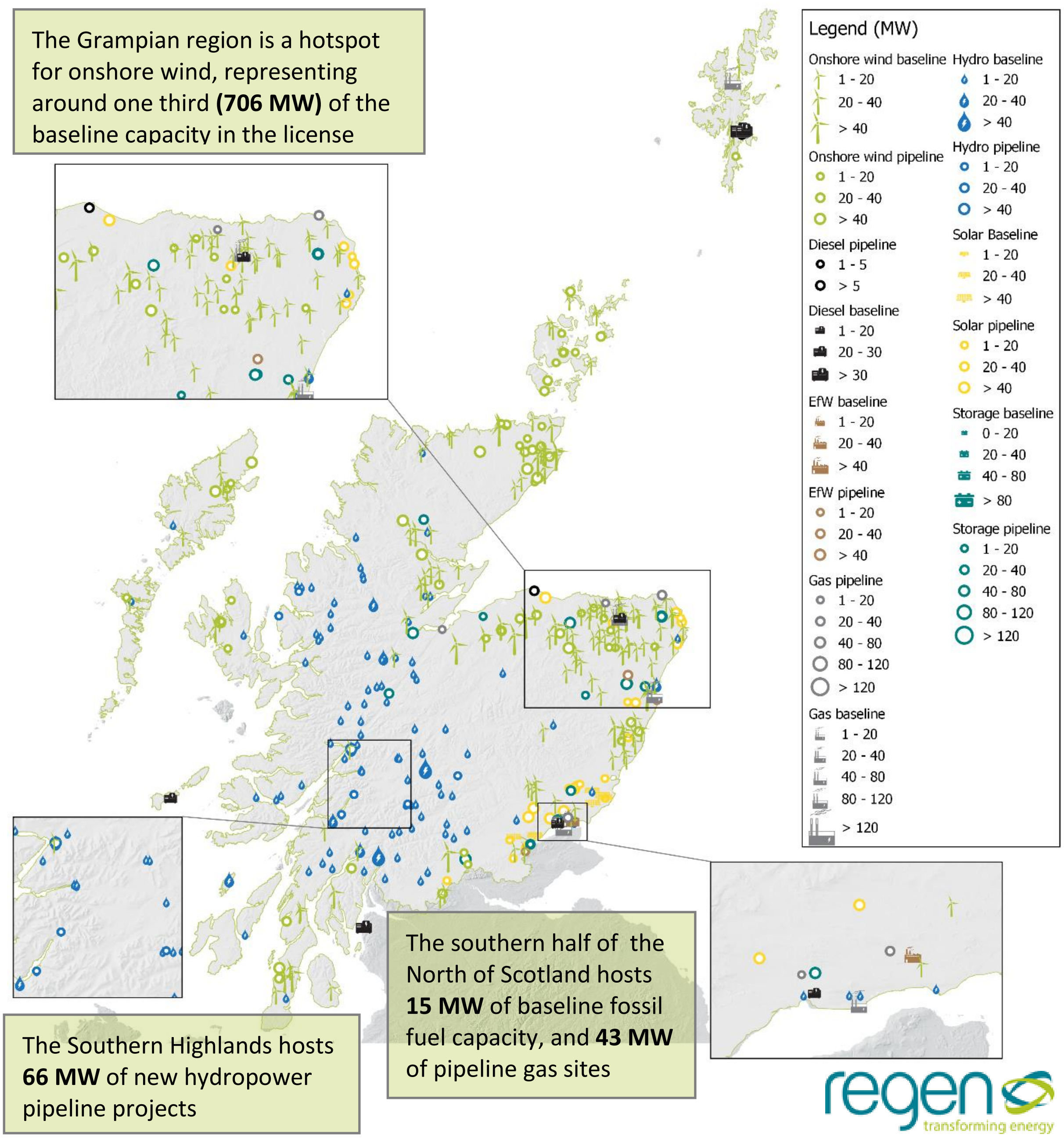
[4] See SSEN DFES 2020: https://www.ssen.co.uk/WorkArea/DownloadAsset.aspx?id=20283

The SSEN North of Scotland Licence Area

The North of Scotland electricity distribution licence area covers the area served by the low voltage, 11 kV and 33 kV network supplying 780,000 customers across northern Scotland and the Scottish Islands.

This area spans the southern borders of Perth and Kinross, Dunblane and Loch Lomond, to the northern coastline of Scotland. It also includes all of the Scottish Islands groups, such as Shetland, Orkney, the Outer Hebrides and the Small Isles.

The licence area includes a significant number of remote and rural areas, such as the Highlands, Lochside regions and the Cairngorms and Trossachs national parks. It also includes more urbanised areas such as Aberdeen, Dundee, Inverness and Fort William.



The licence area includes 14 local authority regions (either wholly or partially). These are: Aberdeen City, Aberdeenshire, Angus, Argyll and Bute, Dundee City, Highland, Moray, Na h-Eileanan Siar, North Ayrshire, the Orkney Islands, Perth and Kinross, the Shetland Islands, Stirling and West Dunbartonshire.

The total capacity of distribution network connected generation in the licence area has steadily increased over the past 10 years to over 3.4 GW as of the end of 2020. Over two thirds of this growth in connected generation capacity has come from distributed onshore wind development, with capacity increasing from 1 GW in 2011 to almost 2.1 GW in 2020.

Unlike much of the rest of the UK, the licence area also has a notable amount of distributed hydropower, with 837 MW connected as of 2020 (an increase from 600 MW in 2011).

The remaining mix of current generation capacity includes:

- A relatively low deployment of solar PV (132 MW)
- A number of back-up diesel generators (126 MW) supporting the Scottish Islands
- A range of waste-drive generation technology assets (93 MW)
- A number of small-scale fossil gas (methane) generation sites (41 MW).

The largest individual generation site connected to the distribution network in the licence area is the 77 MW Clashindarroch onshore wind farm[5].

Electricity demand in the licence area can be considered atypical, partially due to a disproportionately high number of homes with electrically fuelled heating. This is due to significant regions of the licence area that are not connected to the UK's gas supply network.

Driven by strong Scottish Government policy ambition[6], the licence area is beginning to reflect some of the low carbon technology adoption that will be required to deliver the Scottish national target of net zero emissions by 2045.

Adoption of low carbon technologies includes just under 4,000 battery electric cars currently registered in the licence area, around 60 MW of operational electric vehicle charging capacity and over 24,000 homes and businesses with a type of heat pump installed to date.

[5] See Vattenfall website: https://group.vattenfall.com/uk/what-we-do/our-projects/clashindarroch

[6] See Scottish Government *Securing a green recovery on a path to net zero: climate change plan 2018-2032 update*, December 2020: https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/

Wider context for SSEN DFES 2021

2021 has been another transformative year for the UK energy system, the broader energy sector and for the UK in general. This includes overarchin g global concerns such the Covid-19 pandemic, the UK's hosting of the COP26 climate conference, as well as a number of recent energy policy commitments by the UK and Scottish government. UK energy consumers have also felt the impact of events in the wider energy market, such as gas price spikes and the collapse of several small-scale energy suppliers.

Covid-19

Both the UK and Scotland have been managing the twists and turns of the Covid-19 pandemic, responding to the omicron variant and the move towards restrictions and measures being eased at the end of 2021 and into 2022. The pandemic has continued to impact the everyday life of individuals, households, businesses and developers alike, as well as impacting organisations like SSEN, who are responsible for maintaining a stable electricity supply to end consumers. This unprecedented public health emergency affected the building of energy projects, new housing and commercial developments in 2020 and whilst the impact of Covid-19 restrictions begins to lessen, the pandemic continues to impact the progress of some energy projects and this is reflected in the DFES scenario modelling.

COP26

2021 also saw the UK host the United Nations Climate Change Conference (COP26) in Glasgow in November[7], leading to the Glasgow Climate Pact.[8] The goals agreed at the conference that are relevant to the energy sector included:

- A commitment to the significant phasing-down of the use of coal internationally.
- A commitment to reduce methane emissions globally, with 100 countries signing up to the *Global Methane Pledge* to reduce methane emissions by 30% by 2030.
- An increased commitment to investment in renewable energy.
- An acceleration of the uptake of electric vehicles, including:
    - Many of the major global vehicle manufacturers committing to 100% zero emission vehicle production by 2035.
    - 110 major international companies signing up to the *EV100 Pledge* to operate fully zero-emission vehicle fleets by 2030.

These far-reaching commitments may feel distanced from specific project developments or technology adoption rates in the licence area. However, the UK and Scottish governments have continued to enact a package of policies designed to increase ambition and action on decarbonisation. In a different sense, the hype surrounding the build up to and outcomes of COP26, has resulted in an increased awareness of climate change, the energy crisis and the pressure on world leaders to act[9].

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[7] See UK COP26 website: https://ukcop26.org/cop26-goals/

[8] See COP26 Glasgow Climate Pact: https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf

[9] See YouGov statistics summary, *What impact did COP26 have on public opinion?*, Nov 2021: https://yougov.co.uk/topics/politics/articles-reports/2021/11/22/what-impact-did-cop26-have-public-opinion

UK government strategy

Building on the UK government's 'ten point plan' published towards the end of 2020, across the latter half of 2021, the Department of Business, Energy and Industrial Strategy (BEIS) published a suite of other strategy documents defining more specific policy ambitions and targets related to net zero emissions, power, hydrogen and heat (see Figure 2).

Figure 2: UK government energy strategies published mid/late 2021

Within the **Net Zero Strategy** were a number of specific sector pathways, reducing UK emissions from c.450 $MtCO_2e$ in 2020/21 to c.150 $MtCO_2e$ by 2037. For the power sector, the strategy set a target to fully decarbonise the electricity system by 2035, a specific offshore wind capacity target of 40 GW by 2030 and more support to deploy storage and other forms of flexibility. Whilst the growth of offshore wind will be on the transmission network, the North of Scotland distribution network is expected to see a significant growth in onshore wind capacity. Although Scotland has seen less solar capacity deployment than areas further south, there are areas of higher irradiance in the south and east of SSEN's licence area which could now become viable for solar energy projects in a net zero scenario.

The Net Zero Strategy also set a target for hydrogen production, aiming for 5 GW of production capacity by 2030. This was supported by the publication of an accompanying **Hydrogen Strategy**, outlining an interim aspirational target of 1 GW of production capacity by 2025, as well as a £240m Net Zero Hydrogen Fund and a £60m Low Carbon Hydrogen Supply Competition. The introduction of such a capacity target and supporting innovation funds could be the trigger point to encourage the development of hydrogen electrolysis capacity across the UK, including in SSEN's licence areas. Although larger hydrogen plants may be connected to the transmission network, the distribution network could also provide the input electricity to these projects, especially in hydrogen hub areas.

The much-delayed **UK Heat and Buildings Strategy**[10], published in October 2021, sets out the government's ambition to decarbonise homes and workplaces, while at the same time creating 240,000 new green jobs. In terms of specific measures, the strategy restates the target to deploy 600,000 heat pumps per year by 2028, starting with a £5,000 Boiler Upgrade grant scheme.

These measures will help the developing heat pump market which has shown some recent signs of

[10] Heat and Building Strategy https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1036227/E02666137_CP_388_Heat_and_Buildings_Elay.pdf

growth from a very low base. There is still however a lot of doubt around the UK's overall progress towards heat decarbonisation and ability to reach the targets that have been set[11].

In other policy areas, the DFES has been produced at a time when the industry is awaiting the outcome of Ofgem's **Network Access and Charging Significant Code Review (SCR)**. This policy could have a significant impact on both generation and demand projects wishing to connect to the distribution network. The impact of the SCR is not clear cut as different provisions could work both for, and against, new connections. Reducing up front connection costs, with "shallower" connection charges, could increase the rate of deployment of low carbon projects. However, this could be offset by higher on-going network charges and by a requirement for distribution network connected generators to pay additional transmission network costs. These factors are discussed in more detail as they pertain to each technology in the different scenarios.

The most recent "minded-to" announcement from Ofgem[12] however, suggests that the impacts of the SCR may be less dramatic than previously thought. Upfront network charges will be reduced but a "High Cost Cap" threshold will be in place to dissuade the highest cost connections. The future of ongoing network charges is delayed, as is the decision to wider the payment of transmission network charges.

Scottish Government strategy

As in 2020, the Scottish Government's engagement with the DFES 2021 process has been invaluable. Specific points of input are presented in the Stakeholder Engagement section and within the relevant technology summary sheets. More generally the DFES has tried to reflect the higher level of ambition towards net zero in Scotland at both a national and local authority level. This includes the targets to achieve net zero by 2045, and higher level of growth for technologies like hydrogen, marine energy and offshore wind. Regional actions taken under the Local Heat and Energy Efficiency Strategies (LHEES) have been reflected in a higher level of uptake of low carbon heating technologies.

New policy announcements in 2021 have included the updated Climate Change Plan, Scotland's own Heat and Building Strategy and a draft national planning framework to deliver net zero.

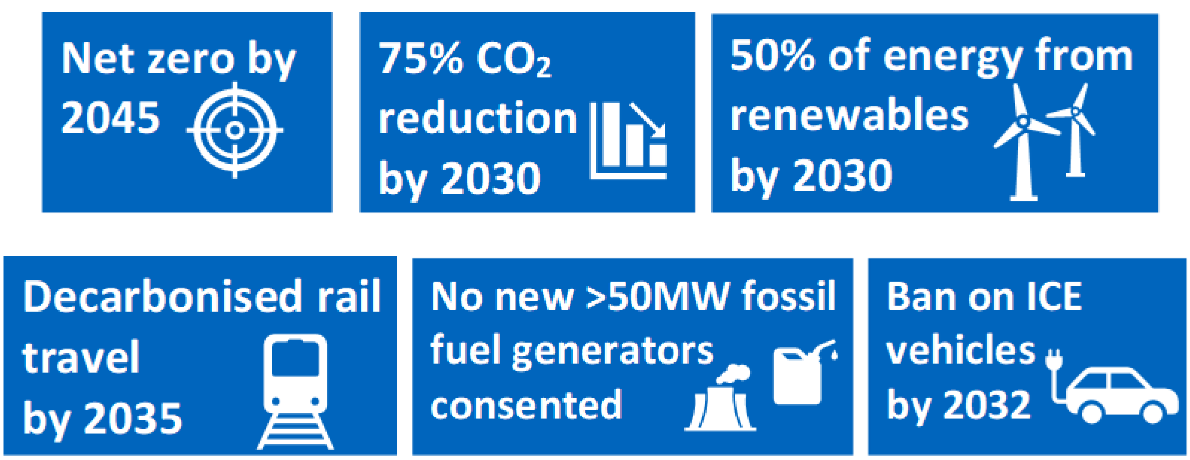


Figure 3: Scottish Government high level energy and decarbonisation policy targets

[11] See for Example BEIS Select Committee Report and Enquiry https://committees.parliament.uk/committee/365/business-energy-and-industrial-strategy-committee/news/160772/net-zero-decarbonising-heat-in-homes-governments-approach-lacks-strategic-direction-says-business-committee/ February 2022

[12] Ofgem SCR Minded to consultation January 2022 https://www.ofgem.gov.uk/publications/access-and-forward-looking-charges-significant-code-review-updates-our-minded-positions

Activity in the wider energy sector

Alongside COP26 and net zero policy changes, the big news in the energy sector has been the spike in gas[13] and electricity wholesale prices, and the impact this has had on both consumers and electricity supply companies[14].

Modelling short term market volatility into long term growth projections for individual technologies is extremely difficult. In the case of the recent gas prices rises however, there is a strong argument that the global market has passed a watershed and is now entering a period when gas prices will remain high in the medium term, or at least extremely volatile. This, coupled with the decline of the UK's gas production, should accelerate the transition to all forms of renewable energy including energy storage and green hydrogen.

As a more direct consequence of the gas price rise, electricity wholesale prices have also increased which has created a market where subsidy free wind and solar projects are far more likely to be commissioned. There should also be an increase in the deployment of energy efficiency measures and low carbon heating, although this may take some time to materialise.

[13] See BBC News article, *Why are gas prices so high and what is happening to fuel bills,* January 2021: https://www.bbc.co.uk/news/business-58090533

[14] See The Guardian article, *Zog Energy becomes 25th UK supplier to go busy in three months,* Dec 2021: https://www.theguardian.com/business/2021/dec/01/zog-energy-becomes-25th-uk-supplier-to-go-bust-in-three-months

DFES methodology

The broad DFES methodology can be summarised under five key areas or stages:

	The **technologies** that are in the scope of the future scenario analysis.
	The **scenario framework** that is used to define the overarching societal, technological and economic 'worlds' that DFES scenario projections sit within.
	The **stakeholder engagement evidence and input** used as a direct input to the scenario modelling.
	The **analysis stages** that are undertaken, for each technology, when developing and modelling scenario projections.
	The **geographical distribution** of the projections down to sub-regional (11kV substation) or local (Low Voltage) levels.

Technologies in-scope

The technology scope of the SSEN DFES includes technologies and load sources that directly connect to SSEN's electricity distribution network assets in the North of Scotland – see Table 1. DFES analysis does not include projections for any technologies directly connected to the transmission network.

Table 1: DFES Technologies and demand sources

Electricity generation technology classes	Electricity storage technology classes	Future disruptive sources of electricity demand
Renewable energy generation technologies: solar PV, onshore wind, offshore wind, hydropower and marine. **Waste and bio-resource electricity generation technologies:** biomass, landfill gas, sewage gas and anaerobic digestion from food waste and other feedstocks. **Fossil-fuel electricity generation technologies:** diesel and natural gas fuelled generators.	**Battery storage:** Grid-scale, commercial and domestic battery storage asset classes. **Liquid air energy storage (LAES)** Also referred to as cryogenic energy storage, demonstrator scale LAES plants connecting to the distribution network.	**Electric vehicles**: cars, vans, motorbikes, LGVs, HGVs and buses. **Electric vehicle chargers**: on-street residential, off-street domestic, car parks, destination, workplace, fleet/depot, en-route local and en-route national. **Electricity fueled heating and cooling technologies:** air source and ground source heat pumps, hybrid heating, direct electric heaters and domestic air conditioners. **Hydrogen electrolysers** **New properties:** strategic housing developments and commercial and industrial developments.

The National Grid ESO Future Energy Scenarios 2021 framework

As with previous DFES assessments, the SSEN DFES 2021 has used the National Grid ESO Future Energy Scenarios 2021[15] (FES 2021) as the overarching framework to base the analysis upon. As well as providing a scenario framework, the FES 2021 provides:

- National system-wide and technology sector-specific assumptions, some that vary by scenario
- National and regional (where available) projections to reconcile DFES projections against
- Technology and sub-technology definitions, using industry standard “Building Block” definitions

The FES 2021 scenario framework is based on two key axes; **the speed of decarbonisation** and **the level of societal change**, as summarised in Figure 4. Whilst some scenarios see similar or aligned projections in the near, medium or even long-term for some technologies, there are other aspects of the energy system that have very different outcomes, depending on the scenario. A general description of each of the scenarios can be found in Table 2. The various technology summary sections within this report also outline specific scenario variances seen under each technology and how the DFES applies them.

Where available, FES 2021 grid supply point (GSP) projection data has been used to provide a SSEN DFES 2021 to FES 2021 reconciliation, for each of the technology building blocks. In some instances, regional building blocks were not available or not directly comparable, due to sub-technology division. In these cases, national FES 2021 projections have been used to complete a more general reconciliation

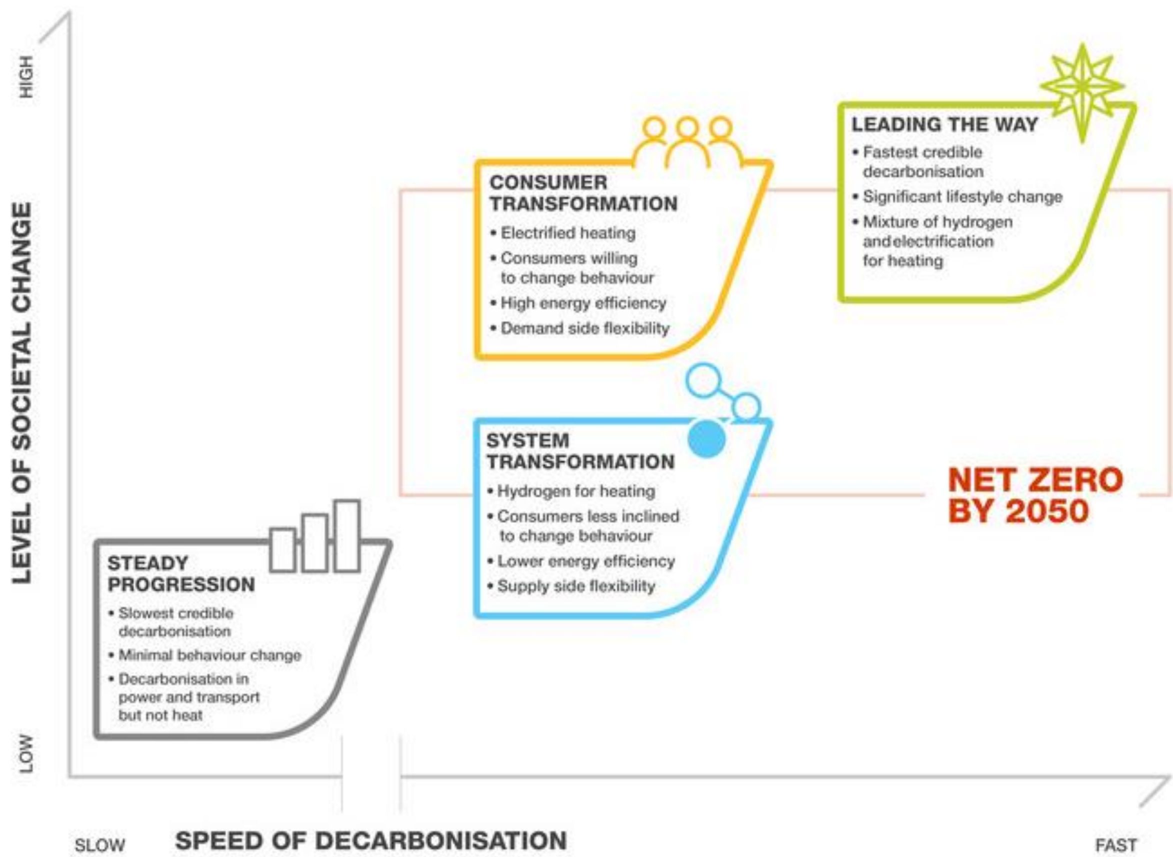


Figure 4: Future Energy Scenarios 2021 framework, National Grid ESO

[15] See National Grid ESO *Future Energy Scenarios 2021*: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021

Table 2: FES 2021 scenario descriptions. Source, credit and description wording: National Grid ESO FES 2021, https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021/scenarios-net-zero

National Grid ESO FES 2021 scenario	High level description *Wording sourced from National Grid ESO FES 2021 publication
Leading the Way *Meets GB net zero targets by 2048*	Assumes that Great Britain decarbonises rapidly with high levels of investment in world-leading decarbonisation technologies. FES 2021 assumptions in different areas of decarbonisation are pushed to the earliest credible dates. Consumers are highly engaged in reducing and managing their own energy consumption. This scenario includes more energy efficiency improvements to drive down energy demand, with homes retrofitted with insulation such as triple glazing and external wall insulation, and a steep increase in smart energy services. Hydrogen is used to decarbonise some of the most challenging areas such as some industrial processes, produced mainly from electrolysis powered by renewable electricity, and no hydrogen production from natural gas.
Consumer Transformation *Meets GB net zero targets by 2050*	The 2050 net zero target is met with measures that have a greater impact on consumers and is driven by greater levels of consumer engagement. A typical homeowner will use an electric heat pump with a low temperature heating system and an EV. They will have made extensive changes to improve their home's energy efficiency and most of their electricity demand will be smartly controlled to provide flexibility to the system. The system will have higher peak electricity demands managed with flexible technologies including energy storage, demand-side response and smart energy management
System Transformation *Meets GB net zero targets by 2050*	The typical domestic consumer will experience less disruption than in Consumer Transformation as more of the significant changes in the energy system happen on the supply side, away from the consumer. A typical consumer will use a hydrogen boiler with a mostly unchanged heating system and an EV or a fuel cell vehicle. They will have had fewer energy efficiency improvements to their home and will be less likely to provide flexibility to the system. Total hydrogen demand is high, mostly produced from natural gas with carbon capture and storage.
Steady Progression *Does not meet GB net zero targets by 2050*	There is still progress on decarbonisation compared to the present day. However, it is slower than in the other scenarios. While home insulation improves, there is still heavy reliance on natural gas, particularly for domestic heating. Electric vehicle (EV) take-up grows more slowly, displacing petrol and diesel vehicles for domestic use; however, decarbonisation of other vehicles is slower with continued reliance on diesel for heavy goods vehicles. In 2050 this scenario still has significant annual carbon emissions, short of the 2050 net zero target.

DFES analysis stages

The SSEN DFES analysis follows a four-stage process where, for each of the technologies in-scope:

1. The **historic deployment** is investigated and the **existing baseline** of operational or connected projects is established. For this assessment, the baseline year is defined as the end of 2020.
2. The **near-term development pipeline** is then assessed, recording and reviewing projects with network connection offers or planning applications. For technologies with strong pipeline evidence, the range of outcomes across the scenarios may be quite narrow in the near-term.
3. **Medium and long term projections** are then modelled under each scenario out to 2050. Depending on the technology, a much higher level of variation can be seen across the four scenario results over the 2030s and 2040s.
4. Annual licence area projections of either MW of capacity (e.g. onshore wind) or the number of units (e.g. heat pumps) are then **geographically distributed** across the licence areas.

There is a degree of scenario variation which can increase over time and may depend on the technology. This results in a widening of the projected outcomes across the four scenario results by 2050:

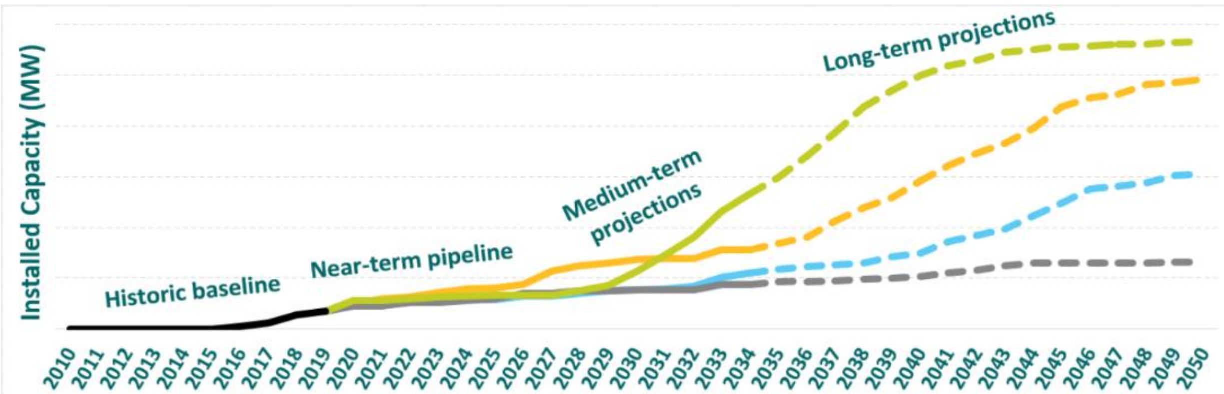


Figure 5: Illustrative stages of DFES scenario analysis

Technology and scenario uncertainty

When developing scenario projections for a broad range of technologies and sources of demand, a number of uncertainties inevitably influence the assumptions that are made and the projection outcomes that are determined. This uncertainty can range by technology and over time.

In the near-term, DFES projections are heavily based upon the analysis of known pipeline projects and new developments. Projects are researched using SSEN's connection database, national and local planning portals, Capacity Market auction registers and through direct discussions with project developers, sector representatives and other stakeholders.

Over the medium and longer-term, projections tend to reflect the underlying scenario assumptions defined for each technology. This is also augmented by levels of certainty provided by e.g. regional and national policies. Some of the uncertainties in the DFES analysis include:

1. The range of different outcomes assumed across the FES 2021 scenarios themselves.
2. National government, devolved government, regional and local policy uncertainty.
3. Commercial and financial uncertainty.
4. Technology development and capability uncertainty.
5. Consumer adoption and behaviour uncertainty.
6. Local spatial distribution factors.
7. Transmission vs distribution network connection uncertainty.

Whilst important to highlight areas of uncertainty, the future of energy in the UK and Scotland is becoming more focused, with the adoption of legally binding net zero emissions targets and the emergence of strategies and government consultations. This includes policy commitments around heat pumps, internal combustion vehicles, renewable energy and hydrogen – to name a few. Therefore, when assessing scenario uncertainty in the DFES, some key underlying assumptions can be made:

- Distributed renewable energy generation capacity is very likely to significantly increase
- Unabated fossil fuel electricity generation is very likely to decline
- The shift to more decentralised energy generation assets will continue (to some degree)
- The electrification of transport is already in progress and will accelerate significantly
- Hydrogen has a key role to play for industrial processes and some forms of transport
- The production of low-carbon hydrogen is inevitable, but its scale and location is unclear
- Further energy efficiency deployment is vitally needed in both homes and businesses
- The electrification of heat will increase, although there remains some uncertainty over the role that hydrogen boilers and heat networks could play in some areas.

At an individual technology level, uncertainty is considered as a key part of the analysis and is reflected in the range of scenario outcomes presented. Specific uncertainties, and an overview of the technology-specific assumptions that have been made, is summarised in each of the technology summaries.

Granularity and geographical distribution of the DFES

A key stage of the DFES analysis is to provide an estimation of the geographic spread of the modelled scenario projections across the licence area. This provides granular, locationally broken-down data that the SSEN Network Planning teams can use to inform the need for long-term network investment at specific locations or for individual substation assets.

The DFES uses a method to geographically distribute licence area projections down to so-called **Electricity Supply Areas** (or ESAs). An ESA is a geographical zone representing a block of demand or generation, as visible from the distribution network and sharing upstream network infrastructure.

The DFES uses two levels of ESA distribution modelling, depending on the technology (see Figure 6).

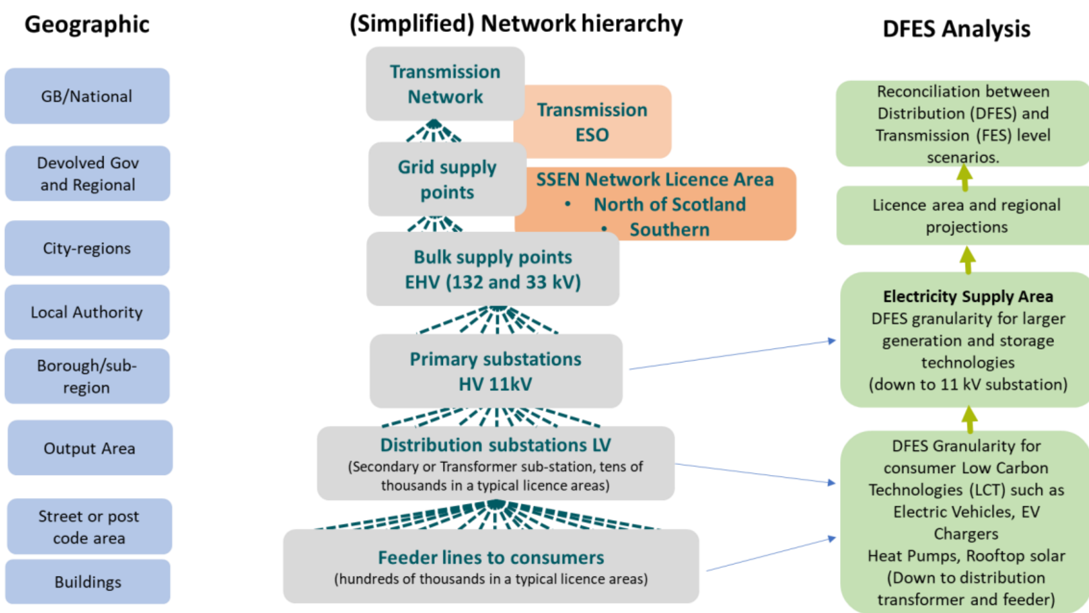


Figure 6: Network hierarchy that informs DFES geographic distribution to ESA

In the North of Scotland licence area for large generation and storage technologies, projections are distributed to approximately 500 individual 11 kV primary ESAs, which in urban areas such as Dundee or Aberdeen would equate to a group of post codes or a small borough. In rural areas, this could equate to a wider area covering part of a county. The accompanying DFES projection dataset has been designed so that it can be aggregated up to support network analysis at higher voltage levels, or to provide data aggregated to local authorities or other regional boundaries.

For smaller low carbon technologies (specifically EVs, EV charger capacity, domestic heat pumps, rooftop PV and domestic battery storage), scenario projections have been distributed down to the lower voltage levels. This equates to either secondary distribution substation or individual LV feeder lines serving small groups of customers. This level of granularity corresponds to roughly a post code or street level analysis. The precision of this very granular distribution analysis should be treated with caution, especially looking out to 2050. The distribution of technology deployments is still based on a series of high-level assumptions and weighted distribution factors. The analysis does, however, enable SSEN network planners to model the potential impact of demand and technology changes on the low voltage network and to understand the scale and range of network reinforcement that might be required.

The spatial distribution factors that underpin this ESA modelling are described in more detail within each of the individual technology summaries. These factors are based on data gathered from a wide range of datasets including Ordnance Survey AddressBase, Department for Transport road traffic flow data, Census Output Area data, affluence and demographic data, postcode statistical data and individual property EPC data. Engagement with local authorities and Scottish Island stakeholders has also specifically influenced the spatial distribution factors for the SSEN DFES 2021. A summary of the spatial distribution granularity by technology is shown in Table 3 and Figure 7.

Table 3: Summary of the granularity of SSEN DFES spatial distribution, by technology building block

Level of DFES granularity and distribution	North of Scotland	Southern	DFES building blocks technologies
Electricity Supply Areas (ESAs) **(Primary 11 kV substation)**	505	933	• Electricity generation except rooftop PV • Grid and commercial scale battery storage • Liquid air energy storage • Hydrogen electrolysis • Air conditioning • New housing • New commercial property developments • EVs – HGVs, buses, motorcycles.
Low Voltage secondary substation 'transformers'	48,789	55,062	• Commercial EV chargers (Car park ; Destination ; En-route ; Fleet ; Workplace) • Non-domestic heat pumps
Feeder lines to consumers	114,891	349,097	• Electric Vehicles – Cars • Electric Vehicles – LGVs • Domestic off-street chargers • Residential on-street 7 kW chargers • Heat pumps (hybrid and non-hybrid) • Small scale Rooftop Solar < 10 kw • Direct electric heating • Domestic battery storage

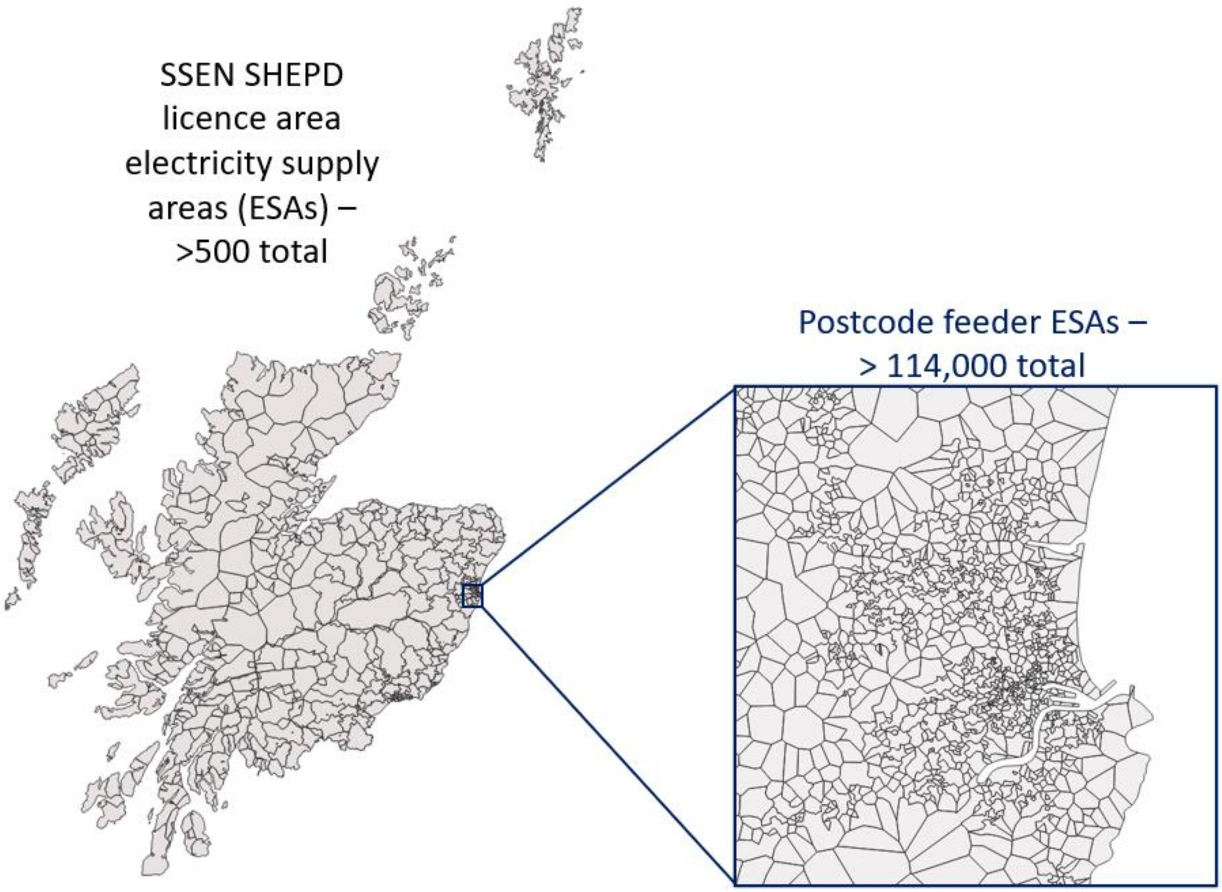


Figure 7: Map of 11 kV and feeder ESAs in the North of Scotland licence area

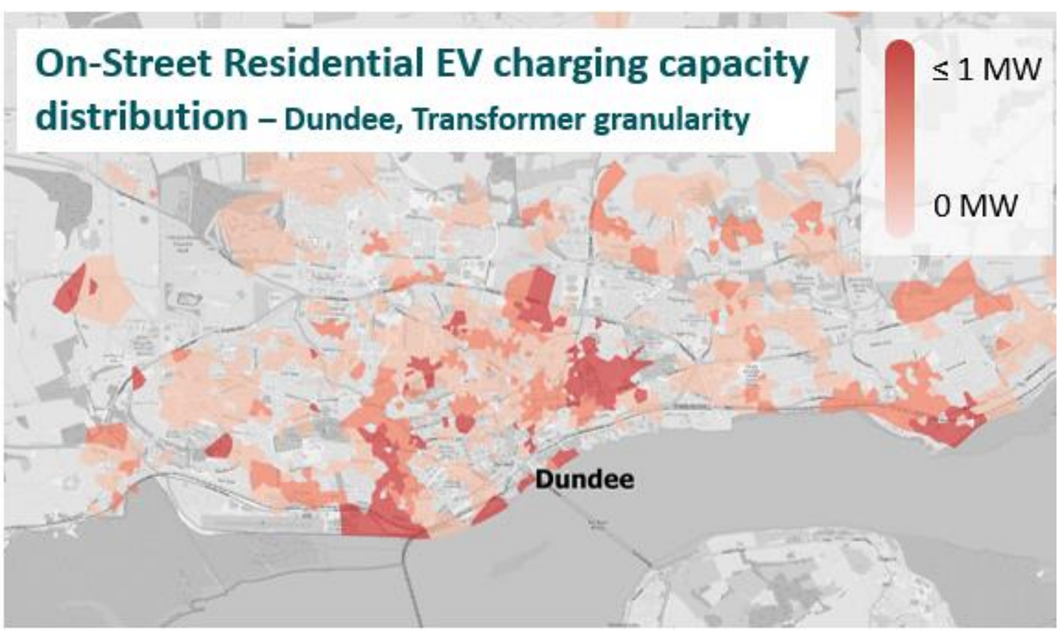


Figure 8: Transformer level geographic distribution of on-street residential EV charger capacity (MW) in Dundee in 2050, under the Consumer Transformation scenario

Stakeholder engagement

DFES analysis is informed by a wide range of inputs, evidence and data. Whilst based on a set of four national energy scenarios, the DFES is intended to be an assessment of future energy scenario outcomes at a regional, sub-regional and local level. The modelling is heavily influenced by what is connected today and an analysis of known pipeline projects. However, in addition to this, consultation and engagement with stakeholders is critically important to inform the modelling of individual technologies. To support the SSEN DFES 2021 analysis the project team has engaged with a wide range of stakeholders through a number of different approaches. These include:

	An **interactive online webinar** held in October 2021[16] with a broad range of regional and energy sector stakeholders and members of the SSEN team. *SSEN summarised how the DFES outputs are used to inform longer-term network planning. This session also made use of an online polling platform to capture specific views and statistical data about the future of a number of energy technologies.*
	A dedicated **Scottish Islands - future energy workshop** held in October 2021, with representatives from the Scottish Islands and relevant local authorities. *Bringing together residents and project developers from many of the major Scottish Islands, as well as local councils and community energy groups. Attendees shared views on low carbon technology deployment, decommissioning of island diesel generators and specific aspects such as the Orkney transmission link needs case[17].*
	A **Scottish Government DFES workshop** held with representatives from the Scottish Government energy team. *Discussing how to directly reflect Scottish energy policies, targets and ambitions for a range of energy technologies in the DFES. Policies discussed included the Scottish Onshore Wind Policy Statement, Draft Heat and Buildings Strategy and Hydrogen Action Plan. These and specific targets around heat pump deployment, the ban on sale of internal combustion engine vehicles and the decarbonisation of Scotland's electricity supply were directly reflected in the DFES 2021* **Consumer Transformation** *scenario.*
	A **new developments online data exchange**, liaising with the planning departments of all of the local authorities within SSEN's licence areas. *Hosted on a Sharepoint site, this data exchange enabled Regen to directly engage with planning and housing teams within the relevant regional councils. This data exchange provided the project team with detailed information on specific new strategic domestic property developments (of 20 houses or more) and non-domestic developments, such as new supermarkets, offices or airports.*
	A **local energy strategy questionnaire** completed by wider environmental and city planning teams from a number of the regional local authorities. *Asking questions about individual council strategies and plans for: zero emissions targets, renewable energy development, low carbon transport, low carbon heat, waste collection and hydrogen. The responses and accompanying documents supplied by the councils were used to inform the spatial distribution of some scenario projections.*
	A number of **targeted technology and sector-specific interviews** with project developers, technology companies and other sector representatives. *These interviews were used to inform the modelling of specific pipeline projects, as well as testing assumptions made about specific sectors or technologies. Interviews included large battery project developers, the Scottish Solar Trade Association, ITM Power and representatives from the European Marine Energy Centre.*

[16] See *SSEN Distribution Future Energy Scenarios – North of Scotland*, recording and slides: https://www.regen.co.uk/event/ssen-distribution-future-energy-scenarios-north-of-scotland/

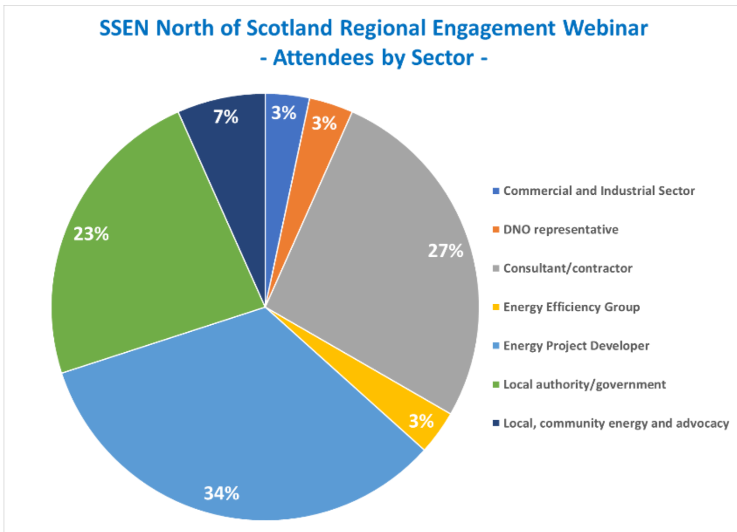
[17] See Orkney transmission link: https://www.orkney.gov.uk/Council/C/a-transmission-link-for-orkney.htm

Regional and island engagement webinars

Across October 2021, Regen worked with members of the SSEN team to host four interactive stakeholder engagement webinars centred around the DFES. These collaborative sessions sought to:

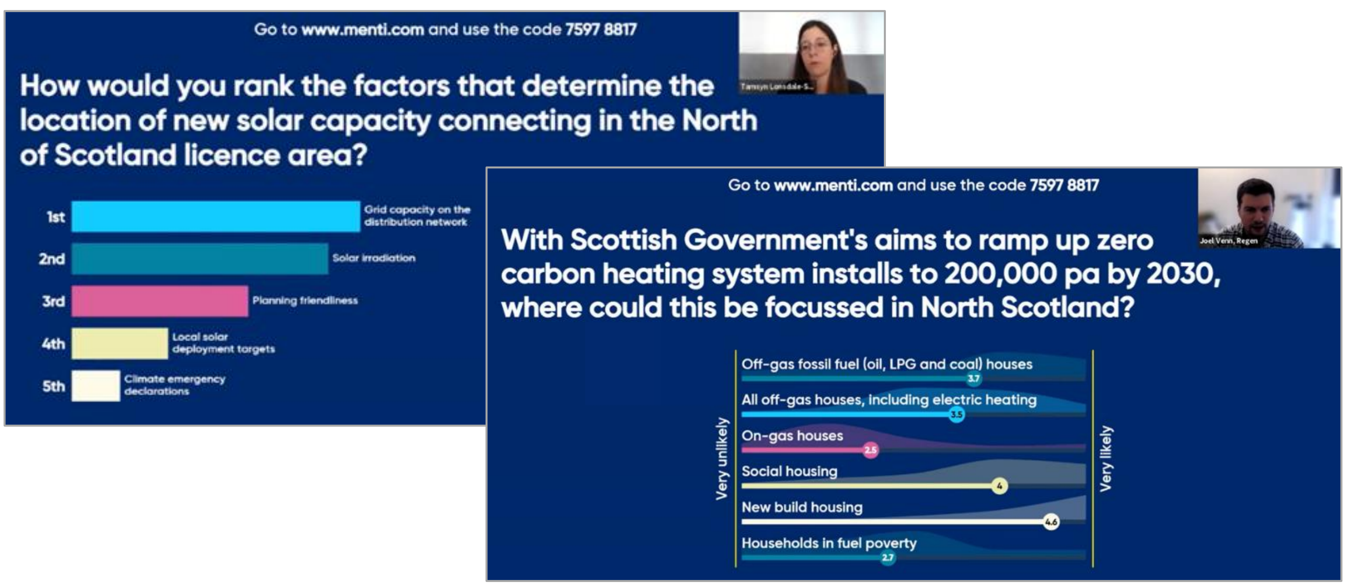
- Provide a summary of the background, method and purpose of undertaking DFES analysis.
- Road-test many of the key assumptions being made around technology capacity growth/ shrinkage and locational distribution factors, that determine the scenario projections.
- Tap in to local and sector knowledge, insights and ambitions relevant to the licence area.
- Discuss views and insights around new or disruptive future technologies, such as hydrogen, heat pumps and EVs and how they may impact the electricity network in the licence area.

The **main regional webinar** brought together representatives from local authorities, community energy groups, project and technology developers and other sector-specific representatives.



The session sought views from stakeholders that could directly apply to the scenario modelling, covering:

- An overview from SSEN around their RIIO-ED2 plan and the general purpose and use of DFES.
- An introduction to the high-level methodology and technology building blocks that form the scope of the 2021 DFES analysis.
- A series of technology-specific interactive polling sessions, via the use of the online voting and live visualisation platform ***Mentimeter***[18].



[18] See https://www.menti.com/ and https://mentimeter.com/

The **Scottish Island DFES workshop** brought together 25 residents and developers from Shetland, Orkney, Lewis, Skye, Stornoway, Barra and Vatersay, as well as representatives from Highlands and Islands Enterprise, Community Energy Scotland, Highland Council, Scottish Renewables and other consultancy organisations developing projects on the islands.

As well as summarising the methodology and assumptions used to inform this year's analysis, the project team presented some technology projections from the SSEN DFES 2020. For some generation technologies, an overview of the current baseline and known pipeline for individual island groups was also outlined, providing a basis for discussing the potential for further deployment and project development on the major islands. See an example of island-specific background data shown in Figure 9.

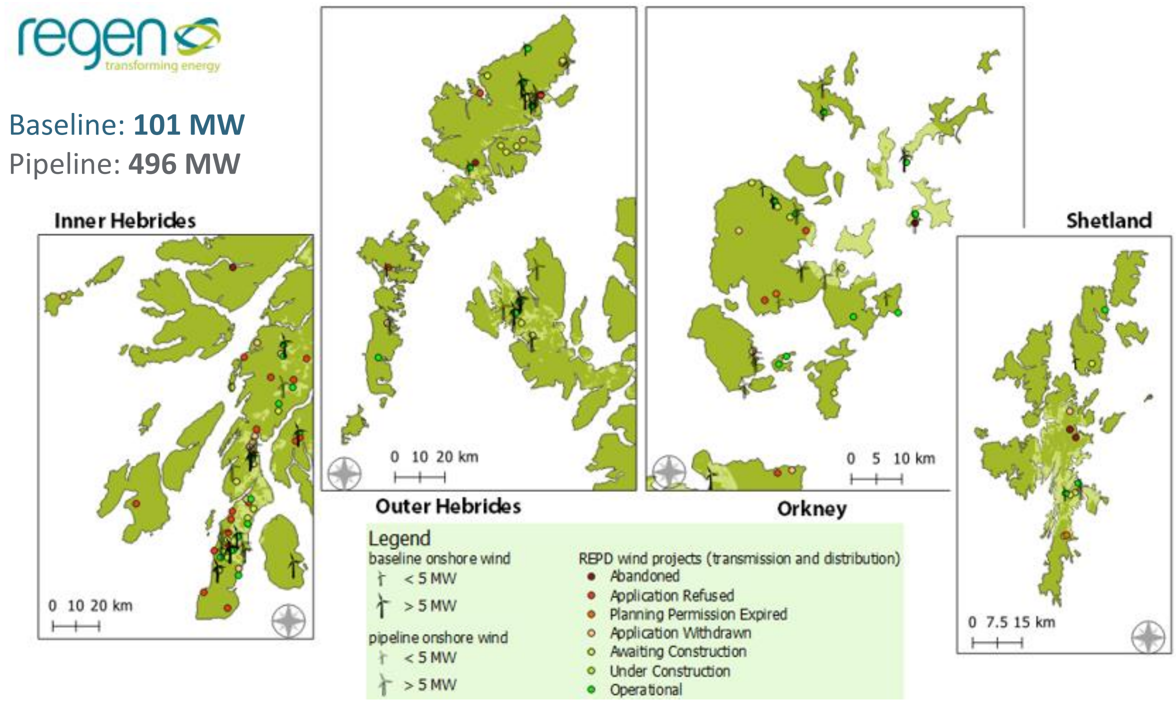


Figure 9: Basline and pipeline capacity of distributed onshore wind (>1MW) on the Scottish Islands

The 2020 projections and known project developments were discussed and contextualised alongside a number of island specific ambitions and other considerations raised by the islanders. These factors influenced the projections and the spatial distribution of capacity on for the islands, including:

- Commitments for the major Scottish islands to be net zero by 2030
- Distribution network constraints present on a number of the islands
- Individual projects and initiatives and being developed on specific islands
- Future developments that may influence the distribution network on the islands, such as significant additional offshore wind capacity[19] and the proposed transmission link for Orkney[20].

Further engagement with the Scottish Island stakeholders is planned for the launch of the DFES 2021 publications and ahead to future iterations of the DFES. The island engagement completed this year has been crucial to understanding the very bespoke nature of island communities, their energy needs and how future island energy should be considered within the future energy scenario framework.

[19] See ScotWind leasing round: https://www.crownestatescotland.com/news/scotwind-offshore-wind-leasing-delivers-major-boost-to-scotlands-net-zero-aspirations

[20] See Orkney transmission link: https://www.orkney.gov.uk/Council/C/a-transmission-link-for-orkney.htm

DFES workshop with the Scottish Government

The project team also engaged with representatives from the Scottish Government energy team, to seek an update on any energy policies, targets or sector-specific strategies that could influence the 2021 DFES analysis, building on the engagement held in 2020 (see Figure 10).

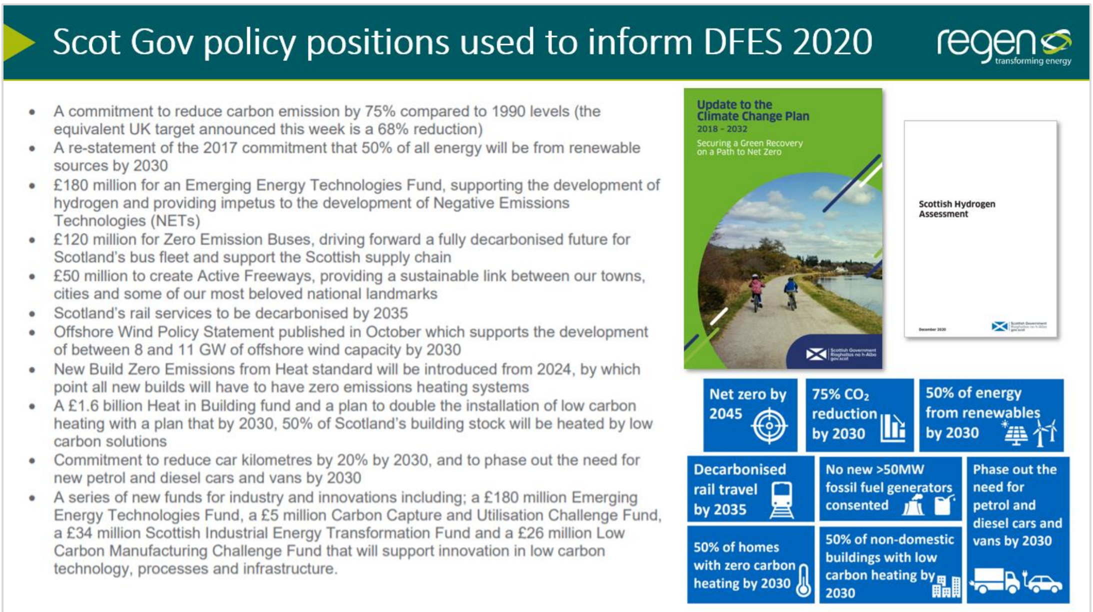


Figure 10: Scottish Government energy policy headlines, used to inform the SSEN DFES 2020

Some of the updates and new Scottish energy policies that the DFES project team were made aware of, that informed the scenario analysis, included:

<table>
<tr><td>Draft Heat in Buildings Strategy
(Published October 2021)
https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/</td><td>This includes an uplift of the Heat and Build Fund, which has been increased to £1.8 billion.
A target for over one million homes to be converted to zero emissions heating systems by 2030.
The introduction of the New Build Zero Emissions from Heat Standard, requiring all new buildings to have zero direct emissions heating systems from 2024.</td></tr>
<tr><td>Onshore Wind Policy Statement
(Published October 2021)
https://www.gov.scot/publications/onshore-wind-policy-statement-9781788515283/</td><td>This includes targets of 8-12 GW of onshore wind capacity in Scotland by 2030. Approximately half of the current installed capacity lies within SSEN, of which another half is distribution connected.</td></tr>
<tr><td>Hydrogen Policy Statement
(Published December 2020)
https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/</td><td rowspan="2">Setting a clear ambition of 5 GW of installed hydrogen production capacity by 2030, and 25 GW by 2045. Noting that this will be a mixture of hydrogen electrolysis and CCUS-enabled hydrogen, as well as being split over the transmission and distribution networks and non-networked arrangements</td></tr>
<tr><td>Draft Hydrogen Action Plan
(Published November 2021)
https://www.gov.scot/publications/draft-hydrogen-action-plan/</td></tr>
</table>

How these policies have been applied to individual technologies is detailed in the corresponding technology summaries. But, at a scenario level, it was agreed that **Consumer Transformation** would be the scenario that most directly accommodates and aligns to Scottish Government policy ambition.

Engagement with local authorities

Building on engagement undertaken in both the 2019 and 2020 DFES assessments, a core data input to this year's analysis came from an online portal of new property developments planned in the North of Scotland licence area. Hosted on an external Sharepoint site (see Figure 11), Regen liaised with the planning departments of those local authorities within the licence area, updating registers of:

- **Planned new houses**, limited to strategic housing developments of 20 houses or more.
- **New non-domestic developments**, measured in sqm, categorised by eight commercial and industrial development archetypes: *Office, Retail, Factory and warehouse, Hospital, Hotel, Medical, Restaurant, School & College, University, Sport & leisure* and *Other*.

Included in this year's data were a small number of very large developments (of 50,000 sqm or more). Within these were some atypical development types, such as:

i) A potential space port to be located at Scolpaig on the island of North Uist[21]
ii) The conversion of Montrose Airfield in Angus
iii) The development of some land around Aberdeen Airport
iv) The proposed Hatston Marine Park in the Orkney islands.

Through follow-up discussions with relevant local authorities, a bespoke modelling approach was applied to these developments, translating the full development land space to a reduced operational development area that could associate more directly to future energy demand.

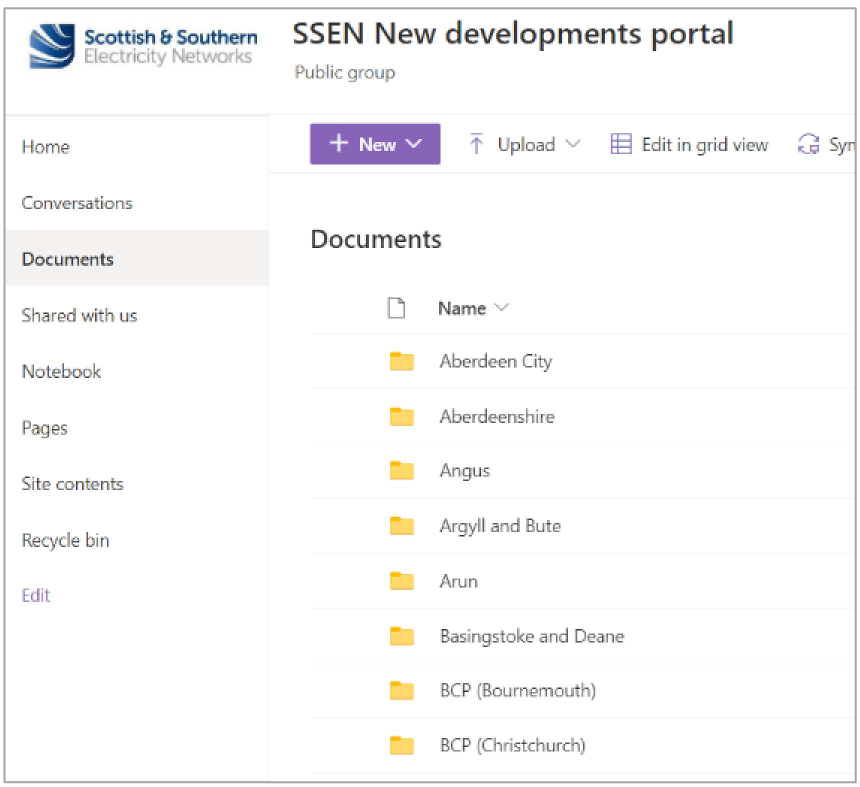
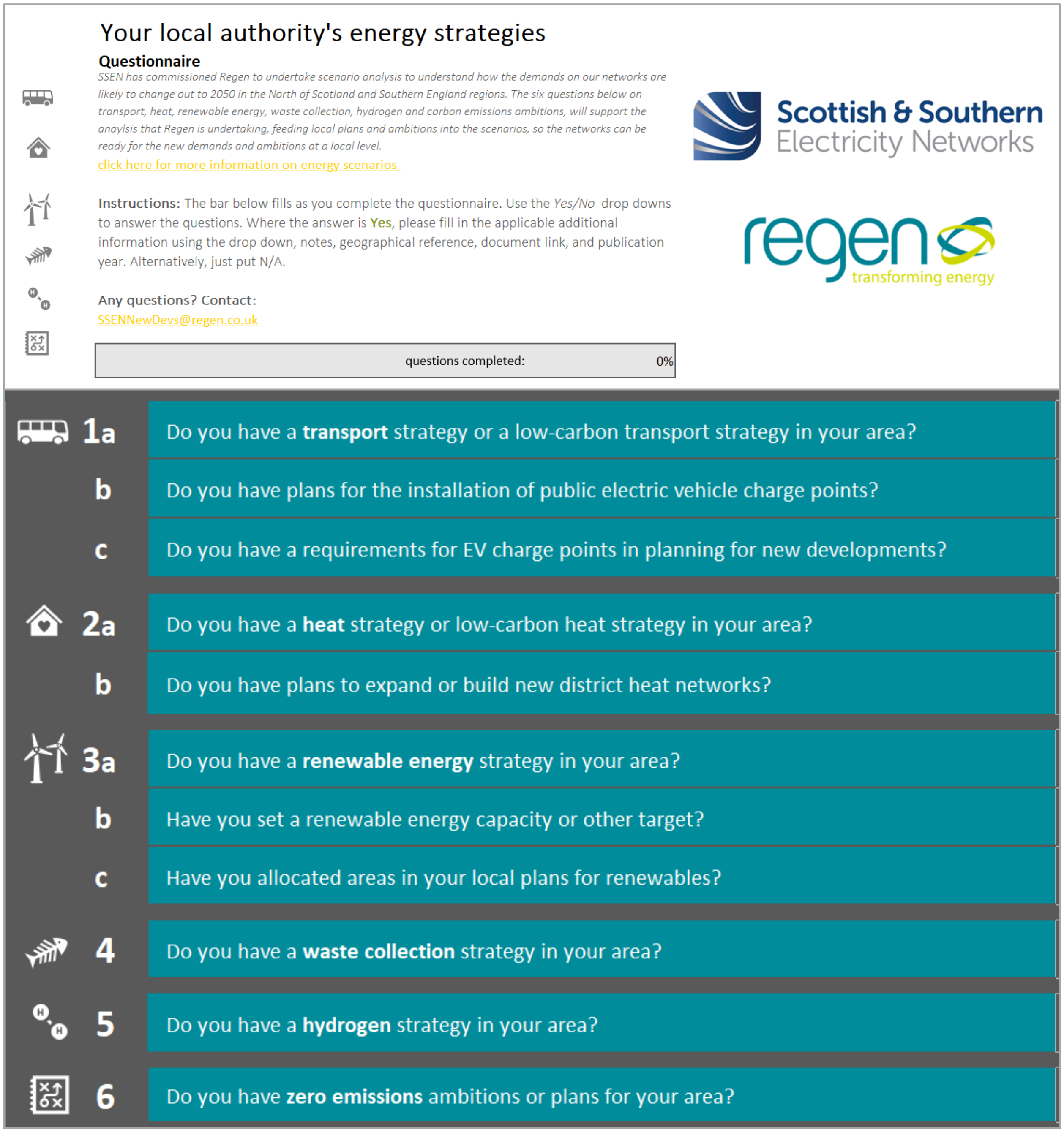


Figure 11: SSEN local authority new developments data exchange, hosted by Regen on Sharepoint

[21] See *Stornoway Gazette* article about potential Spaceport 1 development at Scolpaig, March 2021: https://www.stornowaygazette.co.uk/business/scolpaig-in-uist-could-be-the-next-spaceport-rocket-launch-site-if-planning-is-approved-3159622

In addition to engaging around new developments, the project team also issued a **local energy strategy survey** to broader environmental and climate change project teams within the local authorities.

This survey (see Figure 12) asked a series of targeted questions about local strategies and action plans around zero emissions and climate change, low carbon transport, low carbon heat, renewable energy development, waste collection and hydrogen. The statistical (Yes/No) response data from this survey was used to influence the spatial distribution of individual technology projections. In addition to this, open text fields and web links to downloadable strategy documents and plans provided additional detail and insight into energy planning in individual council areas.



Your local authority's energy strategies

Questionnaire

SSEN has commissioned Regen to undertake scenario analysis to understand how the demands on our networks are likely to change out to 2050 in the North of Scotland and Southern England regions. The six questions below on transport, heat, renewable energy, waste collection, hydrogen and carbon emissions ambitions, will support the anaylsis that Regen is undertaking, feeding local plans and ambitions into the scenarios, so the networks can be ready for the new demands and ambitions at a local level.

click here for more information on energy scenarios

Instructions: The bar below fills as you complete the questionnaire. Use the *Yes/No* drop downs to answer the questions. Where the answer is Yes, please fill in the applicable additional information using the drop down, notes, geographical reference, document link, and publication year. Alternatively, just put N/A.

Any questions? Contact:
SSENNewDevs@regen.co.uk

questions completed: 0%

Scottish & Southern Electricity Networks

regen transforming energy

1a	Do you have a **transport** strategy or a low-carbon transport strategy in your area?
b	Do you have plans for the installation of public electric vehicle charge points?
c	Do you have a requirements for EV charge points in planning for new developments?
2a	Do you have a **heat** strategy or low-carbon heat strategy in your area?
b	Do you have plans to expand or build new district heat networks?
3a	Do you have a **renewable energy** strategy in your area?
b	Have you set a renewable energy capacity or other target?
c	Have you allocated areas in your local plans for renewables?
4	Do you have a **waste collection** strategy in your area?
5	Do you have a **hydrogen** strategy in your area?
6	Do you have **zero emissions** ambitions or plans for your area?

Figure 12: SSEN local energy strategy survey, developed by Regen for DFES 2021 analysis

The results, shown at a summary level, can be seen in Figure 13. Some councils were unable to respond to the survey within the timeframe of the engagement. However, both the number of councils who responded and the number of sector strategies that have been published, or are in development, has increased since an equivalent survey was completed to support the 2020 DFES analysis (see Figure 14).

	Low carbon transport			Low carbon heat		Renewable energy			Waste	Hydrogen	Net zero
Local Authority	**Transport Strategy**	**Public EV charger plans**	**EV charging in new developments**	**Heat Strategy**	**Heat networks**	**RE strategy**	**RE targets**	**Development areas**	**Waste collection**	**Hydrogen strategy**	**Emissions target**
Aberdeen City	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
Aberdeenshire	Y	Y	N	N	N	N	N	Y	Y	N	Y
Angus											
Argyll and Bute											
Dundee City	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y
Highland	N	Y	ID	ID	N	Y	Y	N	Y	ID	Y
Moray	Y	Y	Y	ID	N	Y	N	Y	Y	N	Y
Na h-Eileanan Siar	Y	ID	ID	Y	N	Y	Y	Y		Y	
North Ayrshire											
Orkney Islands											
Perth and Kinross				ID	ID	N	N	N			
Shetland Islands	Y	Y	N	N	N	Y	N	N		N	N
Stirling											
West Dunbartonshire											

Figure 13: High level responses to the 2021 local energy questionnaire, submitted by local authorities

	1	2	3	4	5	6	7
Aberdeen City							
Aberdeenshire	N	Y	N	N	Y	N	2045
Angus	Y	N	N	Y	Y	Y	
Argyll and Bute							
Dundee City	Y	Y	Y	N	Y	Y	2045
Highland							
Moray	Y	N	N	N	N	Y	2030
Na h-Eileanan Siar	N	N	N	Y	Y	Y	2035
North Ayrshire	Y						
Orkney Islands							
Perth and Kinross	N	N	N	N	Y	Y	
Shetland Islands	Y	Y	N	Y	N	N	
Stirling							
West Dunbartonshire							

Figure 14: High level responses to the 2020 local authority local energy survey

Targeted sector and development engagement

In addition to the broader workshops and online surveys, the project team also engaged a number of individual companies and sector representatives to inform the analysis. These consultations included:

- Smaller-scale online workshops and calls with energy sector representatives, such as the Scottish Solar Trade Association and the Marine Energy Council.
- A series of email exchanges with project developers that hold contracted connection offers for individual generation or storage projects, to determine plans to build out their projects.
- 1:1 video or phone interviews with technology companies, developing emerging or innovative technologies such as cryobatteries or hydrogen electrolysers.

The project team have also engaged with the National Grid ESO FES Team to discuss and reconcile some shared assumptions as well as market intelligence around individual technologies, such as data centres and battery storage assets.

An overview of some of the sector-specific consultations is shown below in Table 4.

Table 4: Summary of sector-specific stakeholder engagement undertaken to inform DFES 2021 analysis

DFES building block technology	Organisation(s)	Summary of the feedback received and how it was applied to the DFES analysis
Onshore wind	Orkney Council	Discussed the details around three prospective community wind projects, totalling 90 MW, to potentially be sited on Orkney, as well as information on other onshore wind projects hoping to contribute to the Ofgem 'needs case' for a new transmission cable link to the Orkney islands. The discussions expanded our pipeline project register and directly influenced our near-term scenario modelling for onshore wind.
Large-scale (>1MW) solar PV	Wessex Solar Energy Hive Energy	Provided information about deployment timelines for specific solar projects. Also discussed general challenges facing the solar sector, including network capacity, planning and local objections/NIMBYism. Discussed potentially viable sites on land in AONBs, green belt, high grade agricultural land and flood zones etc. This feedback supported the pipeline analysis and reinforced Regen's solar methodology and in-house solar resource assessment, which takes into account a number of spatial factors and land classification constraints.
Hydropower	Raasay Renewables Low Carbon Hub and Project LEO	Discussion around small hydropower as a business model and the barriers facing it. Feedback provided highlighted a lack of subsidy support after the closure of the Feed in Tariff programme. This is a consensus amongst hydro developers. Other barriers included upstream transmission constraints, legal fees and unfair additional costs to community developers. This insight supported the resultantly conservative DFES capacity projections.

Energy from Waste	Lakeside EfW	The project developer provided information on plans to develop further waste incineration facilities, including information about some delays in planning. The developer also highlighted a broader industry stance to continue developing unabated waste incineration projects until more rigid policy comes into force. This insight influenced how waste incineration was treated under the **Steady Progression** scenario.
Marine energy	European Marine Energy Council	Discussed broad ambitions and timelines for marine energy projects on the Scottish Islands. This input was used to inform the tidal and wave capacity projections for the licence area and the specific spatial distribution across the Scottish Islands.
Battery storage	Battery storage project developer companies, including: XRenewable, Foresight, Low Carbon Alliance and Ili Energy.	Provided information about the timeline and broader intention to progress individual large-scale (>40MW) battery storage projects that have recently accepted connection offers with SSEN. The feedback provided guided the pipeline analysis and the spatial distribution of the significant battery storage pipeline across the licence area.
Liquid Air Energy Storage (LAES)	Highview Power	Information about broad interest to connect LAES projects to the distribution network in SSEN's licence areas. This included specific insights around an appetite to target National Grid ESO's stability pathfinder[22] in Scotland and the potential to co-locate LAES projects with onshore wind generation sites. This insight drove the inclusion of LAES as a separate technology projection, the scale of capacity projected and the spatial location of future LAES sites across both of SSEN's licence areas.
Hydrogen electrolysis	ITM Power	Discussed the general progress of the low carbon hydrogen sector, future electrolysis business models and any existing operational electrolyser sites. The discussion also updated views on typical electrolyser capacity scale (MW) and future use cases. This feedback was used to develop Regen's hydrogen electrolysis scenario modelling in a number of areas.

[22] See National Grid ESO NOA Stability Pathfinder – Phase 2 updates: https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-2

Projection headlines

In the medium and long term, the scale and range of technologies connecting to the distribution network in the North of Scotland licence area will be significantly different to today, under all scenarios.

The distribution network in the North of Scotland in 2030…	
	Collectively, distribution network connected **solar**, **wind**, **hydro** and **marine** generation capacity in the licence area doubles from c.3.1 GW in 2020 to **c.6.3 GW** in 2030 under the **Consumer Transformation** scenario. This is dominated by onshore wind generation deployment, which accounts for most of the increase in connected capacity. However, large-scale solar PV also sees a significant increase, with just over **700 MW** operating in 2030, across all scales.
	Waste-driven generation capacity in the North of Scotland does not change significantly by 2030, increasing from 109 MW in 2020 to **129 MW** in 2030 under the **Leading the Way** scenario. However, landfill gas generation sees some significant decommissioning over this time in many scenarios.
	A range of outcomes is seen for fossil fuel generation in the licence area by 2030. The **126 MW** of unabated island **diesel generation** remains operational under all scenarios except **Leading the Way**. **Fossil gas generation** increases from 41 MW in 2020 to **c.140 MW** in 2030 under **Steady Progression**, driven by the connection of **c.50 MW** of new gas reciprocating (peaking) plant capacity. In addition to this, low carbon hydrogen fuelled generation begins to connect to the distribution network in the licence area, with **91 MW** modelled to come online by 2030 under **Leading the Way**.
	From a very small 2020 baseline (1 MW), **battery storage** capacity (of varying asset classes / business models) significantly increases in all scenarios by 2030, reaching **c.720 MW** under **Leading the Way**.
	The number of **electric vehicles** registered in the North of Scotland licence area also increases significantly in all scenarios by 2030. This ranges from **c.100,000** under **Steady Progression** to just under **330,000** under **Leading the Way**. This equates to a range of **c.500 MW to 1.6 GW** of **electric vehicle charging** capacity by 2030 across these two scenarios.
	In line with Scottish Government policy targets, a significant number of properties switch their heating technologies to low carbon alternatives by 2030, under **Consumer Transformation**. This translates to **c.250,000 homes** and **c.21,000 non-domestic properties** operating a type of **heat pump** by 2030.
	Under the **Leading the Way** scenario, the capacity of distributed **hydrogen electrolysis** in the licence area reaches **c.200 MW**. Whilst **System Transformation** is the scenario where hydrogen is most directly supported, most of the hydrogen production capacity is via alternative methods (i.e. through methane reformation) or connected to the transmission network.
	c.47,000 new houses could be built and just under **c.10,000,000 sqm** of **non-domestic floorspace** could be developed by 2030 in all scenarios.

The distribution network in the North of Scotland in 2050…

Solar, **wind**, **hydro** and **marine** generation capacity in the licence area further increases to **c.10.8 GW** in 2050 under the **Leading the Way** scenario. Distributed onshore wind generation continues to be the dominant technology in the licence area, with over 6 GW online by 2050. Large-scale solar PV continues to see strong support, with 3.3 GW connected in this scenario and hydropower exceeds c.1 GW of operational capacity by 2050.

Waste-driven generation sees a significant evolution by 2050 with landfill gas, waste incineration and ACT capacity all decommissioning from the network under **Leading the Way**. In contrast to this, generation capacity from the anaerobic digestion of other waste feedstocks (i.e. food or agricultural) increases to **40 MW** by 2050 under this scenario.

No unabated **diesel generation** is operating on the system by 2050 under any scenario. Diesel generators supporting the Scottish Islands are replaced with a range of alternative technologies, depending on the scenario. This includes biomass, biomethane, electricity storage and/or hydrogen fuelled generation.

Unbated **fossil gas generation** disappears from the distribution network under the three net zero scenarios by 2050. Under **Steady Progression** **c.100 MW** remains operational, which includes a mixture of newer gas peakers (76 MW) and smaller gas CHPs (23 MW) onsite at a number of commercial premises.

In addition to this, low carbon **hydrogen fuelled generation** capacity increases significantly by 2050 in the licence area, reaching **240 MW** of installed capacity under **Leading the Way**.

Electricity storage capacity continues to see massive deployment in all scenarios out to 2050. Domestic, commercial and grid scale **battery storage** assets total **c.1.2 GW** under **Leading the Way** and **100 MW** of **liquid air energy storage** capacity is also modelled to connect to the distribution network by 2050.

The number of registered **EVs** in the licence area accelerates further out to 2050. However, a general reduction in vehicle numbers is seen by 2050 in the net zero scenarios, driven by an increase in public transport use, in average vehicle mileage and the introduction of autonomous vehicles. EV numbers resultantly range from **c.900,000** in **Steady Progression** to **c.630,000** in **Leading the Way**. **EV charger** capacity reaches **3.7-3.8 GW** by 2050 across all scenarios.

The number of homes and businesses with a type of **heat pump** installed significantly accelerates out to 2050 under all scenarios. This is highest under **Consumer Transformation**, with **c.690,000 homes** and **c.34,000 non-domestic properties** operating a type of **heat pump** (hybrid or non-hybrid) by 2050.

With an increase in the use cases and overall demand for hydrogen in some scenarios, the capacity of **hydrogen electrolysis** in the licence area massively increases in those scenarios. Deployment by 2050 is highest in **Consumer Transformation** with just over **2 GW** operating on the distribution network.

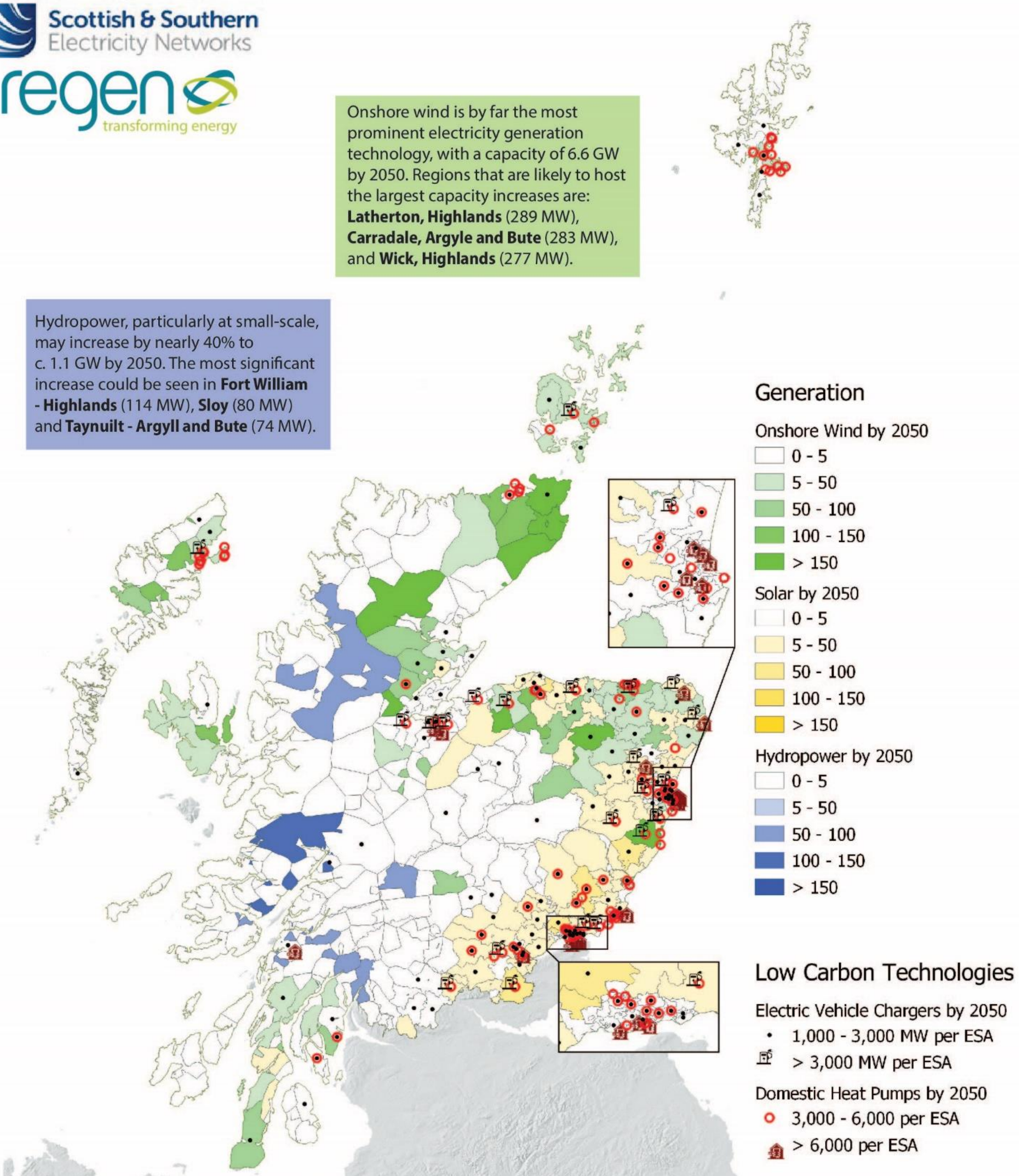
Under all scenarios, up to **c.118,000 new houses** and just under **c.14.5 million sqm** of **non-domestic floorspace** could be developed by 2050.

2050 Technology Projection Headlines - North of Scotland

Consumer Transformation Scenario

Onshore wind is by far the most prominent electricity generation technology, with a capacity of 6.6 GW by 2050. Regions that are likely to host the largest capacity increases are: **Latherton, Highlands** (289 MW), **Carradale, Argyle and Bute** (283 MW), and **Wick, Highlands** (277 MW).

Hydropower, particularly at small-scale, may increase by nearly 40% to c. 1.1 GW by 2050. The most significant increase could be seen in **Fort William - Highlands** (114 MW), **Sloy** (80 MW) and **Taynuilt - Argyll and Bute** (74 MW).



Solar capacity is concentrated in the south of the licnece area due to higher solar irradience levels and proximity to demand sources. However, as costs continue to fall and technologies efficiency improves, areas with lower solar irradience could become feasable, resulting in c. 2 GW by 2050. The regions with the highest capacity are **Leoch, Angus** (69 MW) and **Milnathort, Perth and Kinross** (57 MW).

Low Carbon Technology clusters appear in areas of future increased energy demand, such as **Dundee** and **Aberdeen**. This is influenced by factors such as affluence and land tenure and density of population.

Technology sector scenario analysis – index

The DFES 2021 projections comprise 20 separate technology sector analyses. The following technology summary sections detail the modelling, assumptions and evidence used to produce the scenario projections for each technology sector, categorised into **distributed electricity generation**, **electricity storage** or **future sources of disruptive electricity demand.**

Technology category	Technology/sector
Distributed electricity generation	Onshore wind
	Offshore wind
	Large-scale solar PV
	Small-scale solar PV
	Hydropower
	Marine generation
	Biomass generation
	Renewable engines
	Waste fuelled generation
	Diesel generation
	Fossil gas fired generation
	Hydrogen fuelled electricity generation
	Other generation
Electricity storage	Battery storage
	Liquid air energy storage
Future sources of disruptive electricity demand	Electric vehicles
	Electric vehicle chargers
	Heat pumps and resistive electric heating
	Domestic air conditioning
	Hydrogen electrolysis
	New property developments

Onshore wind

Summary of modelling assumptions and results

Technology specification:

The analysis covers any onshore wind generation connecting to the distribution network in the North of Scotland licence area.

This technology is divided into two sub-categories:

- Large-scale (≥1 MW) onshore wind – **DFES technology building block Gen_BB015**
- Small-scale (<1 MW) onshore wind – **DFES technology building block Gen_BB016**

Data summary for onshore wind in the North of Scotland licence area:

Technology	Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Large-scale (≥1 MW)	Steady Progression	1,984	2,237	2,702	3,485	3,699	3,906	4,022
	System Transformation		2,477	3,324	4,073	4,445	4,623	4,710
	Consumer Transformation		3,017	4,341	5,045	5,695	6,008	6,156
	Leading the Way		3,109	3,747	4,513	5,154	5,553	5,849
Small-scale (<1 MW)	Steady Progression	137	140	146	150	156	161	167
	System Transformation		144	149	157	207	225	229
	Consumer Transformation		182	237	261	365	405	418
	Leading the Way		146	153	169	269	305	315

Overview of technology projections in the licence area:

- The North of Scotland licence area has a strong baseline of large-scale and small-scale onshore wind deployment over the last 20 years.
- A large pipeline of viable projects, many with planning permission, drives strong capacity growth in the near term as subsidy-free onshore wind becomes increasingly workable.
- The licence area has an excellent amount of developable wind resource, resulting in capacity growth out to 2050 in all scenarios.
- A significant amount of capacity growth is also driven by repowering of existing baseline sites with more efficient and higher capacity turbines.

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- The large-scale onshore wind baseline, totalling 1,984 MW, is composed of 163 projects with an average capacity of 12 MW. This is a 54 MW increase compared to DFES 2020.
- The increase includes eight projects with over 50 MW capacity each, such as Berry Burn and Mid Hill wind farms, deployed between 2005 and 2016, which were supported via the Renewables Obligation mechanism.
- The 137 MW baseline for small-scale wind comprises of 319 projects with an average capacity of 0.4 MW. The slight decrease in small-scale baseline capacity, compared to DFES 2020, is due to more thorough investigation of the technologies used at these sites and subsequent reallocation of several sites within connection datasets to other technology categories. This included two hydropower sites with a combined capacity of 1.1 MW, which were misallocated as wind.
- The majority of small-scale onshore wind development occurred as a result of the Feed-in Tariff, with over 100 MW of capacity connected between 2011 and 2016. Since 2017, only 14 small-scale sites have been connected, with only one added project in 2021.

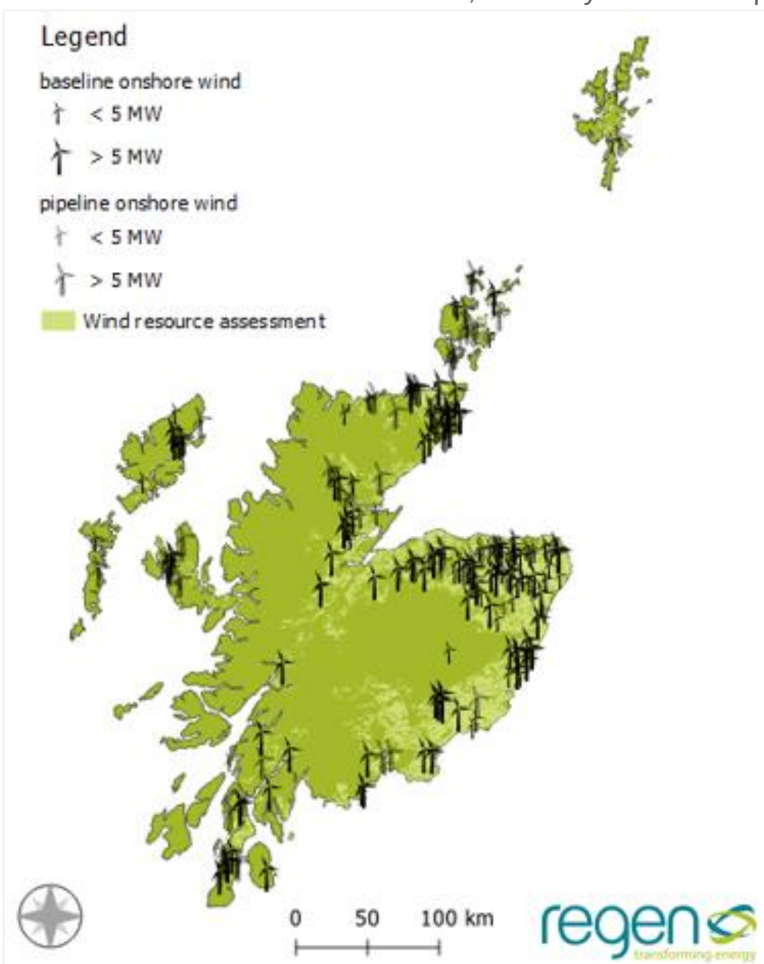


Figure 15: Baseline and pipeline onshore wind sites in the North of Scotland licence area

Near term (2021 – 2025)

- There are 1,772 MW of wind projects with an accepted connection agreement. The average capacity of these projects of 21 MW, which is 75% larger than the baseline average; an indication that developers are seeking larger projects with economies of scale for subsidy-free or Contract for Difference (CfD) backed projects.
- A further 164 MW have been issued a connection offer which has not yet been accepted. These projects have been modelled to connect under the three net zero FES scenarios, but are excluded from **Steady Progression**.
- Between 47 and 281 MW of capacity, depending on the scenario, is projected to deploy by the end of 2022. This near term pipeline is largely composed of sites already under construction or expected to begin construction imminently.
- Several pipeline sites on the islands are dependent on network upgrades to connect, such as the proposed Hoy Wind Farm on Orkney, and as such go ahead later in the pipeline period. A tailored pipeline logic was assigned to the Ofgem Use Case for the proposed transmission cable[i] in Orkney, in which the use case is met in all net zero scenarios but not in **Steady Progression**.
- The Access and Forward-Looking Charges Significant Code Review, and changes to transmission network (TNUoS) charges for embedded generators, has the potential to significantly impact the business models of distributed generation in the North of Scotland. Depending on the outcome of the code review, upfront connection charges may decrease, however, as a generation-dominated region, distribution projects in the North of Scotland could see higher ongoing network charges. Project developers of distribution sites could decide to move to transmission network connections as a result of TNUoS charging. This is a key uncertainty for future development of subsidy-free onshore wind in the region and is reflected in the range of near-term scenario outcomes.

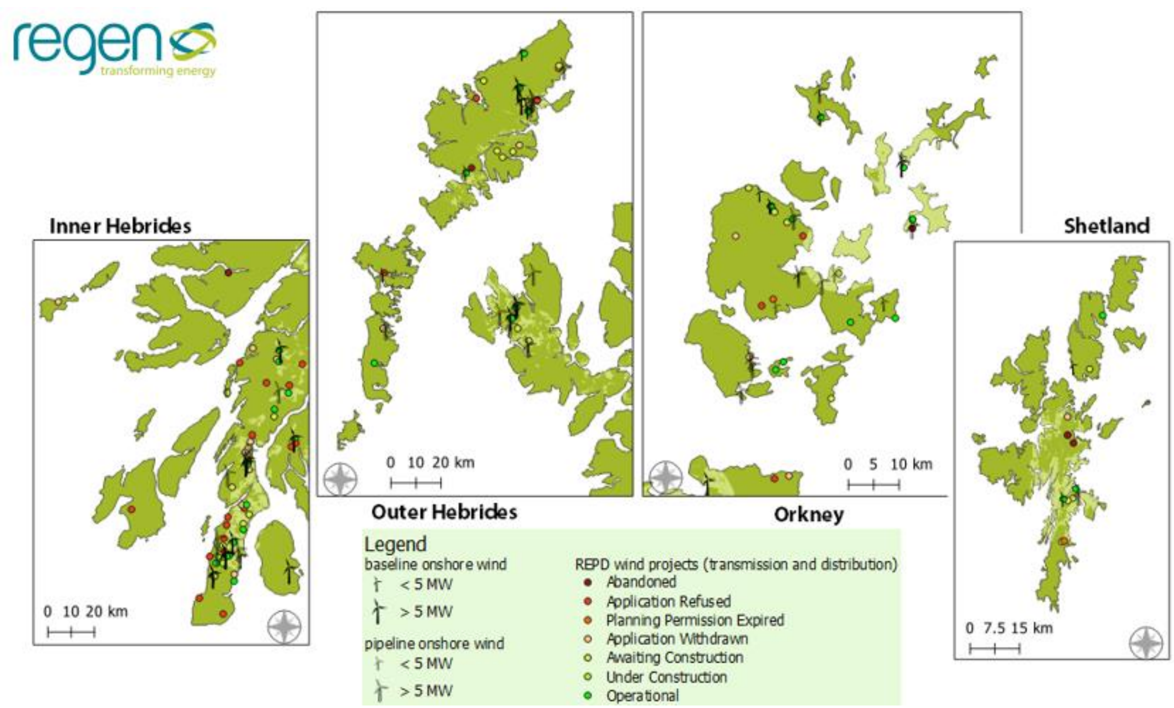


Figure 16: Baseline Onshore wind sites on the Scottish Islands
Source: Renewable Energy Planning Database

Medium term (2025 – 2035)

> **Scottish Onshore Wind Policy Statement**
>
> Following an engagement session with the Scottish Government, Regen was made aware of the Onshore Wind Policy Statement weeks before its release in Oct 2021. The statement targets 8-12 GW of installed capacity by 2030. Approximately half of the current capacity lies within SSEN, of which another half is distribution connected. Regen has elected the **Consumer Transformation** scenario to reflect this and other Scottish policies.

- There are continued high levels of deployment in all net zero scenarios, driven by pipeline sites which are already in development and new projects in areas of high wind resource and fewer planning constraints. Scottish government targets for renewable energy production[ii], and ambitious plans from local councils in the licence area, means that Scotland continues to host the majority of UK onshore wind development.
- By 2035, 4,073 MW of over 1 MW sites connect under **System Transformation**, compared to 5,045 MW in **Consumer Transformation** and 4,513 in **Leading the way**. The lower projection under **System Transformation** is due to a greater focus on transmission connected, large-scale farms in this scenario.
- While the current fourth round of the CfD scheme offers onshore wind subsidy support, this is expected to be an extremely competitive auction. It is therefore expected that, in a high wind scenario, developers will bid into the CfD auction, but will also progress projects on the basis of a subsidy-free business model.
- Repowering of older baseline sites, those developed in the 2000s and reaching the end of their operational life in the medium-term, drives further capacity growth. In the net zero scenarios, it is assumed that these sites are powered with more efficient and larger turbines, as supported in the Scottish Government Onshore Wind Policy Statement.[iii]
- The majority of repowering occurs during the period of 2032-2036 for small scale sites in **Consumer Transformation** and **Leading the Way**.
- The 8-12 GW target set out in the Onshore Wind Policy Statement has been reflected in the **Consumer Transformation** scenario. Under this scenario, it is projected that over 2 GW of additional onshore wind could connect to the North of Scotland distribution network by 2030. This projection is made on the assumption that the northern licence area will continue to make up about half of Scottish wind installed capacity, of which half again is distribution connected.

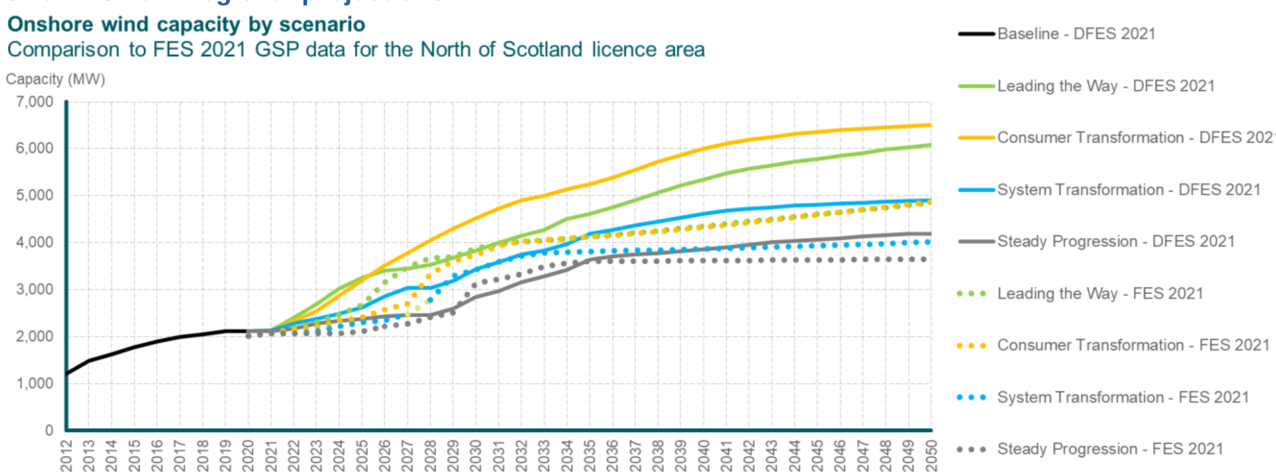
Long term (2035 – 2050)

- Onshore wind capacity continues to increase throughout the time period to 2050, particularly in **Consumer Transformation** and **Leading the Way** scenarios, where renewables on the distribution network play a key role in achieving net zero for Scotland and for the UK. The total capacity in the highest scenario, **Consumer Transformation**, reaches 6.6 GW by 2050; this is around three times the baseline capacity, and is an increase in ambition by c. 300 MW, compared to DFES 2020, due mainly to a revised resource assessment methodology.
- In contrast, the **Steady Progression** scenario only reaches 4.2 GW by 2050, reflecting a continuation of the current slower deployment trend.
- More baseline sites repower during this period, driving a high proportion of capacity growth under all scenarios. It is assumed that the scenarios that have greater societal change allow for greater capacity increase upon repowering, reflecting potential for

larger and taller turbines. For example, under **Consumer Transformation** and **Leading the Way** sites repower at 150% and 140% respectively of their original capacity, on average, for turbines > 5 MW. Contrastingly, **Steady Progression** and **System Transformation** only repower to 125%, reflecting more efficient turbines but not much change in turbine height, or possibly fewer total turbines. Sites are assumed to be repowered 25 years after they came into operation.

- With some of the best wind resource in the country, the North of Scotland licence area continues to be a frontrunner for distributed onshore wind in all scenarios, with long-term projections dependent more on the potential make-up of the whole energy system under each scenario, rather than the North of Scotland licence area in particular. Based on Regen's onshore wind resource assessment, which covers planning constraints, wind resource and network availability, the North of Scotland licence area hosts 22% of GB onshore wind resource area.
- Under **System Transformation** there is still a high level of onshore wind development in North of Scotland, but larger, transmission-scale wind farms continue to be preferred by developers and government.
- This accounts for the over 1 GW difference in distribution connected sites by 2050 compared to **Leading the Way** and **Consumer Transformation**.

Figure 17: Onshore wind projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

- The DFES baseline is constructed directly from SSEN connections data and baseline projects are reconciled against previous studies and the Renewable Energy Planning Database (REPD), yielding a high accuracy of baseline data.[iv] Sites not otherwise evidenced in the REPD are checked through calls with developers and desk research to attain the latest project status updates.
- Analysis of national building block data shows that the total FES GB Onshore Wind Baseline has increased significantly, from 6.5 GW in FES 2020 to 12.6 GW in FES 2021. The North of Scotland regional FES baseline has also increased from 1 GW in 2020, to c. 2 GW in 2021. The National Grid FES 2021 regional data totals is therefore now closer to the DFES 2021 baseline of 2,121 MW, and the discrepancy between the DFES and FES baseline in 2020 has largely been resolved.
- In the near term, the detailed analysis of pipeline projects has resulted in a higher and

faster rate of capacity growth under **Consumer Transformation**, **Leading the Way** and **Steady Progression** than occurs in the same scenarios in the FES 2021 regional dataset. This difference comes from projects that are already well underway in development and targeting commissioning in the next few years, which they are expected to achieve in the three aforementioned scenarios. Projected commissioning years are estimated based on direct qualitative feedback from project developers.

- In the medium and long term, capacity growth rate is similar to the corresponding FES scenarios. However, while in the FES the **System Transformation** and **Steady Progression** projections see limited further capacity growth from 2032 onwards, the DFES 2021 sees a relatively small, continued growth because of baseline projects repowering in these years.
- The total increase from the baseline to 2050 in **Consumer Transformation** and **Leading the Way** has increased from FES 2020 to FES 2021. The DFES 2021 has reflected this increase, but included a faster uptake under **Consumer Transformation** following Scottish policy ambition.

Factors that will affect deployment at a local level:

- New projected onshore wind capacity, not including repowering at existing sites, is based on Regen's onshore wind resource assessment, as seen in Figure 15. This assessment takes into account relevant factors such as wind speed, landscape designations, dwelling proximity, peat land and others.
- Capacity increase due to repowering is located at existing baseline sites.
- The North of Scotland hosts a number of islands that rely to new interconnectors to facilitate new renewable generation projects such as onshore wind. Based on discussion with developers on these islands, and research of the proposed new interconnector cables, the following assumptions have been made:
  - The Orkey to Caithness subsea cable commissions in 2023 with projects able to connect from 2025/2026.
  - The Western Isles transmission reinforcement commissions in 2025, except under **Steady Progression** where it does not go ahead.[v]
  - The Shetland transmission reinforcement commissions in 2024.[vi]

Relevant assumptions from National Grid FES 2021:

Assumption number	4.1.3 - Wind generation (onshore)
Steady Progression	Slower pace of decarbonisation.
System Transformation	Focus on renewables but limited by societal preference for offshore turbines (less impact on land use and visibility)
Consumer Transformation	Strong support for onshore wind across all networks. Some of these projects may be in community ownership.
Leading the Way	High growth driven by the decarbonisation agenda and high demands from hydrogen production from electrolysis.

Stakeholder feedback overview:

Onshore wind	
Stakeholder feedback provided	How this has influenced our analysis
At the North of Scotland stakeholder engagement webinar, 27 local stakeholders responded to two polls on the future of onshore wind development in the licence area	The majority of stakeholders believed that Scotland would remain ahead of the UK for onshore wind deployment out to 2050, and this was reflected in all four scenarios. However, some also saw that growth will level off in line with the UK growth trends in the future, which was reflected in the **Steady Progression** scenario. Stakeholders were generally split when asked if small-scale or transmission scale would dominate future wind projects. However, a slight majority believed that most onshore wind development will be at transmission level, and this preference for growth in transmission-scale wind was reflected in the **Steady Progression** and **System Transformation** scenarios. Under all scenarios, the DFES 2021 has considered that small-scale wind projects will continue to connect in the future, and wind development will not be exclusively transmission-scale.
As part of Regen's engagement with local authorities, data was collected on local authorities who had declared climate emergencies or had specific renewable targets or strategies.	Where these existed, a small positive weighting was given to these local authorities in the near term. However, as this is a snapshot that may not fully reflect local authority ambition in the long-term, it was not used as a major factor in the projections in the medium and long term. Stakeholders during the Menti session also did not consider this to be a strong contributing factor.
Scottish Government were engaged regarding Scottish renewable energy targets and details of the onshore wind policy statement, particularly with regards to repowering.	The aims of Scottish onshore wind policy, approach to repowering and broader renewable energy targets were reflected in the **Consumer Transformation** and **Leading the Way** scenarios.
A further engagement session was held with Scottish Island stakeholders, during which a suggestion was made to explore the potential to cluster islands together as nodes.	Regen has considered including this clustering as part of the output dataset. Another option mentioned in the meeting is that in the event of a failed needs case on the islands, developers could consider battery storage co-located with (or instead of) wind. Stakeholders mentioned the negative planning environment for new connection and capacity limitations. A suggestion was also made to consider transmission sites alongside distribution to not lose sight of the bigger picture and planning implications. The DFES already cross-references with the Transmission Entry Capacity (TEC) register but has not developed a wider methodology to track transmission sites closely as it falls outside the scope of the analysis.

Developers with projects in the pipeline were contacted on an ad-hoc basis to discuss the likely commissioning dates of their projects.	This information was directly reflected in the near-term projections. These discussions also covered the likely trajectory for onshore wind in the medium-term, and the impact of COVID-19 on projects currently in development. Developers involved with the onshore wind projects directly affected by the needs case in Orkney were also consulted by phone call in order to better represent the range of uncertainty associated with the Ofgem imposed needs case to justify transmission works to the Island. As a result of these discussions and to reflect the all-or-nothing effect of a transmission cable unlocking grid constraints, these pipeline projects were either all modelled to connect under scenarios in which the needs case is assumed to be met or delayed in scenarios where the needs case is assumed not to be met. Individual project commissioning years were altered based on information provided by project developers.

Some stakeholders responses to specific questions in the engagement webinars included:

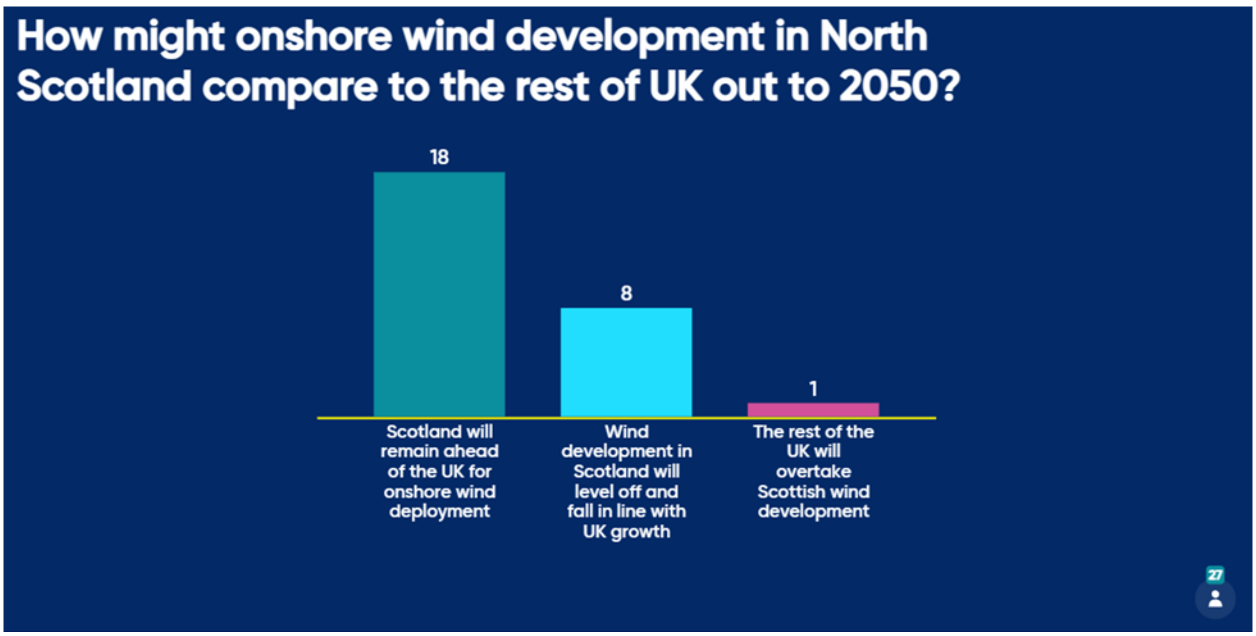
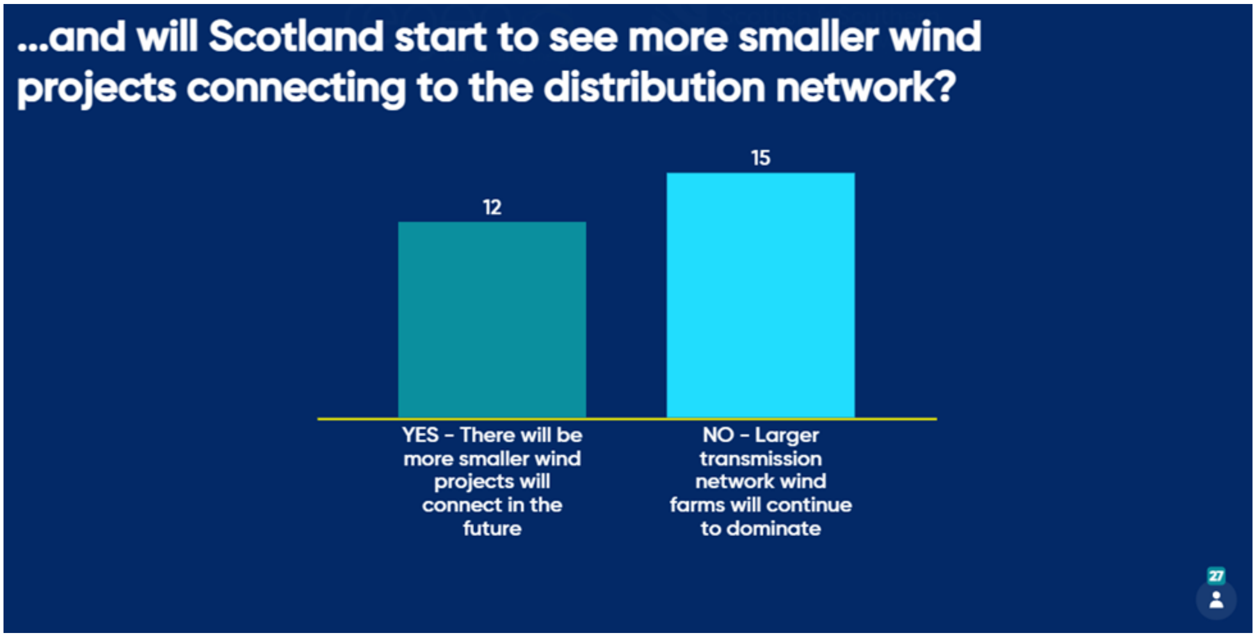


Figure 18: Mentimeter results for onshore wind development in the North of Scotland licence area



References:

SSEN connection offer data, DNO Embedded Capacity Registers, National Grid ESO TEC register, the Renewable Energy Planning Database, Climate Emergency declaration data, Regen consultation with local stakeholders and discussion with developers, Regen questionnaire and consultation with local authorities.

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[i] See Ofgem update on Orkney transmission link: https://www.ofgem.gov.uk/publications-and-updates/ofgem-gives-go-ahead-orkney-transmission-link-subject-conditions

[ii] Scottish Government aims to generate 50% of Scotland's overall energy consumption from renewable sources by 2030: https://www.gov.scot/policies/renewable-and-low-carbon-energy/

[iii] Scottish government onshore wind policy statement: https://www.gov.scot/publications/onshore-wind-policy-statement-9781788515283/

[iv] See Renewable Energy Planning Database from BEIS: https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract

[v] See Ofgem update on Western Isles transmission link: https://www.ofgem.gov.uk/publications-and-updates/ofgem-encourages-revised-proposals-scottish-isles-transmission-links

[vi] See Ofgem update on Shetland transmission link: https://www.ofgem.gov.uk/publications-and-updates/ofgem-approves-600mw-shetland-transmission-link

Offshore wind

Summary of modelling assumptions and results

Technology specification:

The analysis covers offshore wind generation, including fixed and floating foundations, connecting to the distribution network in the North of Scotland licence area.

Note: as a general assumption, very few large-scale offshore wind projects are expected to connect to the distribution network. The SSEN DFES analysis has therefore focused on small-scale demonstration and trial projects that could be distribution network connected.

Network technology data building block: **Gen_BB014 – Offshore wind**

Data summary for offshore wind in the North of Scotland licence area:

Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	80	80	80	80	80	80	80
System Transformation		90	80	80	80	80	80
Consumer Transformation		90	80	80	80	80	80
Leading the Way		90	80	80	80	80	80

Overview of technology projections in the licence area:

- At present, the majority of floating offshore wind development is focused around Scotland and the Celtic Sea. With high wind speeds and several ScotWind leasing[vii] areas around Scotland, offshore wind is a prime technology for the North of Scotland licence area.
- According to the Scottish Offshore Wind Policy Statement, between 8 and 11 GW of offshore wind capacity could be achieved in Scotland by 2030[viii].
- However, the expansion in offshore wind will be almost all transmission network connected, due to the location and capacity of the projects being considered. This is especially the case in Scotland, where the transmission network is at a voltage tier lower than the rest of GB. Therefore, minimal additional offshore wind capacity is expected to connect to the distribution network in the licence area out to 2050.
- The current baseline of distribution network connected offshore wind generation consists of two pioneering floating wind projects totalling 80 MW: the Kincardine (50 MW) and Hywind (30 MW) projects.
- There is only one distribution connected offshore wind project in the SSEN pipeline: The Pentland Floating Offshore Wind project (10 MW).
- Under the three net zero scenarios, capacity increases by 10 MW in the 2020s to support the Pentland Floating Offshore Wind demonstrator, and remains at this level out to 2050. No additional distribution network connected capacity is modelled to come online under **Steady Progression**.
- If new demonstration or island-based projects are identified, these will be incorporated into future DFES studies.

Scenario projection analysis and assumptions:

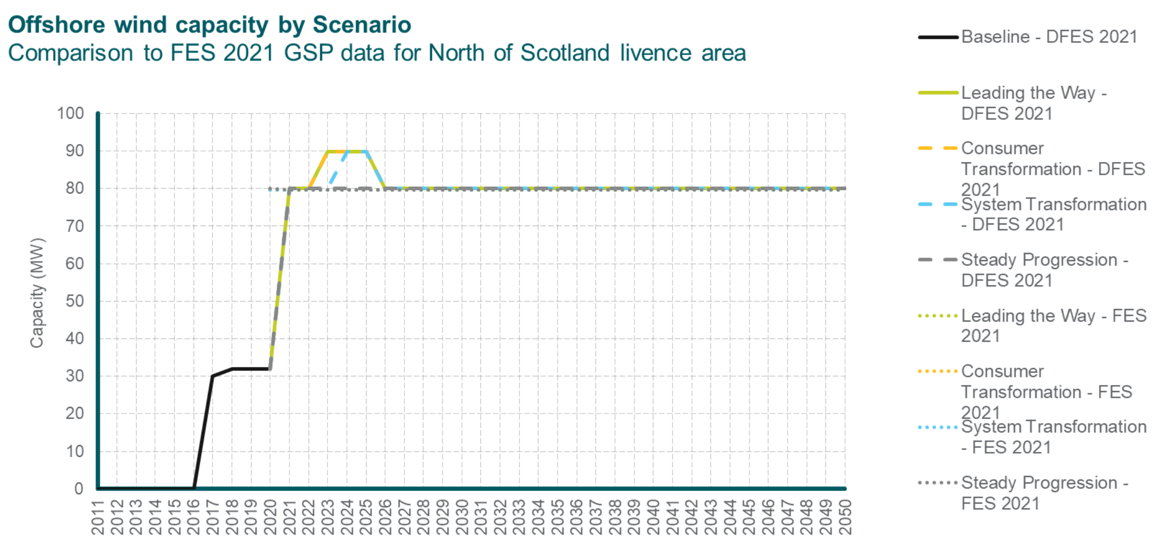
Baseline (up to end of 2020)

- The baseline consists of two projects totalling 80 MW, both with floating foundations.
- Most of this capacity is the Kincardine floating offshore wind farm, which was fully connected to the distribution grid in October 2021 at a capacity of 50 MW. As of October 2021, this site was the world's largest floating offshore wind site and is capable of providing power for over 50,000 homes in Scotland[ix].
- The other operational project is the 30 MW Hywind project, which was the first commercial floating offshore wind farm in Scotland, commissioned in 2017[x].

Projections (2020 – 2050)

- There is one known pipeline project, the Pentland Floating Offshore Wind demonstrator site. The DFES 2021 has modelled this project to connect in 2023 under **Leading the Way** and **Consumer Transformation**, and in 2024 under **System Transformation**. The nature of this project is a temporary demonstrator site for future, larger, transmission-connected Pentland floating offshore wind site[xi].
- Other than the commissioning of this Pentland Floating Offshore Wind demonstrator, no further offshore wind capacity has been projected to connect to the distribution network in the North of Scotland licence area, in any scenario. There are no further accepted connections in the pipeline and it is expected that any further offshore wind projects off the coast of northern Scotland would be large-scale projects connecting to the transmission network.
- Engagement with representatives from the Scottish Islands, through a dedicated workshop, has highlighted that future offshore wind generation could be integrated with onshore hydrogen electrolysis plants to produce green hydrogen. Workshop discussions suggested that 25-50% of new generation off the west and north coast of Scotland could, in the future, be used for hydrogen production. Using hydrogen production, alongside energy storage, to better balance demand against electricity supply would also help reduce the overall network capacity that would be required.
- If new demonstration or island based projects are identified these will be incorporated into future DFES studies.

Figure 19: Offshore wind projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

SSEN DFES results have been reconciled against the FES 2021 data, for the relevant GSPs within the North of Scotland licence area, for the building block **Gen_BB014 – Offshore wind.**

The baseline SSEN DFES projections for offshore wind are aligned with the National Grid FES projections for the North of Scotland licence area.

FES 2021 projections assume no future distribution network connections for offshore wind.

The only deviation in the SSEN DFES projections from the FES 2021 projections is due to the 10 MW Pentland FLOW demonstration site which has been included in the SSEN DFES under the three net zero scenarios.

Scottish Government policy context:

There are significant targets to connect up to 11 GW of offshore wind in Scotland[xii], confirmed in the Climate Change Plan Update[xiii]. Most of this capacity is expected to connect to the transmission network, which is not modelled under SSEN DFES projections. As a result, the SSEN DFES projections have not reflected large-scale, multi-megawatt projects that are expected to connect to the transmission network over the next decade.

Factors that will affect deployment at a local level:

The distribution of offshore wind is based on the location of known baseline and pipeline projects in the licence area.

Relevant assumptions from National Grid FES 2021:

Assumption number	4.1.3 - Wind generation (offshore)
Steady Progression	Slower pace of decarbonisation.
System Transformation	Focus on renewables but limited by societal preference for offshore turbines (less impact on land use and visibility)
Consumer Transformation	Strong support for offshore wind across all networks. Some of these projects may be in community ownership.
Leading the Way	High growth driven by the decarbonisation agenda and high demands from hydrogen production from electrolysis.

Stakeholder feedback overview:

Offshore wind	
Stakeholder feedback provided	How this has influenced our analysis
Engagement with representatives from the Scottish Islands highlighted the 10 GW of offshore wind targeted for the next decade and the difficulties in separating out distribution and transmission from this projected number. Stakeholder feedback also highlighted the opportunity to integrate higher levels of offshore wind generation with energy storage and hydrogen electrolysis plants, which could be located on Scottish Islands or the mainland.	Regen continues to expect that most offshore wind will be transmission connected in the future, but this remains uncertain. In addition to this, network charging reforms could push developers into connections that don't make sense from a network planning point of view. To address this uncertainty, future SSEN DFES studies will look to revise future scenario projections if evidence of distribution-connected capacity is announced under the 2022 ScotWind leasing round. The location of both onshore and offshore wind has influenced the SSEN DFES projections for hydrogen electrolysis.

References:

SSEN connection offer data, National Grid ESO TEC register, the Renewable Energy Planning Database, Regen consultation with local stakeholders and discussion with developers.

[vii] See Crown Estate Scotland ScotWind leasing round: https://www.crownestatescotland.com/our-projects/scotwind

[viii] See *Scottish Government Offshore Wind Policy Statement* (Oct 2020): https://www.gov.scot/publications/offshore-wind-policy-statement/

[ix] Energy Live News 2021, *'World's largest' floating wind farm starts injecting green electricity into Scotland's grid*. https://www.energylivenews.com/2021/10/22/worlds-largest-floating-wind-farm-starts-injecting-green-electricity-into-scotlands-grid/

[x] Equinor 2017, *The future of offshore wind is afloat.* https://www.equinor.com/en/what-we-do/floating-wind.html

[xi] See Pentland Floating Wind website: https://pentlandfloatingwind.com/

[xii] See Scottish Government Offshore Wind Policy Statement: https://www.gov.scot/publications/offshore-wind-policy-statement/pages/3/

[xiii] See Scottish Government Climate Change Plan Update (Dec 2020): https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/

Large-scale solar PV

Summary of modelling assumptions and results

Technology specification:

The analysis covers solar generation sites of installed capacity of 1 MW and above connecting to the distribution network in the North of Scotland licence area.

Technology building block: **Gen_BB012 – Large solar generation (G99)**

Data summary for large-scale solar PV in the North of Scotland licence area:

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	36	193	323	551	673	792	936
System Transformation		248	431	809	1069	1396	1864
Consumer Transformation		248	433	811	1089	1621	1966
Leading the Way		286	715	1245	1659	2159	2405

Overview of technology projections in the licence area:

- Due to comparatively low levels of irradiance in most areas of the North of Scotland relative to the rest of the UK, deployment of solar PV has historically been very limited compared to other renewable energy technologies, such as hydro and onshore wind.
- There is, however, a significant pipeline of sites with accepted connection offers (414 MW) or connection quotes that have not yet been accepted (262 MW).
- There is also a significant capacity of historic large-scale solar projects with connection quotes that have since expired (674 MW). This suggest that, although there have been a large number of pipeline projects in the past, there is still a high degree of uncertainty whether pipeline projects will be commissioned.
- Ongoing reductions in capital costs[xiv], improvements in yield efficiencies[xv] and the development of more dynamic and lucrative power purchase agreements[xvi] is driving new interest to deploy potentially significant solar PV capacity in general.
- In addition to these market drivers, many Scottish businesses and other organisations have made their own net zero commitments[xvii] and are planning to install new solar projects on their land and buildings to meet their scope 2 emissions reduction targets.
- Engagement with the Scottish Solar Trade Association (STA) has highlighted an ambition to rapidly accelerate the deployment of solar in Scotland, with the STA targeting 3.5 GW of large ground mount solar PV by 2030. Whilst the irradiance zone and developable land space in the North of Scotland licence area is less favourable than South of Scotland, the DFES 2021 analysis has sought to reflect an increase in large-scale solar capacity across all scenarios by 2030 and by 2050.
- The highest resource areas in the North of Scotland are to the south of the licence area and across the east coast. This is the area where the majority of baseline and new development projects have been located.
- The ambition and uptake of large-scale solar is highest under the **Leading the Way** scenario, reaching 715 MW by 2030 and 2.4 GW by 2050. However, even under the least ambitious scenario, **Steady Progression**, large-scale solar capacity still sees a 25-fold increase in capacity to 936 MW by 2050.

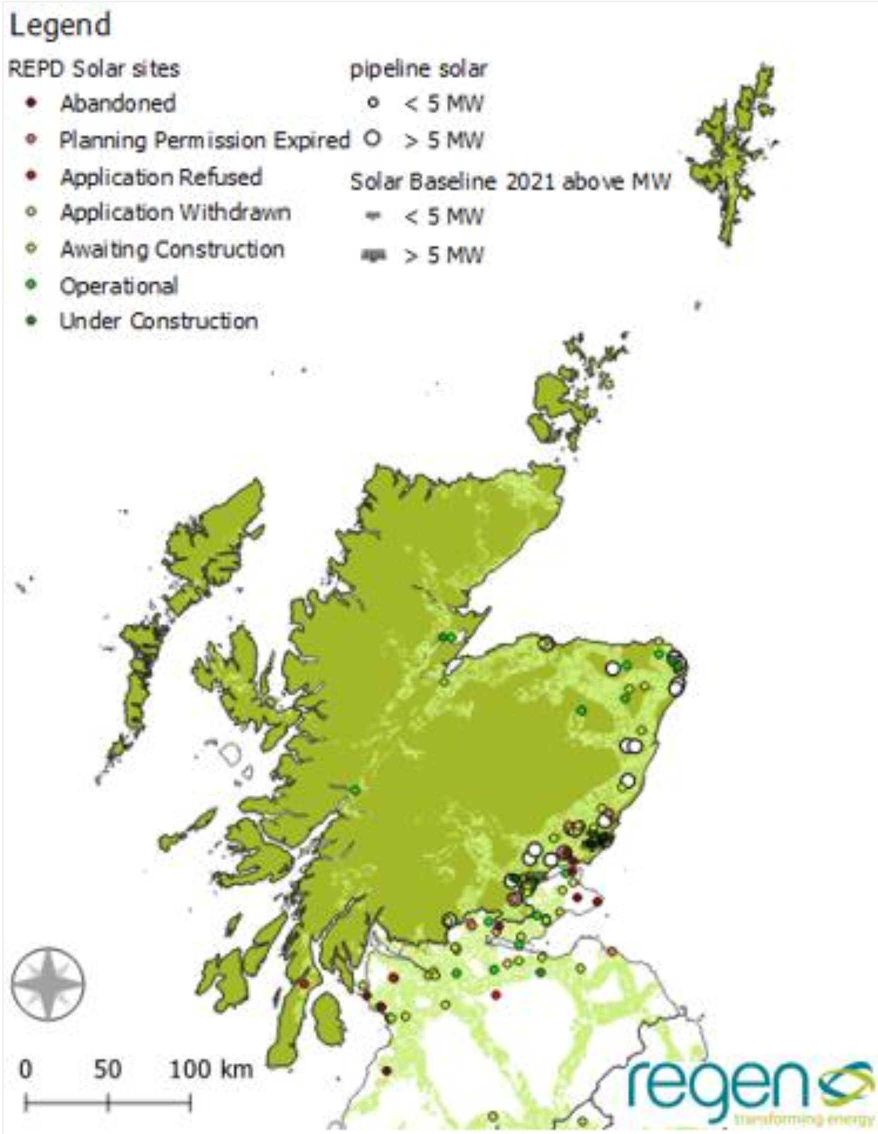


Figure 20: Baseline and pipeline of large-scale solar PV in the North of Scotland licence area, compared to Renewable Energy Planning Database

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- There are six >1 MW scale solar PV sites, totalling 36 MW capacity, connected to the distribution network in the North of Scotland licence area.
- These sites are between 1 MW and 10 MW and connected between 2015 and 2020.
- Since 2018, 38 large-scale solar PV connection offers, totalling 675 MW, have expired in the licence area.
- Whilst the individual reasons for these lapsed connection offers is unknown, engagement with the Scottish STA suggested that some sites were unable to proceed due to high network connection costs. The business case for new solar with limited subsidy support, is compounded the by lower solar irradiance zones in north Scotland.

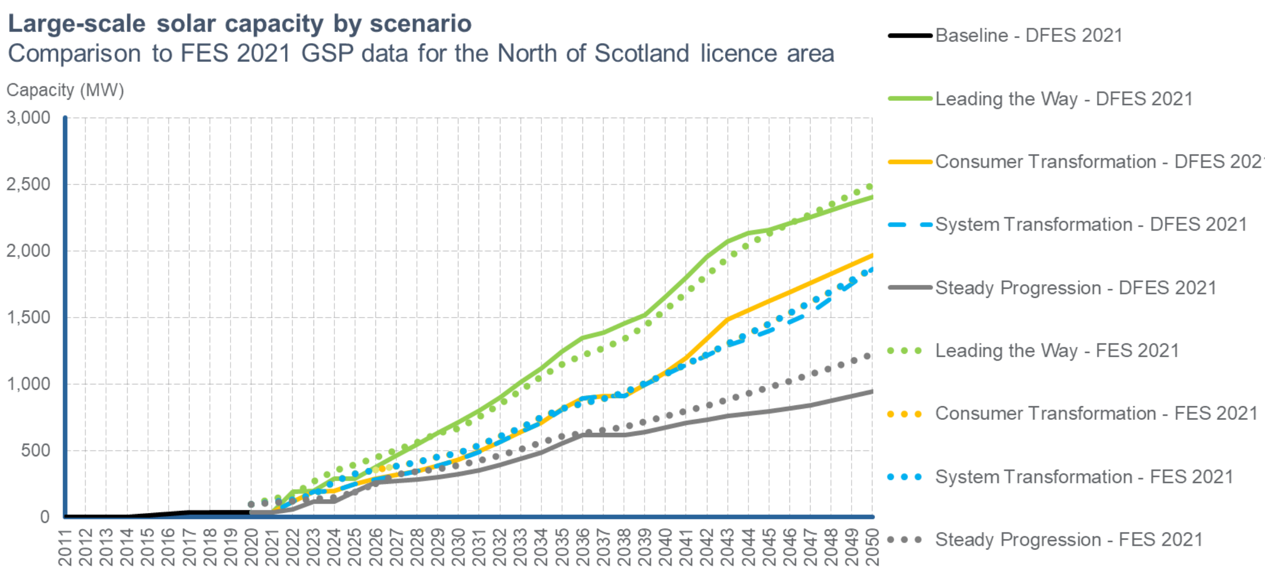
Near term (2021 – 2025)

- There is a significant potential pipeline of 20 sites totalling 414 MW with accepted connection offers in the licence area.
- In addition to this, 10 further sites, totalling 262 MW, have been issued with a connection offer quote by SSEN, that have not yet been accepted.
- Of this total development pipeline, eight sites totalling 187 MW are either already under construction or have positive planning evidence.
- Engagement with the Scottish STA highlighted an ambitious solar development target of 6 GW by 2030 across all of Scotland, of which 3.5 GW could be large ground mount PV.
- Feedback from the stakeholder engagement workshop, held in October 2021 with nearly 30 Scottish energy sector representatives, also suggested that new solar capacity could connect to the distribution network across the 2020s, 2030s and 2040s.
- Whilst the higher irradiance areas in the South Scotland licence area (managed by SP Energy Networks) will see a significant proportion of future solar development in Scotland, the North of Scotland does have some higher resource area in the south of the region and along the east coast.
- There are a number of regulatory reforms in motion that could affect distributed generation connection charging. Notably the Access and Forward-Looking Charges Significant Code Review and changes to transmission network (TNUoS) charges for embedded generators. These reforms have the potential to impact the business models of solar PV (and other distributed energy generation) in the North of Scotland. Depending on the outcome of the code review, upfront connection charges may decrease, however, as a generation-dominated region, solar projects in the North of Scotland could see higher ongoing network charges. This is a key uncertainty for the future development of large-scale solar in the region and has been reflected across the four scenario projections.
- Very high electricity prices over the winter of 2021/20 could also encourage those projects that have been stalled to move forward to construction.
- Given the strong pipeline, positive stakeholder engagement, improving market conditions and Scottish net zero targets, an increase in solar capacity in the next five years has been modelled under all scenarios.
- There is however still a high degree of uncertainty regarding the speed and scale of deployment. This is reflected in the range of scenario outcomes, with capacity reaching 286 MW by 2025 in **Leading the Way** and 193 MW by 2025 in **Steady Progression**

Medium/long term (2025 – 2050)

- An increase in the total solar PV capacity connected to the distribution network in the licence area is projected, in the long term, under all scenarios.
- Under **Leading the Way**, a significant proportion of known pipeline projects and some recently expired projects move through to development across the 2020s and 2030s. In the 2040s, this scenario also sees the most ambitious deployment of large-scale solar PV, exploiting higher performance solar technology and the potential of new business models for co-location with electricity storage and hydrogen electrolysis. Total large-scale solar capacity reaches 715 MW by 2030 and 2.4 GW by 2050 under this scenario.
- Under **Consumer Transformation** and **System Transformation** scenarios, there is also significant growth enabling large-scale solar capacity to reach c.430 MW by 2030. This growth is driven by improving market conditions, the drive by many organisations to achieve their own carbon reduction plans and wider policies aimed to meet the Scottish Government's target to generate at least 50% of its total energy consumption from renewable sources by 2030[xviii]. Growth continues into the 2040s, reflecting the Scottish Government's 2045 net zero target, reaching just under 2 GW by 2050
- Under the lower growth **Steady Progression** scenario, total large-scale solar capacity reaches c.320 MW by 2030 and just under 1 GW by 2050.
- Whilst still representing a significant increase from the 36 MW baseline, this scenario reflects slower progress towards Scottish Government targets, less dynamic solar business models and fewer opportunities for co-location, leading to less financial investment in new solar projects overall.

Figure 21: Large scale (>1MW) solar PV projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

DFES 2021 projections have been reconciled to the FES 2021 data for the relevant GSPs within the North of Scotland licence area for building block Gen_BB012.

- Overall the DFES 2021 and FES 2021 projections are closely aligned (See Figure 21)
- The SSEN DFES 2021 has c.61 MW less capacity in the 2020 baseline than the FES 2021 GSP data. The reason for this is unclear, but could be related to differences in technology classifications.
- Projections in the near-term are a little higher in FES 2021 than modelled in the DFES 2021. This slightly slower uptake in the DFES reflects the limited proportion of the known pipeline that currently has planning approval.
- Beyond 2025, the DFES and FES 2021 projections align well under **System Transformation** and **Leading the Way**, with both analyses seeing c.1.9 GW under **System Transformation** and c.2.4-2.5 GW under **Leading the Way** by 2050.
- The DFES analysis has higher growth between 2040 and 2045 under **Consumer Transformation** than the FES. This scenario reflects Scottish Government policy targets and ambition to achieve net zero by 2045.
- The DFES also reflects lower levels of deployment under **Steady Progression** than the FES 2021, limiting total capacity to c.1GW by 2050.

Factors that will affect deployment at a local level:

- New large-scale solar PV capacity is distributed to developable land area based on Regen's large-scale solar PV resource assessment. This considers irradiance, designated land areas, physical constraints, network proximity, ground slope/aspect and proximal buildings.
- Due to the influence of repowering, some of the future large-scale scale PV capacity will be located at existing sites.
- In addition to this, the location of sites with connection offers that have recently expired has also been used to influence the distribution of medium and long-term capacity.
- Deployment of solar will likely be focused in areas of higher irradiance in the south east and east coast of the licence area. Deployment may also likely occur in industrial areas with brownfield sites, larger buildings and higher levels of demand.

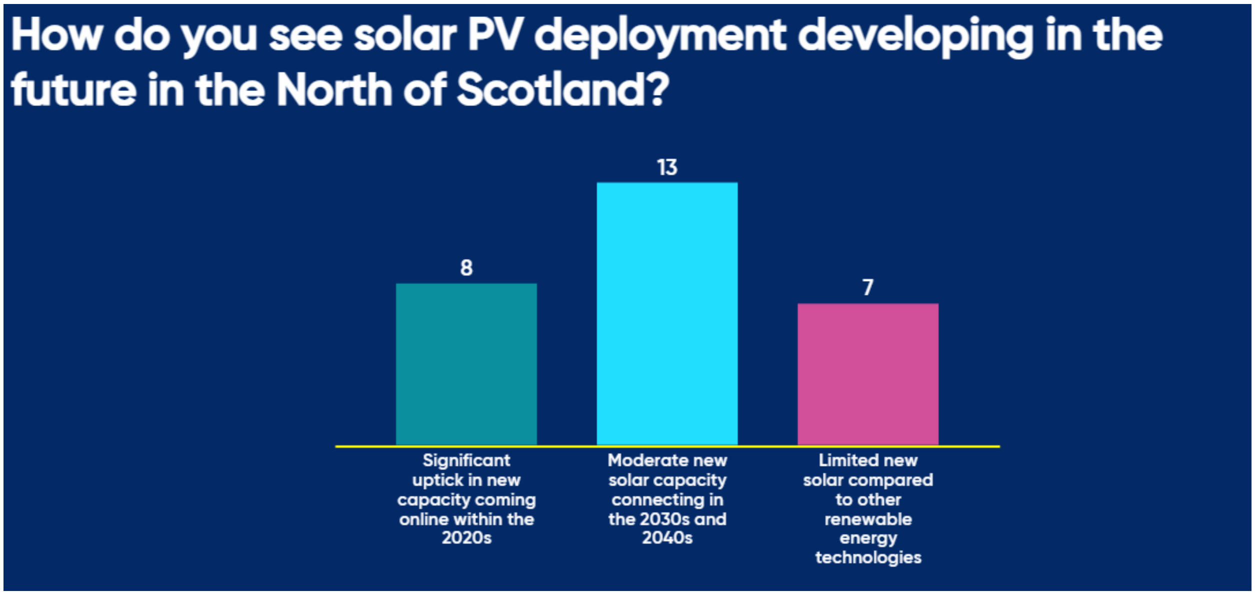
Relevant assumptions from National Grid FES 2021:

Assumption number	4.2.15 – Large-scale solar PV
Steady Progression	Slower pace of decarbonisation.
System Transformation	Transition to net zero results in strong growth in large solar.
Consumer Transformation	Transition to net zero results in strong growth in large solar.
Leading the Way	Very high ambition to decarbonise drives a focus on technologies that are low carbon. Supports production of hydrogen by electrolysis.

Stakeholder feedback overview:

Large-scale solar PV	
Stakeholder feedback provided	How this has influenced our analysis
A range of stakeholders were engaged through a dedicated North of Scotland DFES workshop in October 2021. There was a range of views around future solar PV deployment in the North of Scotland, with 38% of stakeholders suggesting there could be a significant uptick in new capacity within the 2020s and 62% suggesting there would be a more moderate growth in the 2030s and 2040s. Distribution network capacity, solar irradiation and planning friendliness were voted as the most significant factors determining the location of new solar capacity connecting in the licence area. Stakeholder feedback suggests that solar deployment in the region is increasingly being linked with battery storage, and to high energy users such as new data centres. It is significant therefore that the pipeline for solar, battery storage and new data centres have all increased in the past two years.	The range in views around the scale of near/medium term uptake of new large scale solar capacity has been reflected in the range of capacity outcomes across the four scenarios. **Steady Progression** sees a less ambitious and slower deployment and **Leading the Way** reflects almost all known pipeline sites with positive planning evidence, some recently lapsed projects moving forward to development and additional future capacity being deployed in strong solar resource areas. Regen's solar resource assessment and geographical distribution model applies solar irradiance, other geographical factors and planning friendliness to distribute solar capacity across the licence area. The range of capacity projections across the scenarios also reflect a range of outcomes for releasing distribution network capacity in the licence area and the timescale and significance of network connection cost reforms.
Engagement with the Scottish STA highlighted a deployment high ambition target of 3.5 GW of large-scale solar across Scotland by 2030.	The STA ambition has added weight to the evidence that solar PV has significant potential in Scotland. However, given the current levels of uncertainty, and previous trend of stalled projects in the North of Scotland, the SSEN DFES 21 has not gone as far as the STA's most ambitious growth target. **Leading the Way** sees some 715 MW connected by 2030 in the North of Scotland licence area. This is a 20-fold increase from the 36 MW baseline, but recognises that a significant proportion of new solar capacity could be deployed in the south Scotland.

Figure 22: Stakeholder responses to solar PV question in the online engagement webinar



References:

SSEN connection offer data, DNO Embedded Capacity Registers, the Renewable Energy Planning Database, Regen consultation with local stakeholders, representatives from the Scottish Solar Trade Association and solar project developers.

[xiv] See IRENA study showing cost of utility scale solar could fall by a further 55% by 2030: https://www.powerengineeringint.com/renewables/irena-wind-and-solar-costs-will-continue-to-fall/

[xv] See NREL solar cell efficiency tracker: https://www.nrel.gov/pv/cell-efficiency.html

[xvi] See EY solar PPA agreement, Dec 2020: https://www.ey.com/en_uk/news/2020/12/ey-agrees-its-first-zero-carbon-power-purchase-agreement-in-uk-with-solar-energy-farm

[xvii] See Scottish Enterprise net zero framework, published June 2021: https://www.scottish-enterprise.com/media/4044/net-zero-framework-for-action.pdf

[xviii] See Scottish Government renewable energy policy target: https://www.gov.scot/policies/renewable-and-low-carbon-energy/

Small-scale solar PV

Summary of modelling assumptions and results

Technology specification:

The analysis covers any solar generation sites of installed capacity less than 1 MW connecting to the distribution network in the North of Scotland licence area.

- Domestic solar PV (<10 kW) – **technology building block Gen_BB013**
- Commercial solar PV (10 kW – 1 MW) – **technology building block Gen_BB012**

Data summary for small-scale solar PV in the North of Scotland licence area:

Installed power capacity (MW)		Baseline	2025	2030	2035	2040	2045	2050
<10 kW	Steady Progression	69	76	98	124	151	178	206
	System Transformation		91	152	221	289	356	423
	Consumer Transformation		108	201	305	408	513	618
	Leading the Way		117	242	379	515	652	790
10 kW – 1 MW	Steady Progression	22	25	30	36	41	46	51
	System Transformation		31	44	59	72	86	99
	Consumer Transformation		35	57	79	101	122	144
	Leading the Way		38	69	101	125	162	193

Overview of technology projections in the licence area:

- Domestic-scale solar PV has historically seen high levels of uptake in the North of Scotland licence area, despite the lower levels of irradiance compared to the rest of the country. This deployment was driven by particularly high rates in the early years of the Feed-in Tariff.
- While domestic-scale solar PV is a more attractive investment in sunnier regions, levels of irradiance are less influential on uptake, compared to utility-scale ground-mounted solar PV. As a result, the capacity of domestic-scale solar PV in the licence area is expected to broadly align with national trends in each of the four scenarios. This is driven largely by consumer engagement, uptake of other domestic technologies (such as electric vehicles and domestic batteries), and a future reduction in the costs of domestic solar array installations.
- In **Leading the Way** (the scenario reflecting the highest decarbonisation ambition), around one in five domestic properties host rooftop PV by 2050.
- Small-scale commercial-scale solar PV is typically impacted by a blend of the drivers of

domestic-scale and utility-scale solar PV. Consequently, commercial-scale solar PV deployment has a similar trajectory to these other solar asset classes, with strong capacity growth under the **Consumer Transformation** scenario in particular.

- The DFES 2021 projections are higher than those projected in DFES 2020. This reflects the higher small-scale solar PV projections seen in FES 2021 compared to FES 2020 and high ambition for solar PV across Scotland as highlighted through engagement with the Scottish Solar Trade Association (STA).
- Reflecting the higher ambition of the FES 2021 and feedback from the Scottish STA, the DFES 2021 **Leading the Way** scenario has an annual deployment rate that is, at its peak, 75% higher than the historic maximum annual deployment rate seen in the licence area under the Feed-in Tariff.
- **Consumer Transformation** has a maximum deployment rate about 30% higher than the historic maximum annual deployment rate, while **System Transformation** and **Steady Progression** remain below historic trends. These trends are illustrated in more detail in Figure 24.
- The trajectory for small-scale solar in the near term may depend strongly on the uptake of the Smart Export Guarantee[xix], and attractiveness of rooftop solar for homeowners in terms of installation costs, and savings from reduced wholesale electricity consumption.
- However, despite the Smart Export Guarantee having been in place for two years, it has not increased small-scale solar PV deployment, as deployment rates nationwide remain at similar levels to those in the years after the Feed-in Tariff closed in 2015. Therefore, the cost of installation and return on investment (discounting the Smart Export Guarantee) may be the more significant factors.
- Despite increased ambition, the DFES 2021 projections remain below those in FES 2021. This is primarily based on a lower baseline capacity, a less ambitious pipeline and near-term trajectory. This resultantly reduces ambition for solar deployment in the licence area. However significant capacity is still projected in the DFES 2021, with capacity reaching c.1 GW by 2050 under **Leading the Way.**

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- There is 69 MW of domestic-scale solar PV in the North of Scotland licence area, equivalent to rooftop arrays on 3.4% of domestic buildings, slightly above the GB-wide average figure of 3.0%.
- Around 85% of these installations occurred between 2010 and 2015, supported by the Feed-in Tariff. The installation rate peaked at 18 MW installed in 2012.
- Deployment slowed notably as the Feed-in Tariffs reduced and the eventual end of the Feed-in Tariff programme, with only 8 MW installed since 2016.
- The commercial-scale solar PV baseline totals 22 MW. As per domestic-scale installations, the Feed-in Tariff supported this deployment, and development has equivalently tailed off since 2016.

Near term (2021 – 2025)

- There are 20 solar PV sites of 1 MW or lower with an accepted connection offer in the licence area. This contracted capacity totals 3.3 MW.
- In addition to this, there are 10 sites totalling 2 MW with a quote issued for a network connection, that have not yet been accepted.
- It is assumed that all sites with an accepted connection offer will go ahead in all

scenarios. This is modelled to happen within two years under **Leading the Way** and **Consumer Transformation** scenario and within four years under **Steady Progression** and **System Transformation**.

- Sites with a quote issued are modelled to connect with the 2020s in the **Leading the Way** and **Consumer Transformation**.
- None go ahead in **Steady Progression**, while only sites with a quote issued within the last three years go ahead in **System Transformation**.
- The **Consumer Transformation** and **Leading the Way** scenarios, with high levels of green ambition from the public and high near-term uptake of electrified transport, see a corresponding uptake in solar PV due to both ambition and financial benefits. Capacity reaches c.160 MW by 2025 under **Leading the Way**.

Medium term (2025 – 2035)

- Beyond the near term, small-scale solar uptake depends strongly on national trajectories and less on licence area-specific factors.
- The North of Scotland licence area has lower levels of solar irradiance than the rest of the UK. However, historic uptake is around 13% higher than the overall GB trajectory on a per home basis. This could be due to number of factors, from higher levels of social housing to more large detached and semi-detached properties in rural areas.
- As a result of the balance between solar irradiance, factors such as social housing, affluence and available roof area, the uptake of rooftop solar PV in the North of Scotland licence area is expected to be in line with national trajectories.
- Rooftop solar PV on new build housing accounts for 10-20% of the uptake seen in all scenarios, owing to lower installation costs than retrofit panels.
- Beyond the next few years, the volume of new housing developments are expected to reduce, especially in more rural areas of the Highlands and Islands, where population is steady or expected to decline. Therefore, the impact of solar PV on new build housing decreases over time.
- **Leading the Way** sees a large increase in new small-scale solar PV capacity, as a result of high consumer ambition and engagement, and high levels of electrification in transport, heat and cooling. The two other net zero scenarios have strong uptake as panel costs fall, but to a lower extent than **Leading the Way**.
- By 2035, total small-scale solar PV capacity in the licence area ranges from 480 MW in **Leading the Way** to 160 MW in **Steady Progression**.

Long term (2035 – 2050)

- In line with the FES 2021, the overall trends established in the medium term continue out to 2050, with deployment rates remaining relatively constant between 2026 and 2050.
- Figure 24 illustrates how the scenario's annual deployment rate of small-scale solar PV capacity varies relative to the baseline's annual deployment rate.

Figure 23: Small-scale solar PV projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections

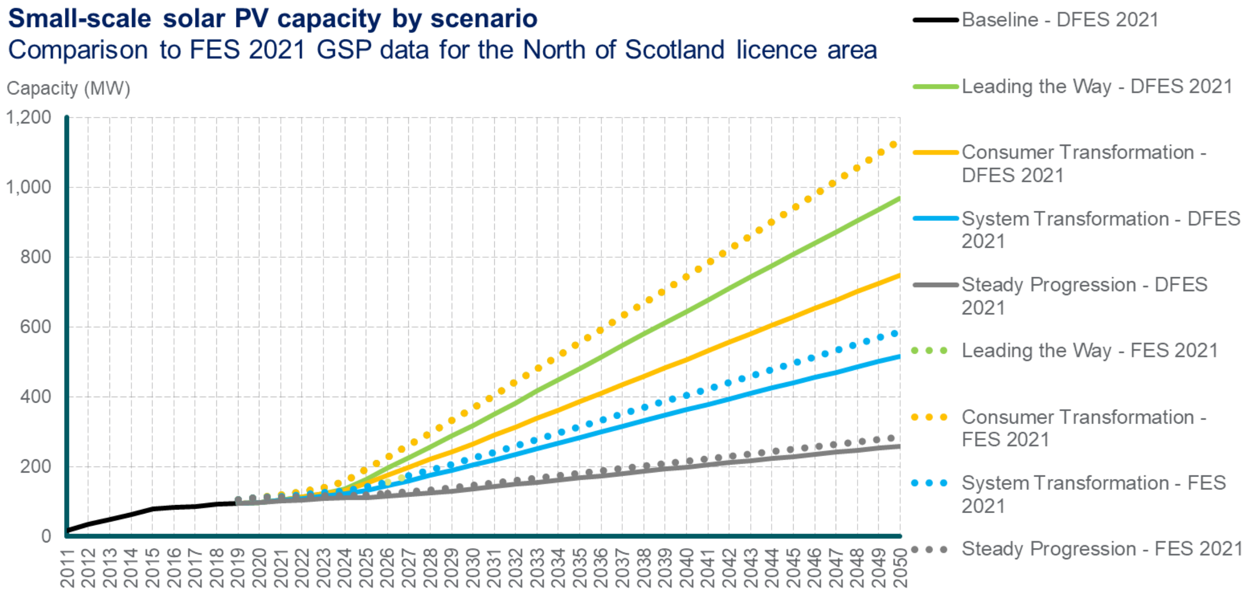
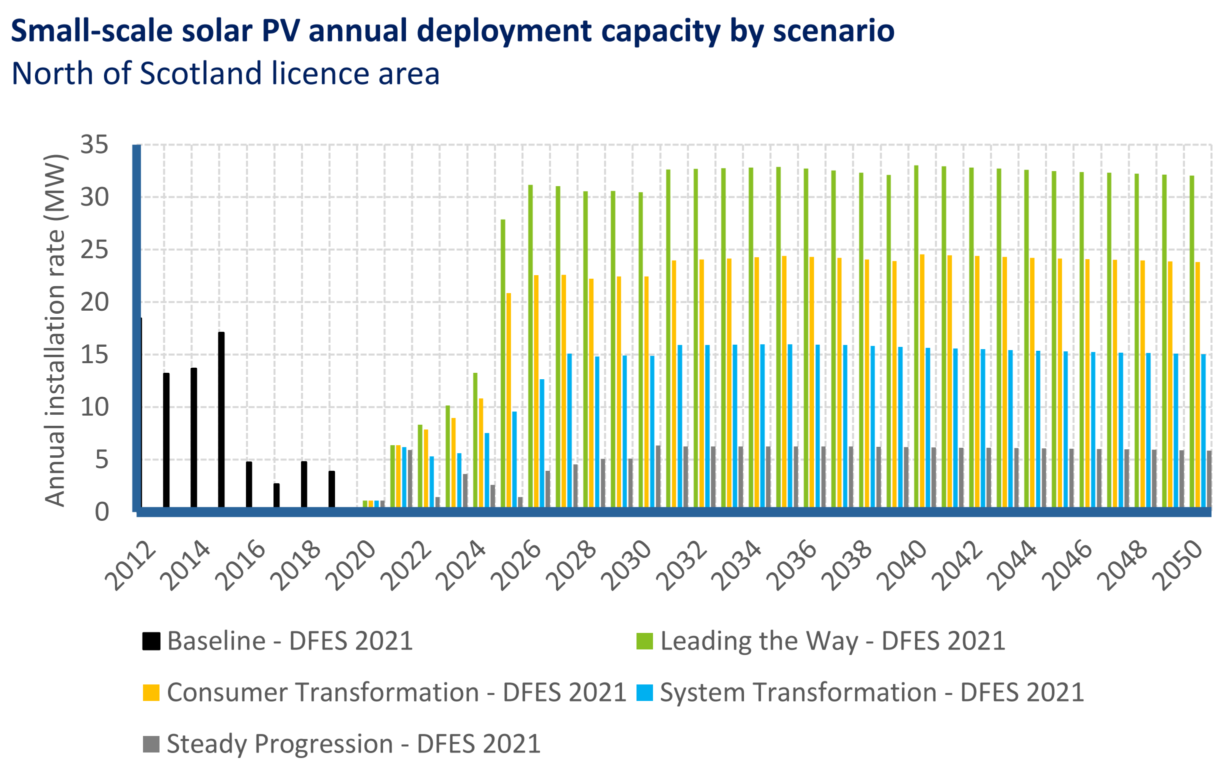


Figure 24: Annual small-scale solar PV projections for the North of Scotland licence area scenarios relative to the baseline annual deployment rate



Reconciliation with National Grid FES 2021:

Results in this section relate to the FES 2021 data for the relevant GSPs within the North of Scotland licence area.

- As small-scale solar PV is more strongly driven by national considerations, support, policy and public sentiment, the DFES 2021 aligns with the FES 2021 regional data in terms of the range of projections between scenarios.
- However, most DFES 2021 scenario projections are consistently lower that the FES 2021 projections, due to a lower baseline capacity, and a less ambitious pipeline and near-term trajectory, which combined has a lasting impact to dampen future ambition.
- The exception is the **Consumer Transformation** scenario, where the DFES uptake is significantly lower than the FES 2021 regional figures. The DFES modelling for this scenario increased its ambition on last year to reflect stakeholder feedback (including insight from the Scottish STA), but the projections under this scenario remain dampened compared to FES 2021 due to the evidence of historic trends and the pipeline.

Factors that will affect deployment at a local level:

- The spatial distribution of new small scale solar PV in the licence area has been divided into domestic scale solar PV (<10 kW) and commercial scale (10 kW – 1 MW).
- Domestic uptake is mainly influenced by factors such as affluence, home ownership, and social housing. In the early years, uptake is weighted towards affluent areas and social housing where solar is installed by housing associations and becomes more spread across all affluence levels towards 2050, especially in **Leading the Way** and **Consumer Transformation**. The impact of these variables reduces over time as solar PV becomes increasingly ubiquitous.
- Over 110,000 new homes are projected to be built in the licence area between now and 2050. In **Consumer Transformation** (the highest deployment scenario), 45% of the new build homes have a total of 116 MW of rooftop solar capacity installed by 2050, a fifth of the total domestic projection.

Relevant assumptions from National Grid FES 2021:

Assumption number	4.1.5 - 'Solar generation (plant smaller than 1 MW)'
Steady Progression	Slower pace of decarbonisation.
System Transformation	Transition to net zero results in strong growth in small solar. Supports production of hydrogen by electrolysis.
Consumer Transformation	Very high growth in small solar as it supports the transition to net zero and is highly aligned to the high societal change.
Leading the Way	Transition to net zero results in strong growth in small solar. Supports production of hydrogen by electrolysis. Growth limited by overall lower annual demands than **Consumer Transformation**.

Stakeholder feedback overview:

Small-scale solar PV	
Stakeholder feedback provided	How this has influenced our analysis
Engagement with the Scottish STA highlighted a high ambition target for solar in Scotland that surpasses historic trends. The STA projects 6 GW for all solar across all Scotland (North and South) by 2030, of which: • 3.5 GW large ground mount • 1.5 GW commercial rooftop • 1 GW domestic rooftop	Compared to DFES 2020, the DFES 2021 scenarios have increased their ambition significantly and two scenarios now have deployment rates above historic trends, including **Leading the Way** which has a deployment rate 75% above the peak Feed-in Tariff rate consistently for nearly 25 years.

Small-scale solar PV was not discussed directly at the engagement events, with priority given to technologies that had more regional considerations. However, Regen's existing market insight and knowledge from undertaking previous and ongoing DFES projects, was used to inform these scenario projections.

As part of Regen's engagement with local authorities, data was collected on whether each local authority had declared a climate emergency or had specific renewable targets or strategies. Where these existed, a small positive weighting was given in the near term. However, the projections in the medium and long term the level of ambition reflects more the ESO FES scenarios themselves.

References:

SSEN connection data, Climate Emergency declaration data, Feed-in Tariff data, Regen resource assessments, Regen consultation with local stakeholders and local authorities.

[xix] See Ofgem Smart Export Guarantee overview: https://www.ofgem.gov.uk/environmental-and-social-schemes/smart-export-guarantee-seg

Hydropower

Summary of modelling assumptions and results

Technology specification:

The analysis covers any hydropower generation connecting to the distribution network in the North of Scotland licence area.

The analysis does not include pumped hydropower, which is considered an energy storage technology.

Technology building block: **Gen_BB018 – Non-pumped hydro**

Data summary for hydropower in the North of Scotland licence area:

Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	812	876	879	882	884	886	888
System Transformation		884	897	909	922	935	949
Consumer Transformation		900	965	1,015	1,057	1,092	1,129
Leading the Way		884	903	917	929	943	956

Overview of technology projections in the licence area:

- Hydropower is a well-established technology in the North of Scotland licence area, with 812 MW of capacity connected to the SSEN distribution network as of the end of 2021.
- The reduction in subsidy support has affected deployment rates since 2016, but interest in hydropower development has increased in recent years. The key advantage of hydropower is that its rainfall-dependent generation profile does not follow that of wind or solar, with most generation occurring in the wintertime, when electricity prices are typically higher. This reduces the risk of price cannibalisation, as well as potentially avoiding periods of grid constraint. This means that the wholesale capture price and PPA prices for hydropower tend to be above that of the main renewable technologies.
- There is some uncertainty about how much more hydropower resource could be developed in the North of Scotland.
- To obtain a rough estimate of hydropower potential in the region, the last comprehensive study of hydropower resource, commissioned by the Scottish Government and published in 2008, was used as part of the SSEN DFES 2021. This study used the Hydrobot geospatial model and found that there could be 657 MW of untapped hydropower potential across Scotland; of which 594 MW (90%) is located in the highlands[xx]. Accounting for the capacity that has already been deployed to date, 443 MW of residual resource could be available across Scotland, of which c.400 MW is likely to be in the North of Scotland licence area. The calculations behind this estimate are shown in Figure 26.
- However, this estimate is extremely rough and relies heavily on the accuracy of the 2008 study. Other resource assessments found a maximum of 1.2 GW of untapped hydropower potential in Scotland, using more ambitious economic assumptions[xxi].

- To reflect this remaining potential, the DFES 2021 has modelled a higher rate of growth in the **Consumer Transformation** scenario than has been estimated in the FES 2021 GSP regional datasets. This scenario also reflects a higher proportion of small-scale hydropower being developed to meet localised electricity demand in the highlands.
- Although largely an established technology with relatively slow capacity growth in recent years, there has still been a consistent pipeline of projects coming forward. The industry outlook is now more positive, as evidenced by the 30 new sites that have connected in the SSEN licence area in 2020 and in 2021.
- As hydropower is also suited to rural off-grid applications, it is expected that a small proportion of new schemes will not need a grid connection.
- The DFES analysis has also considered other factors such as the intermittency and seasonality of rainfall patterns in the future, due to the impact of climate change in Scotland. This has the potential to positively affect hydropower business models in some locations. While sites would not be able to produce power all year round, they would generate more energy during winter months due to the projected increase in rainfall[xxii]. This could complement solar and wind generation profiles during these months, and allow for a more balanced supply of renewable energy during peak winter demand.
- As a result of these various factors, the total distribution connected capacity in the North of Scotland licence area is projected to increase to 888 MW under a **Steady Progression** scenario and c.1.1 GW under a **Consumer Transformation** scenario in 2050. The DFES 2021 **Consumer Transformation** projection is slightly higher than the National Grid FES 2021 regional projection.

Figure 25: Baseline and pipeline hydropower sites in the North of Scotland licence area

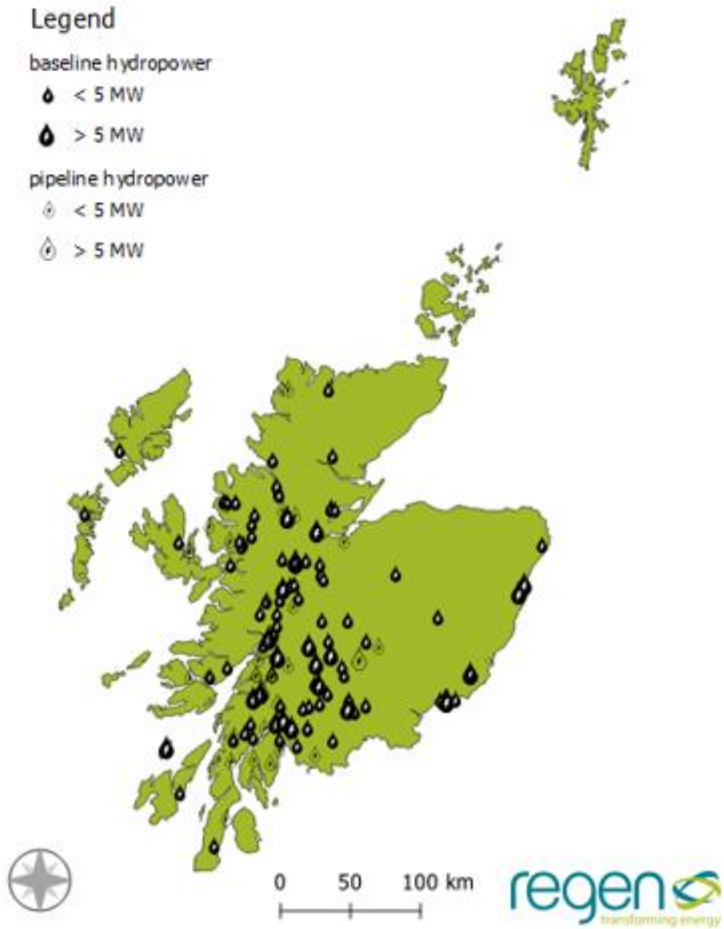


Figure 26: Estimate of remaining hydropower potential in Scotland

Approximate calculation of remaining hydropower resource potential based on 2008 Hydropower resource assessment [xx]	
Hydropower capacity in Scotland in 2008 totalled	1,438 MW
a) 2008 hydropower study estimate of remaining resource potential for Scotland	657 MW
b) 2008 study estimate of remaining resource potential for Scottish Highlands (90% of total)	594 MW
c) Hydro capacity in Scotland in 2020[xxiii] totalled	1,653 MW
d) Deployment across Scotland 2016-2020[xxiv]	214 MW
e) Estimate of remaining resource potential (a – d)	443 MW
f) Estimate of remaining resource potential in the North of Scotland @ 90% of e.	400 MW

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- There is currently 812 MW of hydropower capacity connected to the North of Scotland distribution network.
- 16 sites, representing 436 MW of capacity, are over 10 MW in size. All of these projects were built before 2002.
- Since 2005, 66 projects with a capacity of 1 MW or greater have been developed. The average size of projects in this time is 2.3 MW, with only four sites above 5 MW, which shows a clear trend towards much smaller scale hydro projects in recent years.
- Sites below 1 MW in capacity account for 123 MW (c.15% of the baseline), of which approximately 92 MW has been developed since 2010 as a result of the Feed-in Tariff.
- Development has slowed in recent years with the reduction in Feed-in Tariff rates and the removal of the Feed-in Tariff programme altogether.
- However, across 2020 and 2021 there has been an increase in small-scale hydropower projects, which has led to the commissioning of 30 new hydropower sites totalling 22.5 MW in the North of Scotland licence area.
- The most significant addition came from a 6.8 MW scheme at Loch Etive, made up of 7 different generation sites, which was connected in February 2021.

Near term (2021 – 2025)

- A pipeline of sites with accepted connection offers totals 70 MW in the licence area.
- The majority of this capacity is associated with a 52 MW project at Lochaber, an existing hydropower plant that directly powers the co-located industrial plant. The additional contracted capacity is to ensure that the operational project can export all generated energy to the network in the future.
- The remaining 18 MW pipeline of hydropower projects is spread across 22 sites. Of these sites, 4 are medium-sized schemes (> 1 MW) which total 13 MW. The remaining 18 sites are small-scale schemes (≤ 1 MW) with an average capacity of only 280 kW.
- The majority of these new projects have planning permission or are already under construction, and are expected to connect within the next few years in all scenarios.

- Planning friendliness for hydropower projects in the licence area is high, so most projects that do not yet have permission are modelled to connect in all scenarios, with a delay reflected in **Steady Progression**.
- The Access and Forward-Looking Charges Significant Code Review, and changes to transmission network (TNUoS) charges for embedded generators, has the potential to significantly impact the business case for distributed generation in the North of Scotland. Depending on the outcome of the code review, upfront connection charges may decrease; however, as a generation-dominated region, distribution projects in the North of Scotland could see higher ongoing network charges.
- Project developers of distribution connected sites could decide to move to the transmission network, as a result of TNUoS charging. This is a key uncertainty for the future development of new hydropower in the region, which is reflected in the range of new sites connecting between the scenarios.

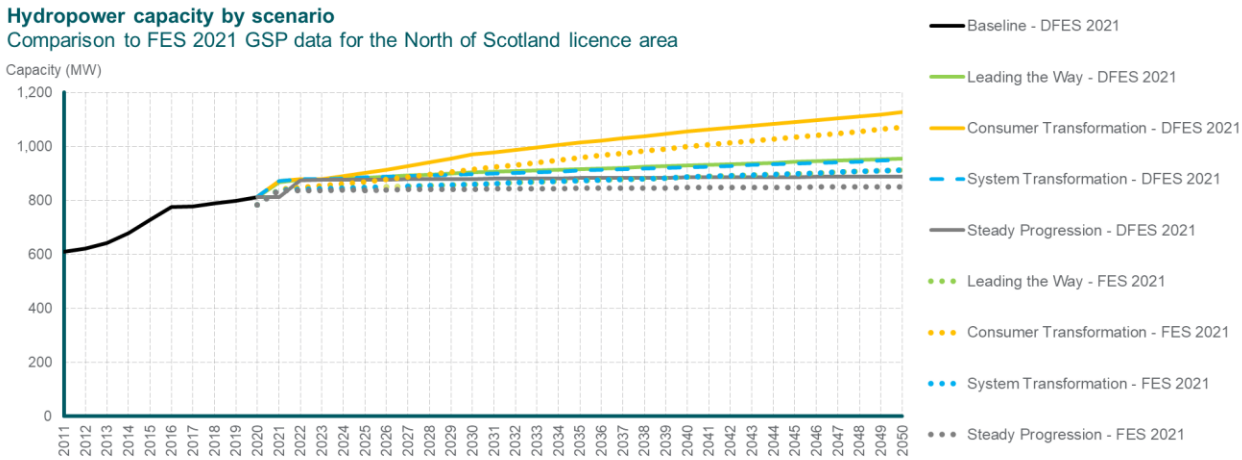
Medium term (2025 – 2035)

- Scottish Government policy continues to support renewable generation technologies (including hydropower), with an aim to generate 50% of Scotland's energy consumption from renewable sources by 2030.
- Beyond the known pipeline, the **Consumer Transformation** and **Leading the Way** scenarios see continued deployment of c.10 MW per year, reflecting trends seen since 2016. These projects are supported primarily by the Smart Export Guarantee[xxv], with potential value from power purchase agreements or direct co-location with electricity demand, for example at industrial sites.
- Under **System Transformation** and **Steady Progression**, new hydropower development is low as preference is given to large-scale generation. This results in more hydropower projects failing to develop. As these scenarios also feature lower levels of societal change, revenue streams such as corporate power purchase agreements are less commonplace than under **Consumer Transformation** and **Leading the Way**, leaving hydropower projects struggling to produce a viable business model in all but the most optimal areas.

Long term (2035 – 2050)

- The long-term trajectories for hydropower are very similar to those outlined in the medium term, reflecting national assumptions for renewable energy technologies under each scenario.
- **Consumer Transformation** and **Leading the Way** scenarios see the majority of economically viable projects developed in the licence area, reflecting greater ambition and the possibility of a sector revival. This projected increase in capacity relies heavily on the assumption that, under these scenarios, alternative financial models are developed to continue the support for small-scale hydropower.
- Additionally, further policy initiatives could provide additional support to the hydropower sector, including:
    - The 60% relief for non-domestic rates for hydropower generators (endorsed by British Hydropower Association[xxvi])
    - The small-scale hydro plant and machinery review, proposing to revise rateable values for hydro plants[xxvii].
- **Consumer Transformation** is the only scenario that sees distribution network connected hydropower reach more than 1.1 GW by 2050 (1,129 MW), and **Steady Progression** sees the lowest overall capacity by 2050 of 888 MW.

Figure 27: Hydropower projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

Results in this section relate to the FES 2021 data for the relevant GSPs within the North of Scotland licence area for building block **Gen_BB018 – Non-pumped hydro**.

- The 2021 FES baseline is 783 MW compared to the DFES 2021 baseline of 812 MW, a difference of 29 MW. The baseline variance has reduced compared to the DFES 2020.
- The remaining discrepancy is most likely due to a combination of factors including the recent commissioning of new projects in 2020 and 2021.
- The near-term FES 2021 GSP data is unusual, with non-cumulative growth ranging from 53 to 57 MW from 2020 to 2021 depending on the scenario. In all other years, growth does not surpass 3 MW, except for in **Consumer Transformation** where it does not surpass 10 MW in any given year. The trend in all other scenarios follow very similar trajectories.
- The DFES reflects a similar amount of near-term growth to FES 2021, to reflect the known project pipeline. In **Consumer Transformation** and **Leading the Way** scenarios, this growth continues into the 2020s to reflect the untapped resource potential of hydropower. **System Transformation** and **Steady Progression** are more aligned with the FES, showing limited growth in this sector.

Factors that will affect deployment at a local level:

- Naturally, hydropower potential is constrained to rivers and/or watercourses with vertical change in elevation (head) and flow. The Scottish Highlands, being a mountainous region with large amounts of rainfall, hosts most hydropower in the North of Scotland.
- The distribution of future projects, beyond the known pipeline, is dictated by a combination of a hydropower resource assessment based on river flow and head, and the location of known projects, both existing and those that failed in development.

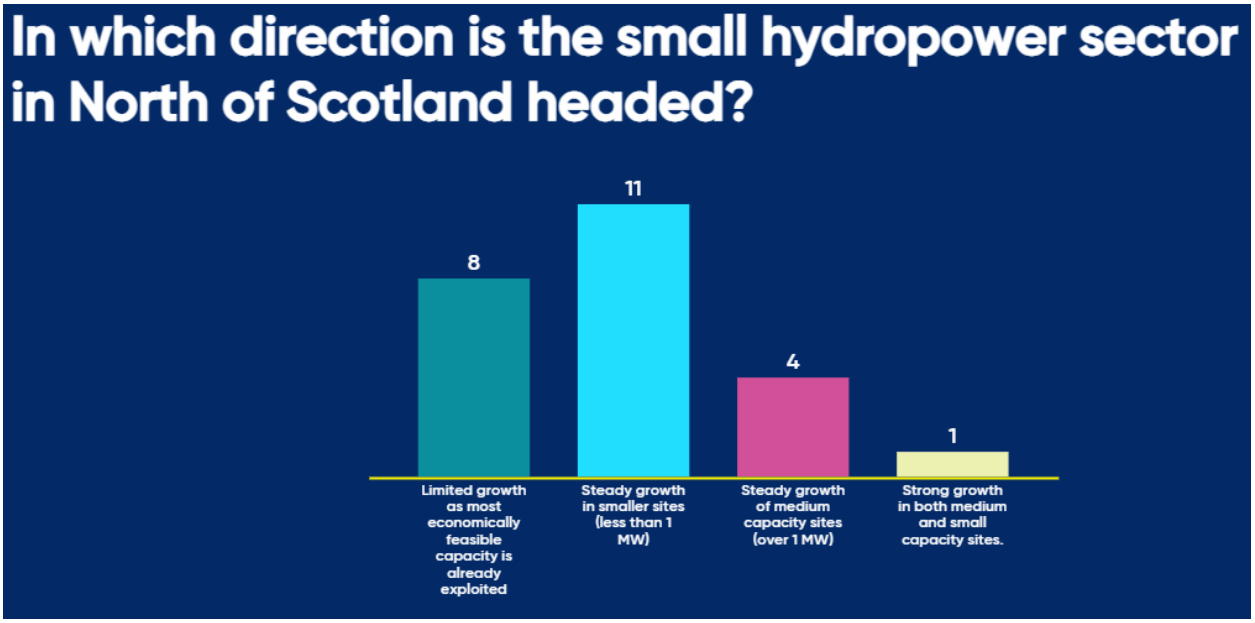
Relevant assumptions from National Grid FES 2021:

Assumption number	4.1.2 - Other renewables including marine and hydro generation
Steady Progression	Low support and therefore other renewables cannot compete with low cost solar and wind generation.
System Transformation	Support for large scale renewable technologies (i.e. tidal marine).
Consumer Transformation	Potential for a lot of small scale projects that will have larger societal impact coupled with support for marine technologies across all scales.
Leading the Way	Focus on rapid decarbonisation results in prioritising renewables that are available at lowest cost today (i.e. solar and wind). Innovation in other flexible solutions results in less need for a wide range of renewables.

Stakeholder feedback overview:

Hydropower	
Stakeholder feedback provided	How this has influenced our analysis
At a North of Scotland stakeholder engagement workshop held in October 2021, stakeholders were asked in which direction they thought the hydropower sector was headed and how they felt climate change would affect the hydro sector.	The potential for steady increase in sites below 1 MW was thought to be highest. The second most popular response highlighted limited growth, due to most economic potential already being largely exploited. Of the user groups, consultants and contractors seemed to be the most pessimistic about the sector, while Local Authorities, and to some degree, Energy Developers, saw a future in small-scale development. In terms of climate change impacts, responses were overwhelmingly in favour of a combined effect, where climate change would result in both positive and negative impacts on hydropower. To reflect these views, the increased seasonality of rainfall was not modelled to greatly alter the future hydro capacity in the licence area.
As part of the engagement process, Regen contacted several small-scale hydropower developers in the North of Scotland.	Responses highlighted grid capacity constraints and the dependency of hydropower on FiT subsidy as key limiting factors for sector development. FiT accreditation also reduced project flexibility. To reflect this, **Consumer Transformation** and **Leading the Way** have assumed that alternative financing models and regulatory changes are found for hydropower, enabling further future development.

Figure 28: Stakeholder responses to solar PV question in the online engagement webinar



References:

SSEN connection offer data, DNO Embedded Capacity Registers, National Grid ESO TEC register, the Renewable Energy Planning Database, Regen consultation with local stakeholders and discussion with developers.

[xx] See *Scottish Hydropower Resource Study*, (2008): https://archive.uea.ac.uk/~e680/energy/energy_links/other_renewables/Scottish_hydropower_2008_0064958.pdf

[xxi] See *The Employment Potential of Scotland's Hydro Resource*, (2009): https://digital.nls.uk/pubs/scotgov/2010/9780755992270.pdf

[xxii] See Scottish Government 2019, *Scottish climate change adaptation programme 2019-2024: strategic environmental assessment*: https://www.gov.scot/publications/climate-ready-scotland-scotlands-climate-change-adaptation-programme-2019-2024-strategic-environmental-assessment/pages/9/

[xxiii] See *BEIS Renewable Statistics* (2021): https://www.gov.uk/government/statistics/regional-renewable-statistics

[xxiv] See *BEIS Renewable Statistics* (2021): https://www.gov.uk/government/statistics/regional-renewable-statistics

[xxv] See Ofgem summary of Smart Export Guarantee: https://www.ofgem.gov.uk/environmental-and-social-schemes/smart-export-guarantee-seg

[xxvi] See BHA article on Scottish rates relief cap: https://www.british-hydro.org/legislation/hydro-sector-welcomes-scottish-rates-relief-cap/

[xxvii] See Scottish Government 2020, *Small-scale hydro plant and machinery review report:* https://www.gov.scot/publications/report-small-scale-hydro-plant-machinery-review/

Marine energy generation

Summary of modelling assumptions and results

Technology specification:

The analysis covers any marine generation projects (tidal or wave) that connect to the distribution network in the North of Scotland licence area. The SSEN DFES analysis has focused predominantly on known small-scale project developments, supplemented by engagement with the Marine Energy Council and representatives from the Scottish Islands, to identify other potential pipeline projects likely to connect to the distribution network out to 2050.

The DFES projections specifically focus on marine generation projects connecting to the distribution network. However, it is recognised that if the technology proves successful at a commercial scale, significantly more marine generation capacity could connect to the transmission network in Scotland.

The technologies included in the DFES marine energy analysis are:

- Wave energy – typically connected to the distribution network as small pre-commercial arrays and demonstration projects
- Tidal stream energy – harnessing kinetic tidal flows around headlands and in channels
- Note: there are no tidal lagoon projects in the study area, and these would, in any case, connect at transmission level

Technology building block: **Gen_BB017 – Marine (Tidal Stream, Wave Power, Tidal Lagoon)**

Data summary for marine generation in the North of Scotland licence area:

Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	27	30	30	30	30	30	30
System Transformation		30	30	30	30	30	30
Consumer Transformation		33	53	151	151	151	151
Leading the Way		43	121	151	180	250	250

Overview of technology projections in the licence area:

- The location of marine energy projects is dependent on a number of specific factors:
  - Available energy resources
  - Seabed depths and conditions
  - Marine environmental designations
  - Port availability.
- The sea areas around the north of Scotland including the Pentland Firth, Western Isles and Orkney have been identified as the best marine energy resources in the UK and indeed in Europe. There are also opportunities to develop further projects on Shetland.
- This offers a significant opportunity to deploy wave and tidal energy technologies.
- Orkney is also home to Europe's most active marine energy test facility at EMEC.
- The marine energy generation sector has faced a number of challenges in recent years and has struggled to build on the success of the 6 MW MeyGen pilot project[xxviii] in the waters between the northern tip of Scotland and the Isle of Stroma in 2015.

- A core issue was the withdrawal of specific Contracts for Difference (CfD) subsidy support for wave and tidal energy in 2016, which affected industry confidence and led to the withdrawal and delay of many pre-commercial projects[xxix].
- The marine sector (specifically the Marine Energy Council) has lobbied BEIS to reform the CfD Allocation Round 4 (AR4) framework to include specific ring-fenced support for marine energy technologies. In late November 2021, BEIS announced that tidal stream would be awarded a £20m ring-fenced minima within AR4, at an administrative strike price of £211/MWh[xxx]. This amendment has been welcomed by the industry[xxxi] and could reignite investment and development of new tidal projects.
- Wave energy development and deployment has been slower than tidal energy and, in the near term, is still limited to testing and demonstration sites.
- If larger scale projects proceed, they are likely to connect to the transmission network and thus not fall within the scope of the DFES 2021 analysis. Therefore, distribution network connected projects may be limited to smaller-scale commercial projects, demonstration projects, trial sites and testing facilities.
- The North of Scotland licence area has some operational marine generation sites connected to the distribution network, located off the coast of Stroma, Islay, Shetland and Orkney, totalling 27 MW.
- In addition to these, there are a number of pipeline projects and project capacity extensions located on the Scottish Islands and west coast of Scotland. This pipeline capacity totals 114 MW and have been modelled to come online in **Leading the Way** and **Consumer Transformation** across the 2020s and 2030s.
- Beyond this pipeline of known developments, additional project capacity has been modelled to connect to the distribution network in the North of Scotland licence area in the **Leading the Way** and **Consumer Transformation** scenarios. These scenarios reflect the region's high resource potential for both wave and tidal energy development.
- By 2045, 250 MW is projected to connect to the distribution network under **Leading the Way** and 150 MW to connect under **Consumer Transformation**. This reflects Scottish Government's 2045 net zero target year. Additional large scale marine electricity generation projects could connect to the transmission network under these scenarios.
- Even under the higher growth scenarios it is recognised that marine energy faces a challenging development environment and the viability of this technology to deliver significant generation capacity is dependent on cost reduction, access to seabed areas and continued policy support.

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

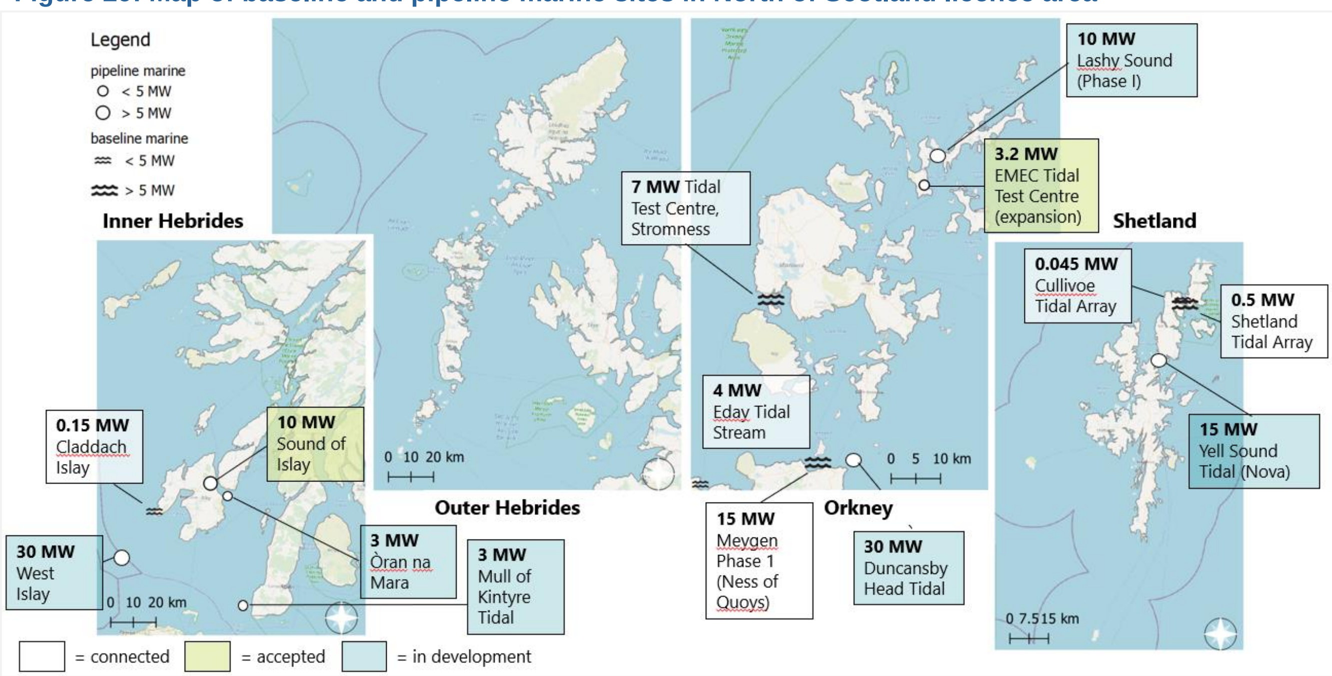
- There are six active marine generation projects in the North of Scotland licence area with a total energised connection capacity of 27 MW.
- These are located in waters near Stroma, Islay, Shetland and Orkney.
- Not all of the baseline connection capacity is being utilised, due to some being connected to test facilities which may host several projects (potentially of differing technology types).
- The largest project, MeyGen, has a 15 MW connection agreement and came online in 2016. Currently only 6 MW (4 Turbines) of this generation capacity is being utilised.

Near and medium term (2020 – 2035)

- There are two projects with accepted connection offers in the licence area:
    - A 3 MW extension to the **EMEC Tidal Test Centre** on Orkney
    - A 10 MW tidal project in the **Sound of Islay** – approved by Marine Scotland

- In addition to these contracted sites, there are a number of other projects known to be in development in the North of Scotland licence area:
  - **West Islay Tidal Marine Energy Park (20 MW) –** approved in planning in 2017
  - **Oran na Mara (3 MW)** tidal generation aiming to supply whisky distillery[xxxii]
  - **Duncansby Head Tidal (30MW)** on Orkney, which submitted a notice to Marine Scotland in September 2021[xxxiii]
  - **Phase 1 and 2 of Lashy Sound Tidal (10 MW + 20 MW)** on Orkney
  - **Mull of Kintyre Tidal (3 MW)** on the Kintyre Peninsula approved in 2014.
  - **Yell Sound (15MW) Tidal project –** being developed by Nova, with an Options Agreement in-place with Crown Estate Scotland, announced Feb 2022[xxxiv].
- These projects have been modelled to come online across the 2020s and 2030s under the **Consumer Transformation** and **Leading the Way** scenarios. The rate of deployment is still very uncertain and this is reflected in the range of scenario projections. Several projects have achieved important development milestones, and the CfD AR4 announcement is positive; however, obtaining a final financial commitment to move to construction is still a significant challenge.
- The MeyGen project is being built out in phases, and while Phase 1A is connected to the distribution network, Phase 1B is likely to connect at the transmission level.

Figure 29: Map of baseline and pipeline marine sites in North of Scotland licence area



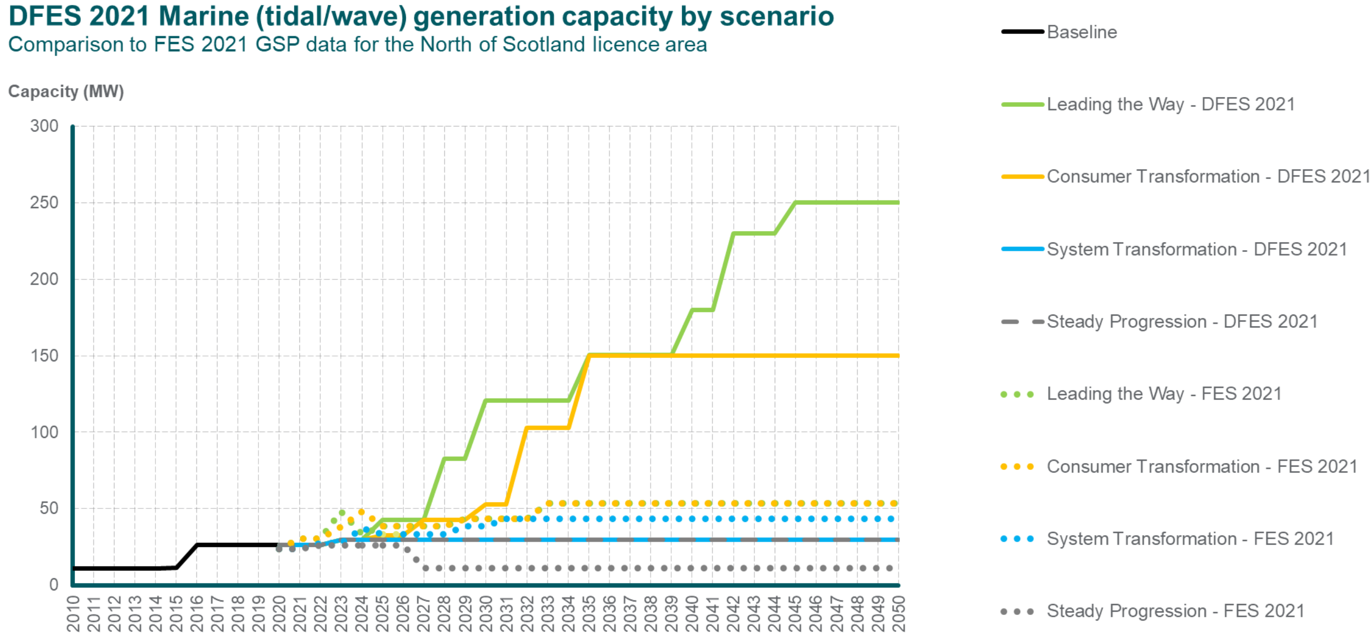
Long term (2035 – 2050)

- Larger scale marine projects are likely to connect to the transmission network. With the transmission network a voltage tier lower in Scotland than in England (i.e. including 132kV), this limits the potential for a significant amount of capacity connecting to the distribution network in the North of Scotland licence area.
- However, there may be opportunities for some additional, small-scale distribution connected trial and pre-commercial projects in the licence area beyond the pipeline, especially on the Scottish islands.
- The total FES 2021 GB projections for distribution network connected marine generation reaches 345 MW under **Leading the Way** in 2050. Since a significant proportion of the

potential tidal and wave projects – at all scales – will likely be located in the North of Scotland, the DFES has modelled a further increase in connected marine generation capacity out to 2050.

- Deployment reaches 250 MW by 2045 in **Leading the Way**, (which according to the FES 2021 projections, equates to c.73% of all GB distribution network marine capacity in this scenario in 2050) and 150 MW by 2048 in **Consumer Transformation**.

Figure 30: Marine projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

Results in this section relate to the FES 2021 data for the relevant GSPs within the North of Scotland licence area, for FES building block **Gen_BB017 – marine generation**.

- The SSEN DFES 2021 has only 2 MW more baseline capacity in the licence area than the FES 2021. This is likely due to small differences in individual site capacities.
- Based on the most recent connection data and stakeholder engagement, the SSEN DFES 2021 has identified and modelled a number of pipeline projects to connect under **Consumer Transformation** and **Leading the Way** which are not reflected in national FES 2021 projections. Marine energy capacity in 2035 reaches 136 MW in the DFES 2021 (the sum of all baseline and pipeline projects), compared to 53 MW in FES 2021.
- Looking further ahead to 2050, the DFES has projected a significantly higher level of distribution connected marine energy in the North of Scotland compared to the FES 2021 regional data. Under **Leading the Way,** the FES 2021 GSP data remains at 53 MW by 2050 which would account for only 15% of all GB distribution network connected marine energy capacity in 2050 (according to FES 2021 GB projections).
- Whilst **System Transformation** is a scenario that supports tidal generation, significant capacity under this scenario is likely to be transmission network connected. Therefore, the DFES has not modelled any trial-scale projects to connect under this scenario.

Factors that will affect deployment at a local level:

- The DFES analysis for marine generation focuses on the location of known pipeline project developments, most of which are located in waters off the north coast, west coast and the major Scottish Islands.
- Beyond the pipeline, the location of future capacity has been based on known wave and tidal resource regions identified through the draft marine sectoral plan developed by Marine Scotland in 2013[xxxv].

Relevant assumptions from National Grid FES 2021:

Assumption number	4.1.2 - Other renewables including marine and hydro
Steady Progression	Low support and therefore other renewables cannot compete with low cost solar and wind generation.
System Transformation	Support for large scale renewable technologies (i.e. tidal marine).
Consumer Transformation	Potential for a lot of small scale projects that will have larger societal impact coupled with support for marine technologies across all scales.
Leading the Way	Focus on rapid decarbonisation results in prioritising renewables that are available at lowest cost today (i.e. solar and wind). Innovation in other flexible solutions results in less need for a wide range of renewables.

Stakeholder feedback overview:

Marine generation (tidal and wave)	
Stakeholder feedback provided	How this has influenced our analysis
Representatives from both the Scottish Islands and from the marine energy development sector were engaged to inform this year's analysis. Stakeholders highlighted that the future outcome for marine generation is driven by regulation and strategic network planning. Projects will only happen if there is investment in the system. Feedback also suggested that more ambitious deployment could be modelled, compared to the 2020 edition of the DFES. Specifically, the projections in the SSEN DFES 2020 were also highlighted to be a little ambitious for Orkney under **Leading the Way** and too low for Shetland. The use of regulatory Uncertainty Mechanisms for SSEN's ED2 business plans was also discussed. It was agreed that these mechanisms enabling SSEN to revisit their determination with Ofgem could be flexed in the scenarios for renewable technologies, such as marine generation.	The 2021 DFES analysis has sought to bring on more pipeline projects more quickly under both **Leading the Way** and **Consumer Transformation**. The spread across the scenarios has also been modelled to reflect the uncertainty of developer interest, financial support and regulatory uncertainty mechanisms. Some capacity outcomes will also be re-allocated between the distribution network supply areas on the Shetland Isles and Orkney to reflect feedback provided.

References:

SSEN connection offer data, Marine Scotland, Regen consultation with Scottish Island stakeholders and discussion with marine energy developers.

[xxviii] MeyGen 6MW Pilot Project: https://simecatlantis.com/projects/meygen/

[xxix] See Guardian article from 2018 about the loss of UK development: https://www.theguardian.com/environment/2018/jun/19/huge-mistake-britain-throwing-away-lead-in-tidal-energy-say-developers

[xxx] See BEIS announcement, 24 Nov 2021: https://www.gov.uk/government/news/uk-government-announces-biggest-investment-into-britains-tidal-power

[xxxi] See Regen https://www.regen.co.uk/eleventh-hour-opportunity-as-tidal-energy-gets-20m-reserve-allocation-in-latest-cfd-round/

[xxxii] See Nova Innovation article, Feb 2021: https://www.novainnovation.com/news/news_/i/creating-water-of-life-from-the-power-of-the-sea/

[xxxiii] See Crown Estate Scotland notice, Sep 2021: https://www.crownestatescotland.com/resources/documents/notice-relating-to-the-grant-of-rights-to-orbital-marine-power-limited-for-a-30mw-tidal-array-in-the-westray-firth-orkney-islands

[xxxiv] See article about Shetland Yell Sound 15 MW project: https://www.marineenergywales.co.uk/nova-innovation-wins-seabed-lease-to-help-drive-shetlands-clean-energy-future/

[xxxv] See Marine Scotland draft marine sectoral plan, 2013: https://marine.gov.scot/information/draft-sectoral-marine-plans-wind-wave-and-tidal-2013

Biomass generation

Summary of modelling assumptions and results

Technology specification:

The analysis covers biomass-fuelled generation connecting to the distribution network in the North of Scotland licence area. This includes both biomass for power generation and biomass CHP. However, the analysis does not include biomass used solely for heat or bioenergy generation with carbon capture and storage (BECCS).

Technology building block ID: Gen_BB010

Data summary for biomass generation in the North of Scotland licence area:

Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	56	56	56	56	44	44	44
System Transformation		56	44	44	43	31	15
Consumer Transformation		56	43	135	119	104	104
Leading the Way		56	43	31	15	0	0

Overview of technology projections in the licence area:

- The North of Scotland licence area has significant local biomass resource as a by-product of the forestry industry across the region. The licence area has a large baseline of distribution network connected biomass generation and CHP plants totalling 44 MW, with biomass turbine capacities ranging from 0.1 MW to 15 MW.
- This range in size reflects a number of different biomass generation business models:
  - Large scale biomass plants for power generation
  - Large and medium scale biomass CHP plants, used as part of heat networks to supply heat to nearby homes and businesses
  - Smaller, farm-scale biomass plants, some CHP-enabled, making use of local feedstock to produce power and/or heat and securing Renewable Heat Incentive (RHI) payments.
- The National Grid ESO FES 2021 scenarios assume that, in the medium term, the capacity of biomass power generation connected to the distribution network will decrease. Instead, there will be growth in new bioenergy generation capacity equipped with carbon capture and storage technologies (BECCS). Since BECCS is likely to require significant investment and economies of scale to be economically viable, it is assumed these will be larger projects connected to the transmission network. The SSEN DFES has adopted this assumption in the relevant scenario projections.
- There is; however, potential for an increase in the uptake of smaller-scale biomass plants in the licence area, following a study underpinning the Scottish Bioenergy Policy that identified between 100,000 and 900,000 hectares of land theoretically available for Short Rotation Coppice (SRC)[xxxvi].
- There is also the potential, under the **Consumer Transformation** scenario, that some of the 126 MW of existing backup diesel generation on the Scottish Islands could be replaced by biomass or biomethane generation, or alternative hydrogen fuel.

- Finally, it should be noted that there is a call for evidence[xxxvii] to remove the 300 MW minimum threshold for Carbon Capture Readiness requirements, which would mean that small-scale generators "*must demonstrate that it will be technically and economically feasible to retrofit carbon capture technology within the lifetime of the plant.*" The call for evidence is also seeking views on the inclusion of biomass (along with other combustion technologies) under the scope of Carbon Capture Readiness requirements. If this policy revision goes through, then small-scale distributed biomass as a business model will become increasingly challenging without further subsidy support.
- As a result of these regional and national factors, no additional capacity comes online across the period to 2050 under **Leading the Way** and **System Transformation**.
- **Leading the Way** sees the most rapid decommissioning of distributed biomass generation, with no capacity online by 2045: Scottish Government's net zero target year.
- Under **System Transformation**, a proportion of the existing site capacity remains online beyond 2050, reflecting economically viable BECCS technology.
- Under **Consumer Transformation** biomass generation also plays a significant role to provide backup generation for islands and remote communities, replacing existing diesel generators. Island diesel conversion has been modelled in 2035 for the purposes of network analysis.

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- In the North of Scotland licence area, the baseline has increased from 44 MW in the 2020 DFES to 56 MW in DFES 2021. This is due to the reassignment of some baseline sites that were previously uncategorised. The bulk of this capacity reassignment is related to the 12 MW Stoneywood Paper Mill Biomass CHP, which came online in 1989.

Near term (2021 – 2025)

- Biomass generation capacity connected to the distribution grid does not see any growth or decommissioning in the near term under any scenario. This is due to the existing facilities having remaining operational life and being unlikely to decommission prematurely based on the current policy context.

Medium term (2025 – 2035)

- In **Leading the Way**, **Consumer Transformation** and **System Transformation**, the North of Scotland licence area sees a decrease of existing biomass generation sites out to 2034. This either happens through decommissioning or through certain facilities upgrading and moving to the transmission grid while incorporating BECCS.
- During this time period, after an initial decommissioning of 12 MW, remaining capacity stays connected under **System Transformation**. This is due to a longer decommissioning timeframe, while some larger-scale distribution connected facilities may be eligible for upgrading with BECCS.
- Under **Leading the Way**, **Consumer Transformation** and **System Transformation**, the SSEN DFES has reflected the decommissioning of existing plants when they reach the end of their operational life. This is assumed to be between 25 and 35 years from coming online, at which point they are to be replaced by either other generation types or transmission connected biomass with CCUS.
- Under **Consumer Transformation** in 2035, 104 MW has been modelled to connect to the network to replace the decommissioned backup standby diesel on the Scottish

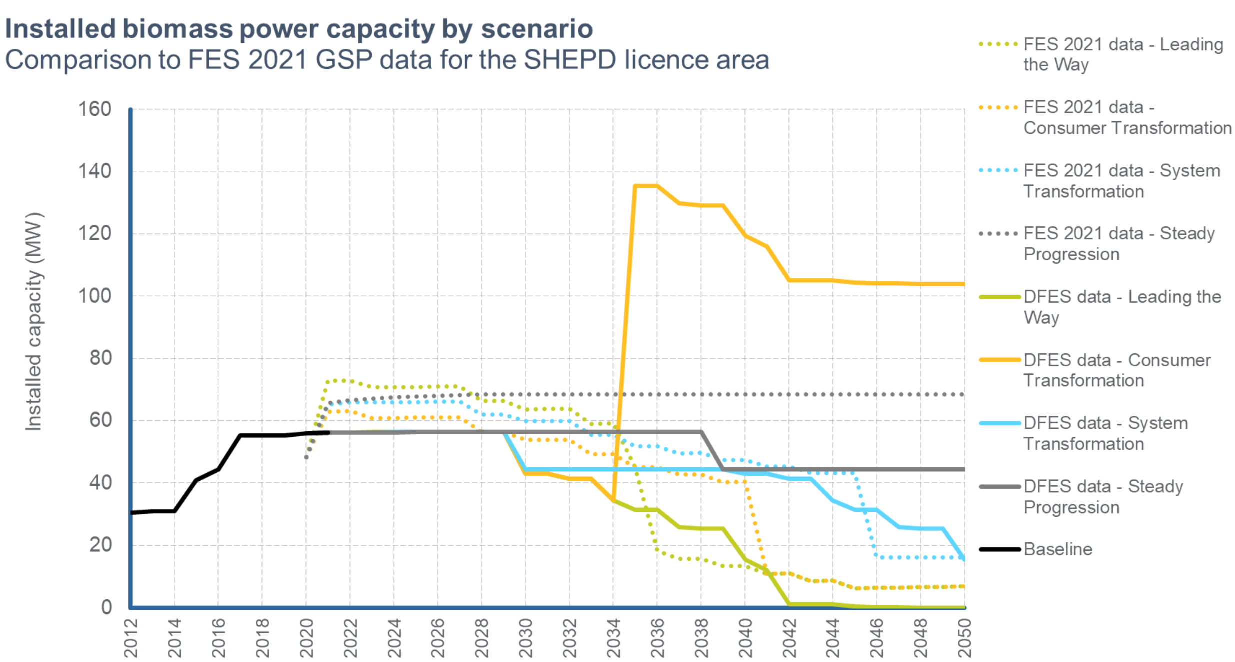
Islands (see the chapter on diesel generation for more information). Under **Leading the Way** and **System Transformation**, this backup diesel capacity is assumed to be replaced by a combination of storage and hydrogen solutions, rather than by biomass.

- The high cost of BECCS technology will likely prevent it from being viable for future small-scale biomass generation plants without subsidy support.
- This consideration is also compounded by the fact that the transmission network is a voltage tier lower in Scotland (132kV or above) and thus the potential for biomass generation directly connecting to the distribution network in the licence area would be even smaller.

Long term (2035 – 2050)

- Virtually all distribution connected capacity has been modelled to decommission by 2042 under **Leading the Way**. Under **Consumer Transformation**, only backup generation on the islands remains connected to the network. Under **System Transformation**, decommissioning is delayed with 15 MW remaining connected to the grid by 2050.
- Under **Steady Progression**, biomass capacity remains flat over time, assuming that existing plants are replaced or refurbished as frequently as they are decommissioned.
- The lack of additional biomass out to 2050, excluding replaced backup generation under **Consumer Transformation**, reflects the assumption that small-scale biomass sites will not be able to connect under most circumstances, as abated biomass will be more financially viable at transmission network scale. This assumption also reflects the recent Biomass Policy Statement[xxxviii], published by BEIS in November 2021, that most off-gas biomass sites will be used for heating purposes. Furthermore, stakeholder feedback and local authority input suggest that biomass in urban environments may be better suited to dedicated heat networks.

Figure 31: Biomass projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

SSEN DFES 2021 has been reconciled to the FES 2021 data for the relevant GSPs within the North of Scotland licence area for **technology building block ID: Gen_BB010**.

- The DFES 2021 baseline is c. 8 MW higher than the FES 2021. This is likely due to the reallocation of several baseline sites that have been identified as biomass technologies, and differences between technology classifications.
- Under the DFES 2021, the assumptions behind **Consumer Transformation** and **Leading the Way** are aligned. However, the modelling of diesel backup replacement under **Consumer Transformation** for the island represents a major regional deviation from the FES national trajectory in 2035. This reflects engagement with island community representatives and Scottish Government that **Consumer Transformation** should be the scenario that most directly reflects Scottish energy and decarbonisation policy. The sudden growth of biomass generation in 2035 is not realistic and has been modelled to enable network constraint analysis.
- In addition to this, DFES 2021 sees all distributed biomass decommissioning by 2045 under **Leading the Way**. This reflects both Scottish Government net zero targets and assumes that BECCS for small-scale biomass has not become financially viable under this scenario.
- Under **System Transformation**, DFES 2021 largely aligns with FES 2021, as some larger capacities are able to stay online with integrated CCUS out to 2050, even at a smaller scale, as more investment is made in developing technology solutions.
- There is a slight decrease in capacity under **Steady Progression** in DFES 2021 to reflect the natural end of life for some legacy biomass sites in the licence area, which is not reflected in FES 2021.
- The limited number of sites means that there are larger 'step' changes in the SSEN DFES projections than the FES 2021 projection, as single sites have been modelled to connect or reach the end of their operational life.

Relevant assumptions from National Grid FES 2021:

Assumption number	4.1.13 - Biomass and Energy from Waste (EfW) generation with CCUS
Steady Progression	Limited support for BECCS due to less of a drive to decarbonise and slowest deployment of CCUS. Some growth in decentralised biomass without CCUS.
System Transformation	High growth driven by the decarbonisation agenda. Linked to CCUS as this results in negative emissions.
Consumer Transformation	High growth driven by the decarbonisation agenda. Linked to CCUS as this results in negative emissions.
Leading the Way	Uptake driven by the decarbonisation agenda. Linked to CCUS as this results in negative emissions.

References:

SSEN connection offer data, DNO Embedded Capacity Registers, National Grid ESO TEC register, the Renewable Energy Planning Database, Contracts for Difference auction data, Regen questionnaire and consultation with local authorities.

[xxxvi] Scottish Government 2021, Bioenergy Policy https://www.gov.scot/publications/bioenergy-update-march-2021/pages/2/

[xxxvii] Department for Business, Energy & Industrial Strategy and Welsh Government 2021, Decarbonisation readiness: call for evidence on the expansion of the 2009 Carbon Capture Readiness requirements. https://www.gov.uk/government/consultations/decarbonisation-readiness-call-for-evidence-on-the-expansion-of-the-2009-carbon-capture-readiness-requirements

[xxxviii] Department fur Business, Energy & Industrial Strategy 2021, *Biomass Policy Statement* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1031057/biomass-policy-statement.pdf

Renewable engines

Summary of modelling assumptions and results

Technology specification:

The analysis covers electricity generated from renewable engines connected to the distribution network in the North of Scotland licence area. This technology sector is broken down into three renewable gas generation sub-technologies: **landfill gas**, **sewage gas** and **biogas from other anaerobic digestion (AD)** (e.g. food waste). The analysis focuses on CHP plants that generate electricity and excludes plants that are solely used for heat and biomethane production.

Building block: **Gen_BB004 - Renewable Engines (Landfill Gas, Sewage Gas, Biogas)**.

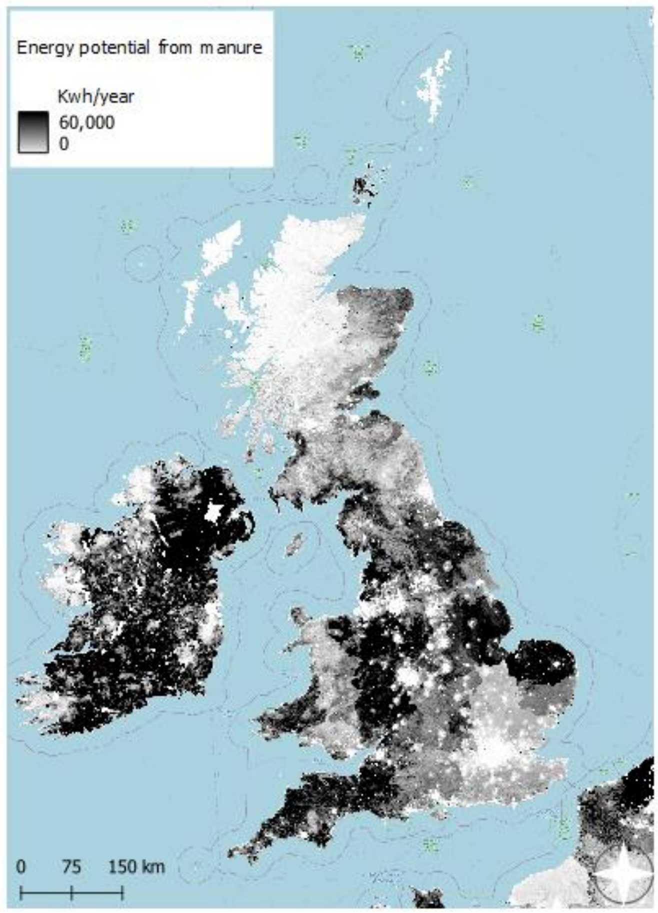
Data summary for renewable engines in the North of Scotland licence area:

Technology	Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Anaerobic digestion	Steady Progression	12	12	12	12	12	13	13
	System Transformation		12	13	14	15	15	15
	Consumer Transformation		12	14	17	19	20	21
	Leading the Way		12	14	17	20	21	23
Landfill gas	Steady Progression	20	20	20	3	1	1	0
	System Transformation		20	3	1	1	0	0
	Consumer Transformation		17	3	1	0	0	0
	Leading the Way		3	1	1	0	0	0
Sewage gas	Steady Progression	1.6	1.8	1.7	0.7	0.6	0.2	0.0
	System Transformation		1.8	1.8	1.8	1.7	0.7	0.6
	Consumer Transformation		1.8	1.8	1.8	1.8	1.8	1.8
	Leading the Way		1.8	1.8	1.8	1.8	1.8	1.8

Overview of AD projections in the licence area:

- There are 12 MW of AD capacity currently operational in the licence area.
- Feedstock from waste is a critical factor in the potential to develop new/additional AD capacity. The North of Scotland licence area has relatively low potential for AD, representing only c.2% of the local authorities in GB that do not yet have separate food waste collection. This means a lot of the municipal feedstock is already accounted for in the licence area.
- Agricultural land grade in the North of Scotland licence area is also relatively low, representing just 4% of all viable land in GB. According to manure resource assessment analysis (see Figure 32), around 9% of total theoretical feedstock potential from manure is located in the North of Scotland licence area. However, more analysis would be needed to discover how much of this potential is technically and economically recoverable.
- In the medium and long term, demand for 'green gas' is expected to increase for a variety of applications, including transport, gas grid injection and heat networks. This is incentivised by the Green Gas Support Scheme[xxxix], which is expected to reduce the interest in electricity generation connections. For this reason, DFES 2021 projections for AD have been notably dampened compared to the results seen in DFES 2020.
- As highlighted by the Committee on Climate Change[xl], there is also the potential opportunity to use biomethane in larger generation plants with carbon capture and storage (CCS) to create negative emissions, with half of the available generation set aside for industry and heat in buildings.
- In the North of Scotland licence area, AD sees limited growth across all scenarios. This ranges from very little development (14 MW in Steady Progression) to some new capacity (40 MW in Leading the Way) by 2050.

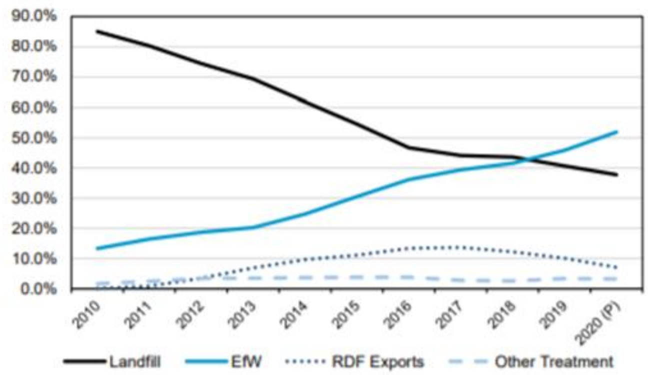
Figure 32: Results of Regen's anaerobic digestion resource assessment from manure feedstocks



Overview of landfill gas projections in the licence area:

- In the North of Scotland licence area, landfill gas generation currently totals 20 MW.
- Operational and pipeline landfill gas sites are expected to decommission in all net zero scenarios by 2050, due to the limited (c.20 year) lifetime of such plants[xli].

Figure 33: UK Residual Waste Market



Source: [UK Energy from Waste Statistics, Tolvik Consulting]

In addition to this, there is an overall declining trend in waste-to-landfill as Energy from Waste (EfW) technologies take prominence. The amount of waste being sent to landfill has declined in recent years, from capturing over 80% of the residual waste market in 2010 to under 40% in 2020. This trend is expected to continue[xlii].
For this reason, the DFES 2021 has modelled the decommissioning to begin as early as 2025 in **Leading the Way** and **Consumer Transformation**. All capacity is decommissioned by the mid-2030s under these scenarios, early 2040s in **System Transformation** and the mid-2040s in **Steady Progression**.

- Many existing landfill sites will be slowly restored, i.e. undergo natural restoration. To exemplify this trend, waste management giants like Viridor are reducing operational landfill sites from 18 to just three remaining sites[xliii].

Overview of sewage gas projections in the licence area:

- Only 1.6 MW of sewage gas generation capacity is currently operational in the licence area. The operation of this technology is largely restricted to regulated water utility companies, which for the licence area is Scottish Water.
- Consultation with Scottish Water Enterprise to support the DFES 2020 analysis, highlighted that there were currently no plans to increase electricity generation from their biogas or biomethane potential.
- Beyond a 180 kW pipeline site, the DFES 2021 has not projected any increase in sewage gas used for electricity generation across the timeframe.
- Some scenarios have modelled decommissioning of some of the baseline capacity, so as to reflect the possibility of conversion to gas-to-grid injection.
- Capacity remains at 1.8 MW under **Leading the Way** and **Consumer Transformation** to 2050. A partial conversion to gas-to-grid injection is modelled under **System Transformation**, with sewage gas generation capacity reducing to 0.6 MW in 2050. Full conversion is modelled under **Steady Progression**, with all generation capacity decommissioning in the late 2040s.

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

Anaerobic digestion:

- There is a limited baseline of grid connected AD facilities in the North of Scotland licence area, with only 12 MW connected as of the end of 2021.
- This represents a 4 MW increase since 2020, following the connection of a new site in Aberdeen and the identification of some sites that were previously unclassified as a particular generation technology.

Landfill gas:

- There are 13 landfill gas generation sites, totalling 20 MW, connected to the distribution network in the North of Scotland licence area.
- Only two sites (1.1 MW) have connected to the distribution network in the licence area since 2010.

Sewage gas:

- There are five sewage gas generation sites totalling 1.6 MW in the licence area.

Near term (2021 – 2025)

Anaerobic digestion:

- In the North of Scotland licence area, there are no pipeline AD sites.
- The only known site in planning is located at the Glenfiddich Distillery[xliv], but this site has plans to use the facility to develop transport biofuels, thus is very unlikely to seek a grid connection for electricity export.

Landfill gas:

- There are no landfill gas generation pipeline sites in the licence area. As a result, no increase in landfill gas generation capacity has been projected under any scenario.
- To reflect Scotland's carbon reduction targets, landfill gas generation capacity begins to decline from 2022 in **Leading the Way**, decommissioning c. 20 years after being put into operation, with the majority of capacity coming offline between 2021 and 2024. Under this scenario, only 3.2 MW remains connected by 2025.
- Under **Consumer Transformation** and **System Transformation**, baseline sites take longer to decommission, with remaining capacity decreasing to 17.3 MW in **Consumer Transformation** by 2025, and remaining at 20 MW in **System Transformation** and **Steady Progression**.

Sewage gas:

- There is one pipeline site situated in Perth with a contracted capacity of 180 kW. This site is modelled to connect in 2022 under **Leading the Way**, 2023 under **Consumer Transformation** and **System Transformation**, and 2024 under **Steady Progression**.

Medium term (2025 – 2035)

Anaerobic digestion:

- In the medium term, AD generation capacity is assumed to be primarily driven by increased valorisation of manure, agricultural and industrial waste from the mid-2020s, followed by a much smaller proportion of remaining food waste that has not yet been valorised.
- A moderate increase in connected capacity is seen in all scenarios in this timeframe, with **Leading the Way** and **Consumer Transformation** reaching c. 17 MW by 2035. This limited increase is based on the assumption that most AD is being valorised through use on-site or via gas grid injection, reflecting policies that incentivise green gas over electricity production.
- **System Transformation** and **Steady Progression** see even less uptake, with 14 MW and 12 MW connected to the network by 2035, respectively. This reflects feedstocks being used for large-scale EfW facilities under **System Transformation**, whereas waste feedstocks are largely left under-managed in **Steady Progression**.

Landfill gas:

- Decommissioning of landfill gas generation sites continues in all scenarios as EfW facilities continue to take precedence. In addition to this, consumers become increasingly conscious of reduced or zero waste practices under the net zero scenarios, further reducing un-recycled and re-valorised waste streams.
- By 2035, only 1.1 MW of installed capacity remains under **Leading the Way**, **Consumer Transformation** and **System Transformation**.
- **Steady Progression** also sees significant decommissioning, with most baseline sites being modelled to disconnect after 30 years of operational life. By 2035, 3.2 MW remains connected to the distribution network under this scenario.

Sewage gas:

- In the medium term, some of the small operational sewage gas generation sites begin to disconnect under **Steady Progression**. This is due to support for green gas production through the green gas levy, resulting in a steady decline in electricity generation in this scenario.
- By 2035, **Steady Progression** decreases to c. 600 kW of installed capacity.
- Under the three net zero scenarios, 1.8 MW of capacity remains online.

Long term (2035 – 2050)

Anaerobic digestion:

- By 2050, AD capacity reaches 23 MW in **Leading the Way** and 21 MW in **Consumer Transformation**. The limited increase seen in these scenarios, despite being the most ambitious in reaching net zero through decentralised solutions, reflects an assumption that waste feedstocks have depleted drastically by this time, due to a waste-conscious consumer society.
- However, there is some uncertainty around the assumed shift in consumer behaviour and waste consciousness. Therefore, there remains a potential under all scenarios in which there is a still notable volume of municipal waste creating the need for more AD capacity.
- AD capacity under **System Transformation** remains limited, at 15 MW by 2050.
- Under **Steady Progression**, the trajectory continues to flatline, with no significant capacity additions being made between now and 2050.

Landfill gas:

- Due to the absence of an evidenced pipeline for landfill gas in the North of Scotland licence area, no new projects were modelled to connect.
- The decommissioning of existing sites culminates in all baseline sites reaching the end of their operational life by (or before) 2050 in all scenarios.

Sewage gas:

- In the long term, the 1.8 MW of sewage gas capacity remains online in **Consumer Transformation** and **Leading the Way**, reflecting ongoing use of sewage waste for electricity generation at heavily regulated water industry operational sites. No additional capacity is modelled by 2050, due to the opportunity for future capacity being centred on gas-to-grid injection.
- **Steady Progression** and **System Transformation** continue to decommission existing sites out to 2050, as limited subsidy support from contracts for difference and interest in the green gas levy will see more water treatment facilities looking to convert existing infrastructure to heat and transport fuels and away from electricity production. All capacity is modelled to decommission under **Steady Progression** and only 0.6 MW remains under **System Transformation** by 2050.

Figure 34: Anaerobic digestion projections for the North of Scotland licence area

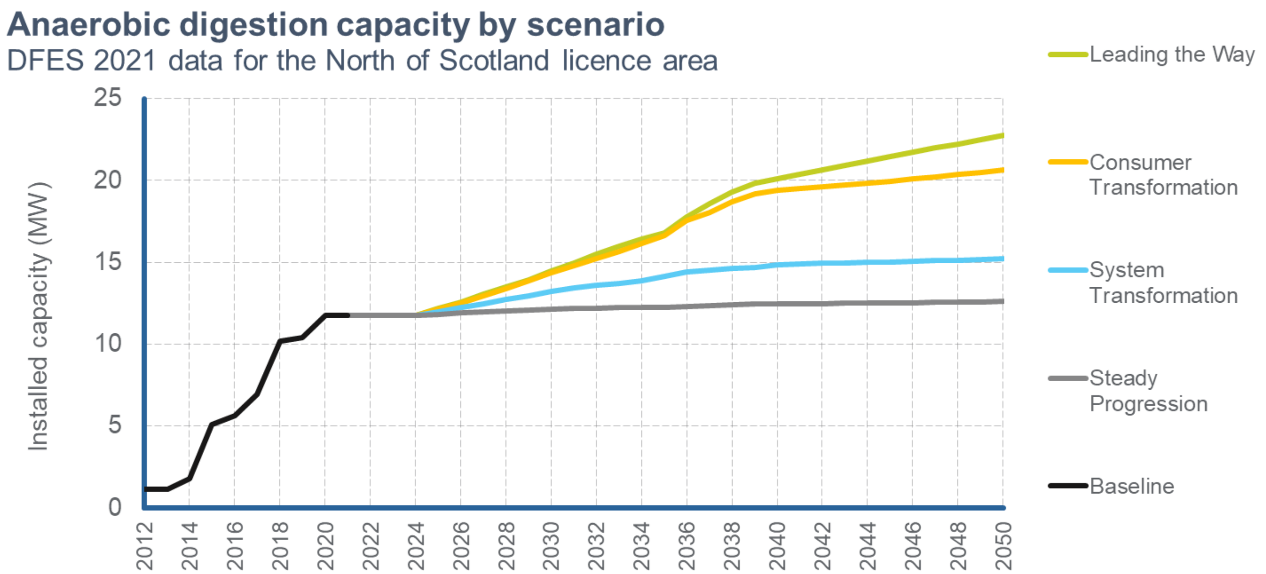


Figure 35: Landfill gas projections for the North of Scotland licence area

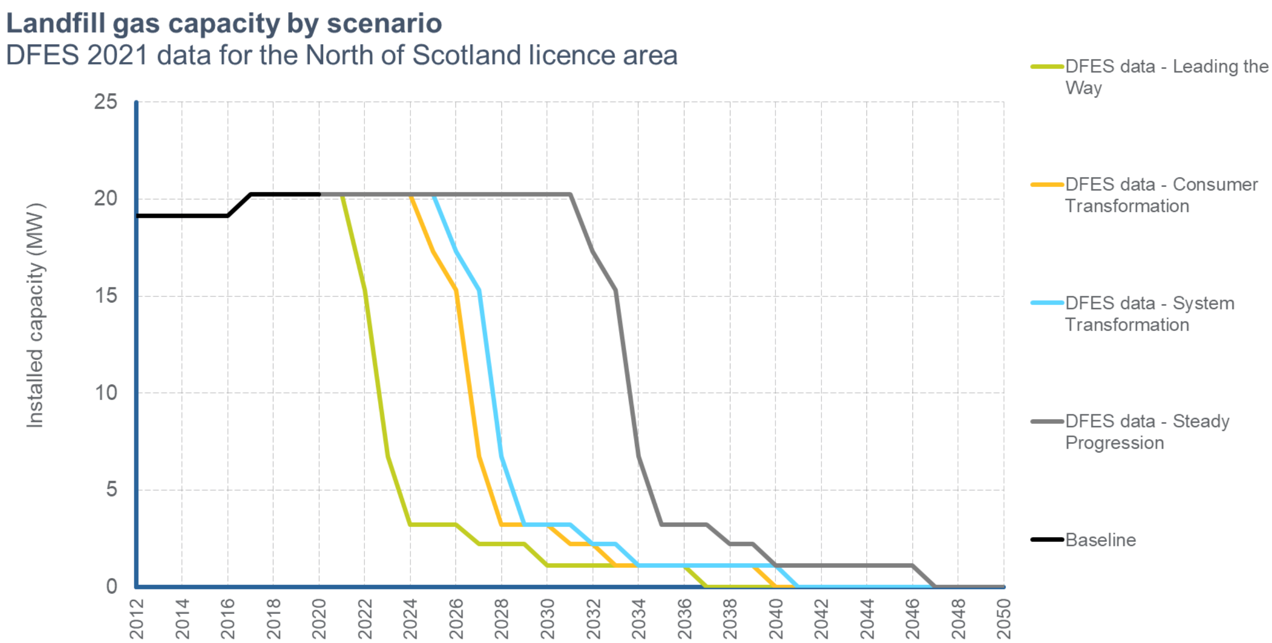


Figure 36: Sewage gas projections for the North of Scotland licence area

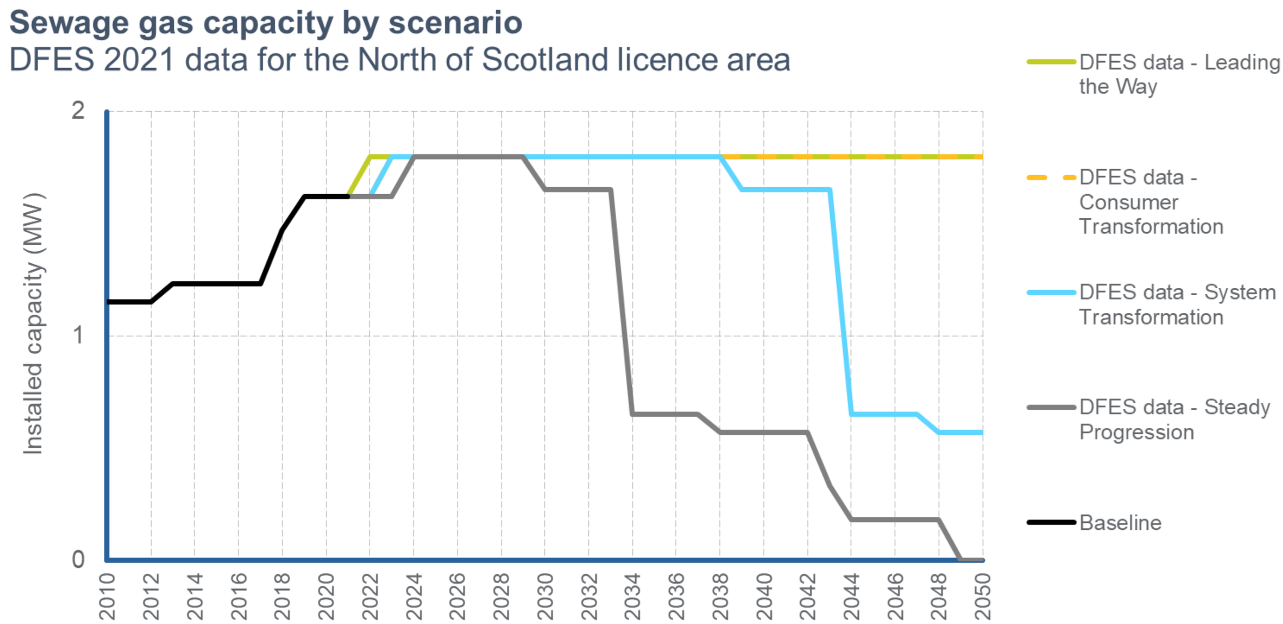
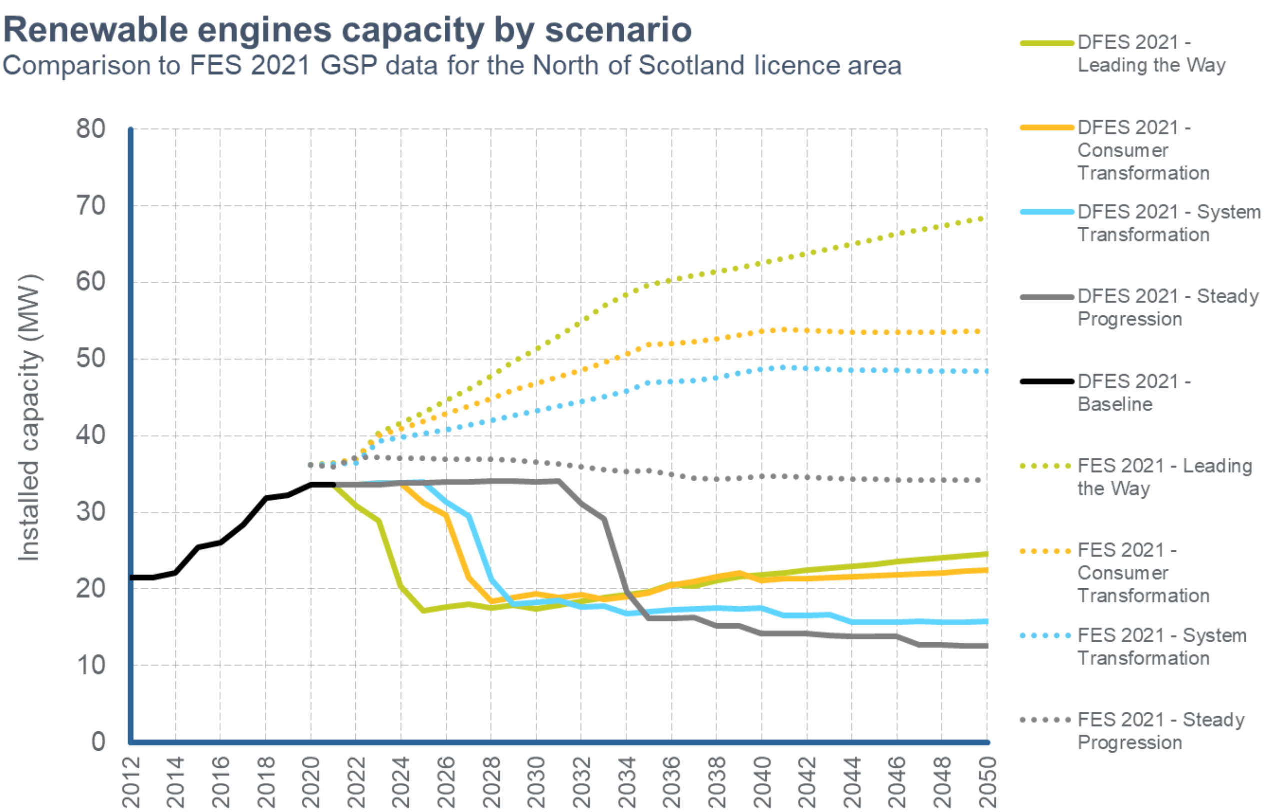


Figure 37: Renewable engines (biogas, landfill, sewage) projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

- The FES 2021 data for renewable engines was not split out by sub-technology. In order to reconcile the DFES 2021 sub-technology projections, data from the FES 2019 renewable engines sub-technologies was used to create a viable reconciliation in the DFES 2021.
- The decommissioning logic used by Regen for sewage gas and landfill gas represents the majority of the deviation from the FES 2021 projections in the North of Scotland licence area. This is partially a reflection of the sub-technology approach to the analysis undertaken in the DFES 2021, making use of stakeholder input and analysis of individual sites, as well as historic and planned industry trends.
- Landfill gas is decommissioned across the 2020s, resulting in the deviation from FES 2021 in this timeframe. Beyond this, DFES 2021 aligns more closely with the FES 2021 projections.
- Landfill gas was modelled to decommission earlier than both FES 2019 and 2020, and DFES 2020 projections. This is based on new insights from the Regen sector leads, identifying a decreasing trend in waste to landfill and the poor levels of energy capture from operational sites, after 20 years of operation.

Factors that will affect deployment at a local level:

- Manure and slurry is a predominant feedstock for AD, followed by crop residues, energy crops and food waste. Thus, these were the three key feedstocks that were used to determine the spatial distribution of future capacity.
- The spatial distribution of future AD sites that connect to the distribution network is weighted towards areas with sufficient agricultural land grade (grades 1 and 2) and also towards local authorities that do not yet collect food waste, as potential new feedstocks can arise in these areas. Additionally, DFES 2021 includes an in-house resource assessment based on gridded livestock density, including bovine, poultry and pigs[xlv], to estimate the total theoretical potential of biogas from each livestock category, using a manure-to-biogas energy yield factor[xlvi] (see Figure 32).
- As part of the stakeholder engagement process, a survey was sent to all local authorities within the licence area. A question on mandatory food waste collection was included in the survey. Responses from local authorities, augmented by further desk-based research, were used to determine a geographic distribution factor for food waste collection. This factor was then scaled to population density to determine locations in the near term that are likely to have an abundance of new food waste feedstock. However, many of these local authorities will be located in England as local authorities race to comply with the 2023 mandate for compulsory food waste collection. Most Scottish local authorities have already rolled out food waste collection initiatives, thus this factor is less influential in the North of Scotland licence area.
- The spatial distribution of landfill gas and sewage gas capacity is based on the location of existing baseline and pipeline sites connecting to the distribution network in the North of Scotland licence area.

Relevant assumptions from National Grid FES 2021:

Assumption number	1.1.5 - Support: incentive regime for biomethane (and other 'green gas') production
Steady Progression	Support is focused on areas with greater potential volumes (UKCS/shale).
System Transformation	Bigger push for renewable gas, as required to meet longer term decarbonisation targets.
Consumer Transformation	Bigger push for renewable gas, as required to meet longer term decarbonisation targets.
Leading the Way	All sources of renewable fuels encouraged and biomethane used in niche areas in transport/industry.

Stakeholder feedback overview:

Biomass	
Stakeholder feedback provided	How this has influenced our analysis
Local authorities were surveyed about their food waste collection policy.	Responses were directly used to inform the geographic distribution of AD capacity.
Scottish Water was consulted in 2020 in regard to their future strategy and plans for sewage gas generation and biomethane production. Feedback was provided that they currently do not have any sewage sludge gas-to-grid injection sites in their portfolio. They also fed back that they are seeking to review their biogas strategy, but as of yet, have no plans to increase their current biomethane production. Engagement was also made with waste water treatment companies for the WPD DFES 2021. This revealed an increased interest from water companies in gas-to-grid conversions.	The SSEN DFES 2021 has not modelled any increase in sewage gas capacity on the electricity network as a result of this feedback. However, sewage gas sites converting to potentially produce (or inject) biomethane, remains an uncertainty factor in the long term, which is reflected in the scenario variation.

References:

SSEN connection offer data, DNO Embedded Capacity Registers, Gridded Livestock of the World database (GLW 3), National Grid ESO TEC register, the Renewable Energy Planning Database, Contracts for Difference Auction Outcomes data, Capacity Market Register, Regen consultation with local stakeholders and discussion with developers, Engagement with Water Treatment companies, Regen questionnaire and consultation with local authorities.

[xxxix] Ofgem 2021, *The Green Gas Support Scheme and Green Gas Levy*: https://www.ofgem.gov.uk/environmental-and-social-schemes/green-gas-support-scheme-and-green-gas-levy#:~:text=The%20Green%20Gas%20Support%20Scheme%20(GGSS)%20is%20a%20government%20environmental,four%20years%20from%20autumn%202021.

[xl] Committee on Climate Change 2019, *Net Zero The UK's contribution to stopping global warming:* https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

[xli] Agency for Toxic Substances and Disease Registry 2001, *Chapter 2: Landfill Gas Basics* https://www.atsdr.cdc.gov/hac/landfill/html/ch2.html

[xlii] Tolvik Consulting 2020, *EfW Statistics 2020 Report* https://www.tolvik.com/wp-content/uploads/2021/05/Tolvik-UK-EfW-Statistics-2020-Report_Published-May-2021.pdf

[xliii] Let's Recycle 2016, *Viridor's Calne landfill site accepts final load*. https://www.letsrecycle.com/news/viridors-calne-landfill-site-accepts-final-load/

[xliv] Biofuels central 2021, *Glenfiddich Fuels Transport Fleet with Breakthrough Green Biogas Made from Whisky Residues*. https://biofuelscentral.com/glenfiddich-fuels-transport-fleet-green-biogas-whisky-residues/

[xlv] Harvard Dataverse 2010, *Gridded Livestock of the World database (GLW 3).* https://dataverse.harvard.edu/dataverse/glw

[xlvi] Scarlat et al 2018, *A spatial analysis of biogas potential from manure in Europe* https://www.sciencedirect.com/science/article/pii/S1364032118304714

Waste fuelled generation

Summary of modelling assumptions and results

Technology specification:

The analysis covers all forms of electricity generation from waste, including both incinerators and Advanced Conversion Technologies (ACT) that are connected to the distribution network in the North of Scotland licence area.

Technology building block: **Gen_BB011 - Waste Incineration (including CHP)**

Data summary for waste-fired generation in the North of Scotland licence area:

Technology	Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Incineration	Steady Progression	19	75	73	73	73	73	63
	System Transformation		75	73	73	63	63	7
	Consumer Transformation		75	73	73	63	0	0
	Leading the Way		59	57	47	47	0	0
Advanced Conversion Technologies (ACT)	Steady Progression	0	0	9	9	9	9	19
	System Transformation		0	9	9	19	19	35
	Consumer Transformation		0	9	9	19	42	42
	Leading the Way		0	9	19	19	26	26

Overview of technology projections in the licence area:

- The carbon emissions from older unabated waste incineration plants are not consistent with net zero emissions targets. As a result, in the DFES 2021 scenarios that meet net zero targets, it is assumed that connected incineration plant capacity reduces after 2030, as older facilities reach the end of their lifetime and the capacity is not replaced.
- New ACT gasification plants are expected to have lower associated carbon emissions and are a compatible technology with net zero 2050 targets, assuming that the residual emissions are abated. The DFES 2021 analysis assumes that all ACT projects with planning permission will go ahead; however, there are currently no ACT sites with planning in the North of Scotland.
- Key uncertainties related to waste technology include the extent to which they are considered to be consistent with decarbonisation objectives, planning issues related to

air quality and the volume of waste that could be reduced or recycled.

- There is currently 19 MW of Energy from Waste (EfW) generation connected to the distribution network in the North of Scotland licence area.
- There is a pipeline of 63 MW of waste incineration plants with accepted connection offers in the licence area, some of which have secured planning approval.
- ACT technology is still relatively new and is more expensive than other waste technologies. A few sites are in development across the UK but there are currently no sites in the development pipeline in the North of Scotland licence area. However, by 2030, it is assumed that ACT technology will begin to replace existing waste incineration plants as they decommission. The growth of ACT technology is highest under **System Transformation**. Under **Leading the Way,** overall waste generation capacity is lower as there is less overall waste produced in this more environmentally conscious scenario.
- As a further uncertainty, it is possible that larger ACT technologies may connect to the transmission network in Scotland
- Waste generation increases slightly from the baseline by 2050 under **Leading the Way** and **Consumer Transformation**, with 7 MW and 23 MW, respectively, from both incineration and ACT.
- Under **Steady Progression**, it is assumed that waste incinerator use continues beyond 2050 and that incineration remains a key solution for waste treatment. This follows the current trend under which landfill treatment centres are gradually phased out.

Scenario projection analysis and assumptions:

Baseline (up to end of 2021)

- In the North of Scotland licence area, there is 19 MW of operational EfW capacity, all of which is from waste incineration facilities.
- The baseline comprises one site, the Baldovie incineration plant in Dundee, which secured a 9 MW connection capacity in 1999 and increased this capacity to 19 MW in June 2020.
- There are no known grid-connected ACT facilities in the licence area.

Near term (2021 – 2025)

- As of 2021, the waste generation pipeline totals 63 MW from three sites.
- Of the three incineration plants in the pipeline, two sites (16 MW and 40 MW) have a connection agreement but no planning permission, while the remaining 7 MW site has a connection agreement and planning permission.
- Compared to DFES 2020, the waste incineration pipeline has doubled in capacity. This is due to a new c.40 MW site at Thainstone Energy Park. This site is projected to come online between 2023 and 2025, depending on the scenario.

Medium term (2025 – 2035)

- Under all scenarios, some pipeline incineration projects continue to connect into the late 2020s with **Leading the Way** reaching 82 MW and **System Transformation**, **Consumer Transformation** and **Steady Progression** all reaching 66 MW by 2030.
- After 2030, incineration capacity begins to decommission in all scenarios as existing facilities reach the end of their operational life or are decommissioned prematurely to reduce associated emissions.
- In **Steady Progression**, incineration sites are assumed to operate longer than their

known lifetime of 25 years[xlvii], and are modelled to decommission after 30 years. The first plant decommissions in 2031and capacity reduces to 73 MW by 2035.

- By 2030, new ACT plants begin to come online as legacy incineration sites are decommissioned.

Long term (2035 – 2050)

- Under **Steady Progression**, 82 MW remains connected by 2050, as little societal change means that waste continues to be treated by incineration at a similar scale, of which 19 MW are ACT sites to replace ageing incineration sites.
- To be compliant with Scottish policy ambition[xlviii], any plants that have not already decommissioned by 2045 are forced out of operation in **Consumer Transformation** and **Leading the Way**, with no unabated incineration plants remaining online by 2045.
- **System Transformation** allows some small sites to generate past 2045, assuming they are coupled with highly efficient CCUS technologies. Other facilities may migrate up to the transmission network with higher capacities and CCUS.
- The medium- and long-term incineration generation projections were determined by a decommissioning logic that was applied to baseline and pipeline sites, based on a defined asset lifetime, which varies according to the scenario:
  - In **Leading the Way**, because of tighter environmental regulations, unabated waste incinerators have a lifetime of 15 to 20 years, generally decommissioning slightly before the end of their optimal operational lifetime to be in line with net zero ambitions.
  - In **Consumer Transformation** and **System Transformation**, incinerators have a lifetime of 20 to 25 years, due to decreasing waste resources.
- Across the three net zero scenarios, it is projected that ACT technologies will continue to replace legacy incineration plants. The rate of ACT growth varies by scenario and will be determined in part by environmental regulations and the extent to which changes in society and consumer behaviour reduce the amount of unrecycled waste that must be processed.
  - In **Leading the Way**, 26 MW of capacity is replaced by ACT generation by 2050 compared to 42 MW in **Consumer Transformation**.
  - In **System Transformation**, 35 MW of incineration capacity is replaced by ACT by 2050. The decrease in incineration capacity since the 2020s is in part due to the assumption that large transmission scale EfW facilities fitted with CCUS will make up a larger portion of waste treatment.

Figure 38: Incineration projections for the North of Scotland licence area

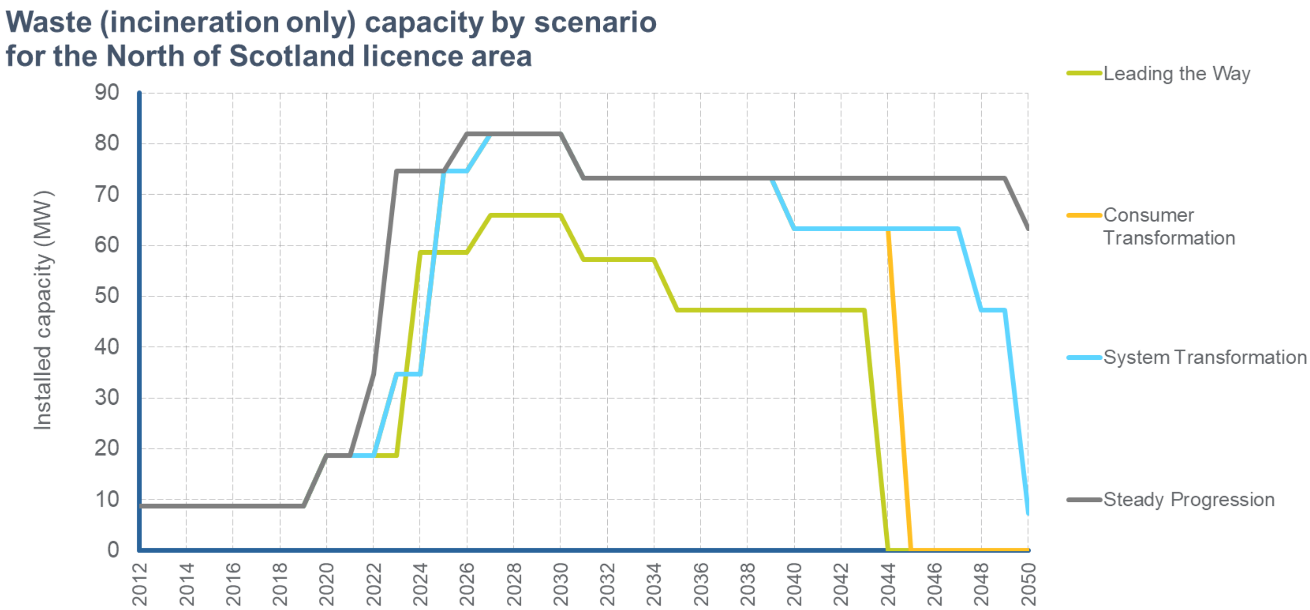


Figure 39: Advanced Conversion Technologies (ACT) projections for the North of Scotland licence area

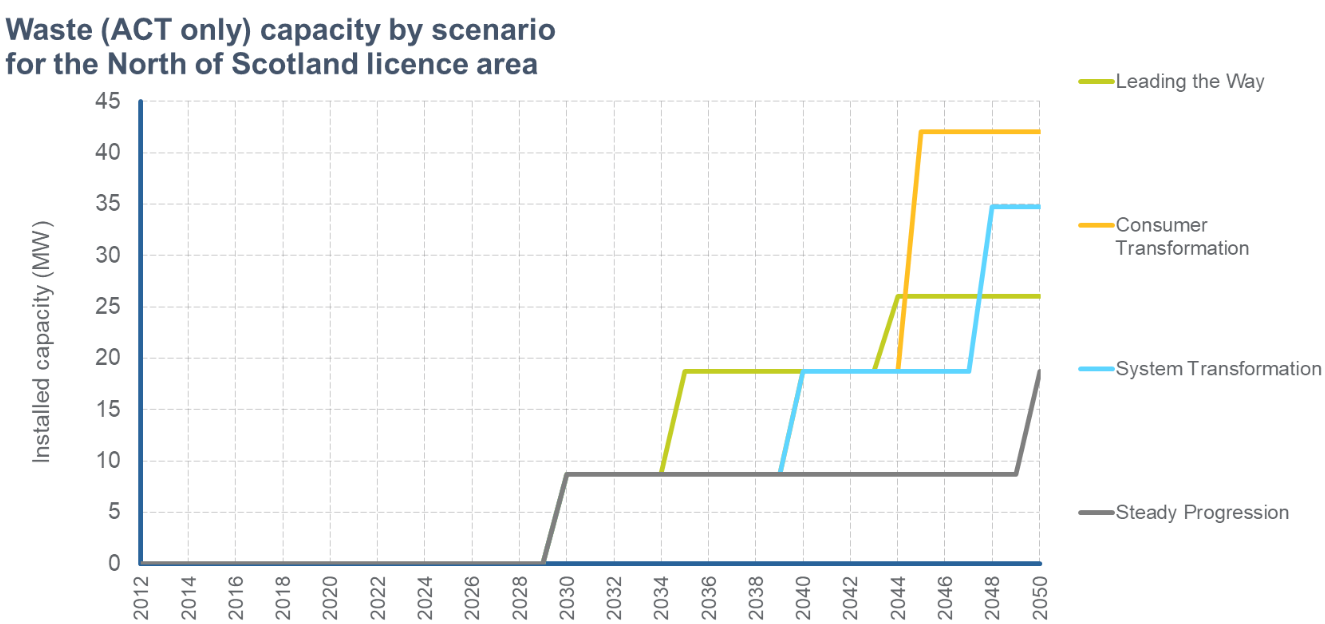
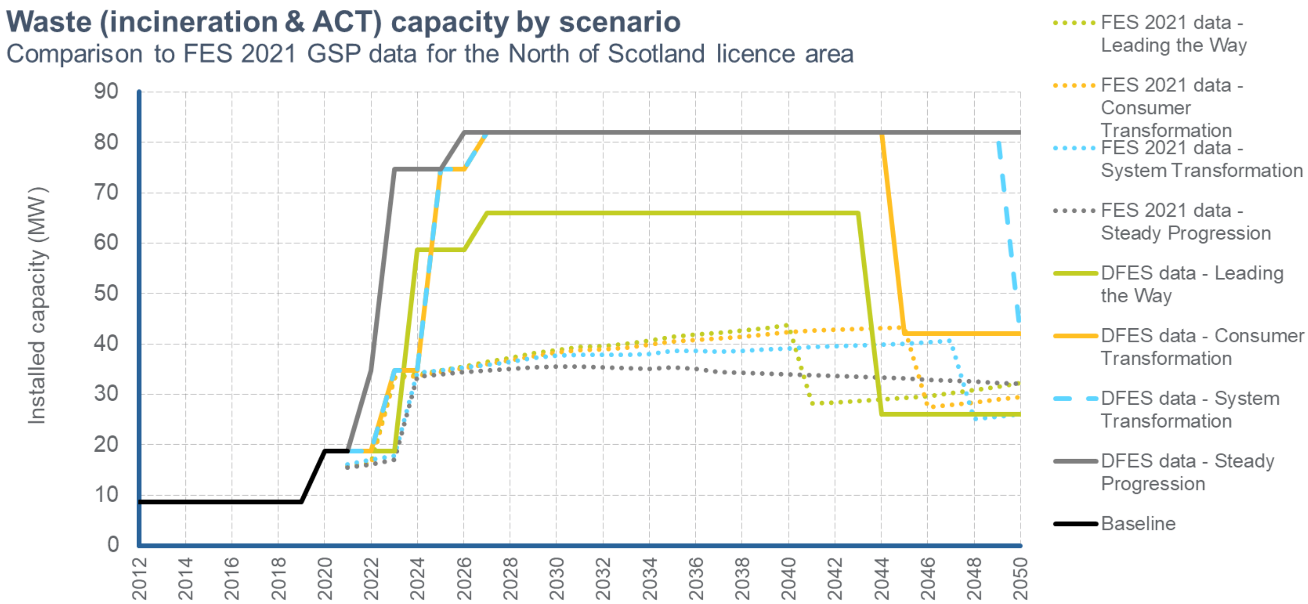


Figure 40: Energy from Waste projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

Results in this section relate to the FES 2021 data for the relevant GSPs within the North of Scotland licence area.

- The DFES 2021 analysis follows the underlying FES 2021 assumption that ACT technologies will replace legacy waste incinerators over time. There is no breakdown by technology type in the published FES datasets and so a sub-technology reconciliation has not been undertaken.
- Assumptions underpinning the DFES analysis are largely aligned with the FES 2021 regional projections, though results differ due to local factors and spatial distribution.
- The baseline in DFES 2021 and FES 2021 is well aligned. The DFES baseline is the same as 2020, but the FES 2021 has been adjusted and is consequentially now more closely aligned to the DFES baseline estimate.
- Pipeline projections for the DFES 2021 are much higher than that of the FES 2021. This is due to the DFES near-term pipeline analysis, accounting for known sites with planning permission and capacity connection agreements.
- Under DFES 2021, the Scottish Government's net zero target year of 2045 is taken into account and reflected under **Consumer Transformation** and **Leading the Way**.

Relevant assumptions from National Grid FES 2021:

Assumption number	4.1.11 - Unabated Biomass and Energy from Waste (EfW) generation
Steady Progression	No significant change in waste management from society, leaving waste available as a fuel source for unabated generation.
System Transformation	Less waste to burn in general due to a highly conscious society adapting to low waste living.
Consumer Transformation	Less waste to burn in general due to a highly conscious society adapting to low waste living.
Leading the Way	Less waste to burn in general due to a highly conscious society adapting to low waste living.

Stakeholder feedback overview:

Waste (incineration & ACT)	
Stakeholder feedback provided	How this has influenced our analysis
Part of the stakeholder engagement informing this year's analysis was an online survey with all of the local authorities in the North of Scotland licence area. Of the five local authorities that responded, all had a waste management strategy already in place.	This information suggests that many councils have already planned efficient waste management systems and have actively pursued a waste-conscious society, further evidencing the assumptions and results seen in the DFES 2021 projections. The supply of waste feedstock should remain relatively stable or decline, depending on the scenario.

References:

SSEN connection offer data, DNO Embedded Capacity Registers, National Grid ESO TEC register, the Renewable Energy Planning Database, Capacity Market Register, discussion with developers and consultation with local authorities.

[xlvii] Department for Environment Food & Rural Affairs 2014, Energy from waste: A guide to the debate https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/284612/pb14130-energy-waste-201402.pdf

[xlviii] Government of Scotland 2019, Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 https://www.legislation.gov.uk/asp/2019/15/contents/enacted

Diesel generation

Summary of modelling assumptions and results

Technology specification:

Diesel-fuelled electricity generation, including standalone commercial diesel plants and behind-the-meter diesel back-up generators that can export to the distribution network in the North of Scotland licence area.

The analysis does not include dedicated back-up diesel engines located on some commercial and industrial premises that are only operated when mains supply failure occurs and cannot export to the network.

Technology building block: **Gen_BB005 – Non-renewable engines (diesel) (non CHP)**

Data summary for diesel generation in the North of Scotland licence area:

Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	126	139	139	126	126	0	0
System Transformation		126	126	0	0	0	0
Consumer Transformation		126	126	0	0	0	0
Leading the Way		126	0	0	0	0	0

Overview of technology projections in the licence area:

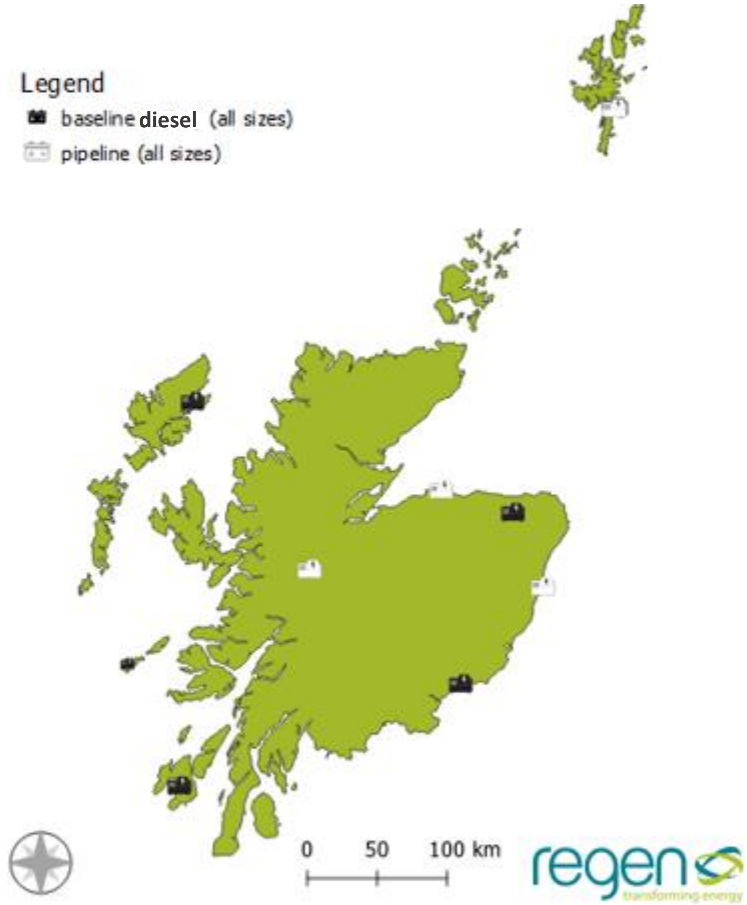
- Diesel generation within scope of the DFES study entirely comprises support generators sited on Scottish Islands, for backup supply in times when subsea cables or the main network supply to the island are offline.
- These island diesel plants range in size from 2 MW to 37 MW, with some being in operation (albeit likely with replacement gensets) since the 1940s and 1950s.
- There are also a handful of potential new diesel sites with accepted connection offers in the licence area, totalling 34 MW.
- The continued use of unabated diesel generation is expected to be time-limited due to net zero carbon emissions targets, and the implementation of stringent emission limits required by environmental permitting regulations.
- The eventual phase out of diesel generation was confirmed during engagement sessions with representatives from the Scottish Islands and Scottish Government. All island diesel capacity has therefore been modelled to decommission from the network in all scenarios, albeit at different time periods.
- Depending on the scenario, a range of alternative technologies have been modelled to replace diesel generation including biomass, biomethane and/or hydrogen fuelled generation as well as battery storage.
- **Leading the Way** has the most rapid disconnection of diesel capacity in the licence area, with all sites decommissioning by 2030.

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- As of Q4 2021, there were 8 operational diesel generation sites in the North of Scotland licence area, totalling 126 MW.
- These are all standalone support diesel power plants, located on Kirkwall on the Orkney Islands, Lerwick on the Shetland Islands, Bowmore, Stornoway, Tiree, Barra and at Loch Carnan on South Uist.
- They range in size and age, from smaller (< 3 MW) sites connected in the 1940s and 1950s, to larger (20-35 MW) sites connected in the 1990s and 2010s.

Figure 41: Baseline and pipeline diesel sites in the North of Scotland licence area



Near term (2021 – 2025)

- There are also two diesel sites totalling 14 MW with accepted connection offers in the licence area. These are both back-up generators of 6 MW and 8 MW in capacity.
- Neither of these sites have evidence of planning approval or activity in the UK Capacity Market. However, as back-up generators that have notified SSEN of an intention to connect, these sites have all been modelled to come online within the early 2020s under the **Steady Progression** scenario.
- The 126 MW of operational baseline capacity on the islands remains online in all scenarios across the early 2020s.

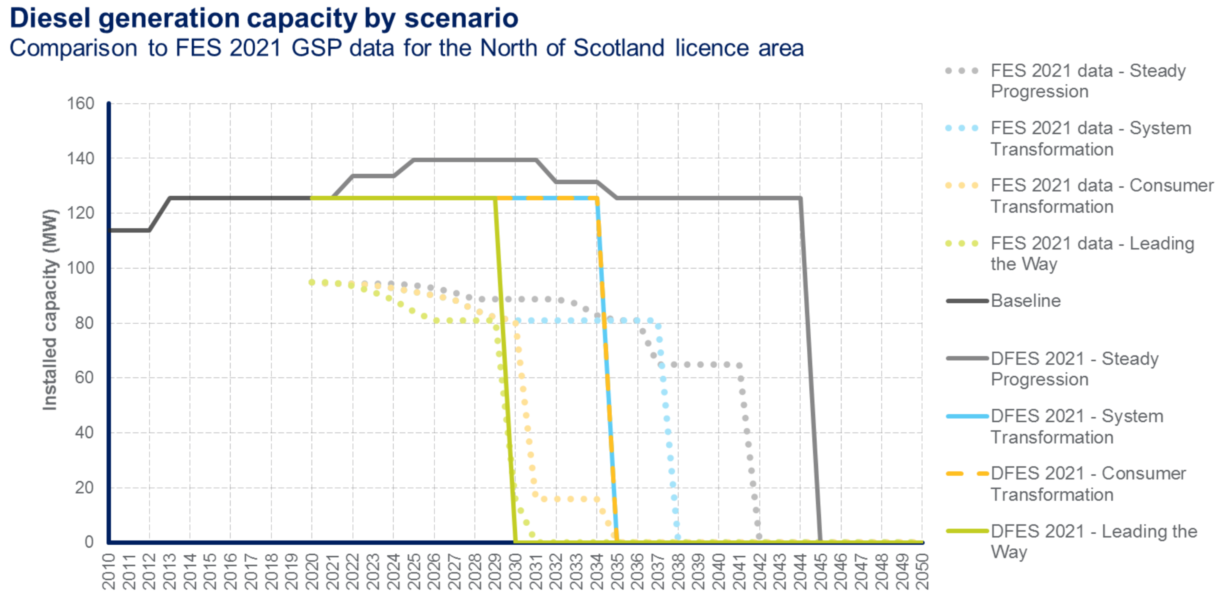
Medium term (2024 – 2035)

- An engagement workshop held with a number of representatives from the Scottish Islands in October 2021 identified a target for the Islands to transition to energy from low carbon sources by 2030. This ambitious target would deliver a more rapid removal of fossil fuel generation than the broader net zero 2045 target set by Scottish Government[xlix]. This 2030 target, to replace all diesel generation with alternative technologies such as hydrogen generation and battery storage, is reflected in the **Leading the Way scenario.**
- Under **Consumer Transformation** and **System Transformation**, diesel generation decommissioning is still ambitious but is delayed to 2035. These scenarios also include the installation of sustainable biomass generation in the 2030s.

Long term (2035 – 2050)

- Under **Steady Progression,** all diesel generation is finally decommissioned by 2045, the latest date to remain aligned with Scotland's 2045 net zero target.

Figure 42: Diesel generation projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

DFES results have been reconciled with the FES 2021 data for the relevant GSPs within the North of Scotland licence area for building block Gen_BB005 - non-renewable engines (diesel) (non CHP).

- The current baseline capacity of diesel generation in the Licence area is c.31 MW higher in the SSEN DFES 2021 than in the FES 2021 GSP data. The reason for this is uncertain, but could be related to a difference in the fuel classification of thermal generators between the DFES and FES.
- FES 2021 also projects that all diesel generators will eventually come off-line. The main difference between DFES and FES is the target date for full decommissioning.
  - The DFES projections have reflected feedback from Scottish Island stakeholders by modelling the decommissioning/conversion of island diesel generators

Figure 43: End dates for diesel generation decommissioning in DFES and FES 2021

End date for diesel generation decommissioning		
Scenario	**DFES 21**	**FES 21**
Leading the Way	2030	2031
Consumer Transformation	2034	2035
System Transformation	2034	2038
Steady Progression	2045	2042

Factors that will affect deployment at a local level:

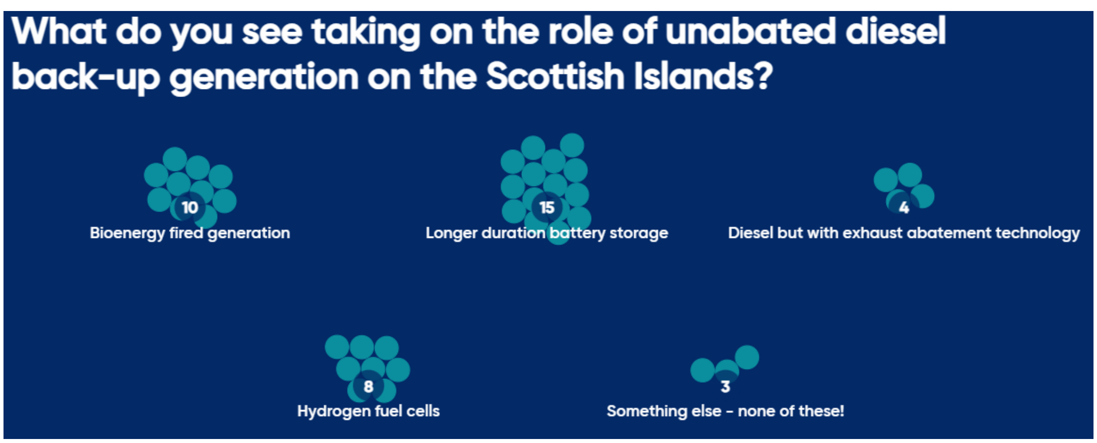
The DFES analysis for diesel generation focuses entirely on decommissioning existing known baseline and pipeline sites. Therefore, spatial distribution references the locations of these sites.

Stakeholder feedback overview:

The DFES 2021 analysis has been based on direct consultation with Scottish Island community representatives. Whilst some islands may see more staggered decommissioning than is currently seen, there are too many variables to ascertain which island generator will convert to which technology under which scenario. A dedicated Scottish Island DFES Contact Group is being established to enable ongoing consultation between Regen, SSEN and the islands.

Diesel generation	
Stakeholder feedback provided	How this has influenced our analysis
A range of stakeholders were engaged through a dedicated North of Scotland DFES workshop in October 2021.	The DFES has modelled the decommissioning of the existing baseline of diesel generation in the licence area.
Stakeholders were in agreement that unabated diesel fuelled generation would decommission from the distribution network.	This results in no diesel capacity operating on the distribution network by 2030 in **Leading the Way** and by 2035 in **Consumer Transformation** and **System Transformation** and by 2045 under **Steady Progression**.
There were a range of views as to which technologies would take on the role of unabated diesel back-up generation. The alternative technologies that most stakeholders considered were long duration battery storage, bioenergy and hydrogen.	The location of the existing island diesel generators has been used to inform the geographical distribution of the uptake of battery storage, new biomass generation and hydrogen fuelled generation in the 2030s and 2040s.

Figure 44: Stakeholder responses to diesel generation question in the online engagement webinar



References:

SSEN connection offer data, DNO Embedded Capacity Registers, Regen consultation with local stakeholders in the North of Scotland licence area, including Scottish Island stakeholders.

[xlix] See Scottish Government net zero commitment: https://www.gov.scot/news/reaching-net-zero-1/

Fossil gas fired generation

Summary of modelling assumptions and results

Technology specification:

Fossil fuel gas fired electricity generation connected to the distribution network in the North of Scotland licence area, covering four gas generation sub-technologies:

- Close cycle gas turbines (CCGT) – **Building block Gen_BB009**
- Open cycle gas turbines (OCGT) – **Building block Gen_BB008**
- Gas reciprocating engines – **Building block Gen_BB006**
- Gas combined heat and power plants (gas CHP) – **Building block Gen_BB001**

The analysis does not include back-up gas CHPs or engines located on some commercial and industrial sites that do not export to the network and only operate when mains supply fails.

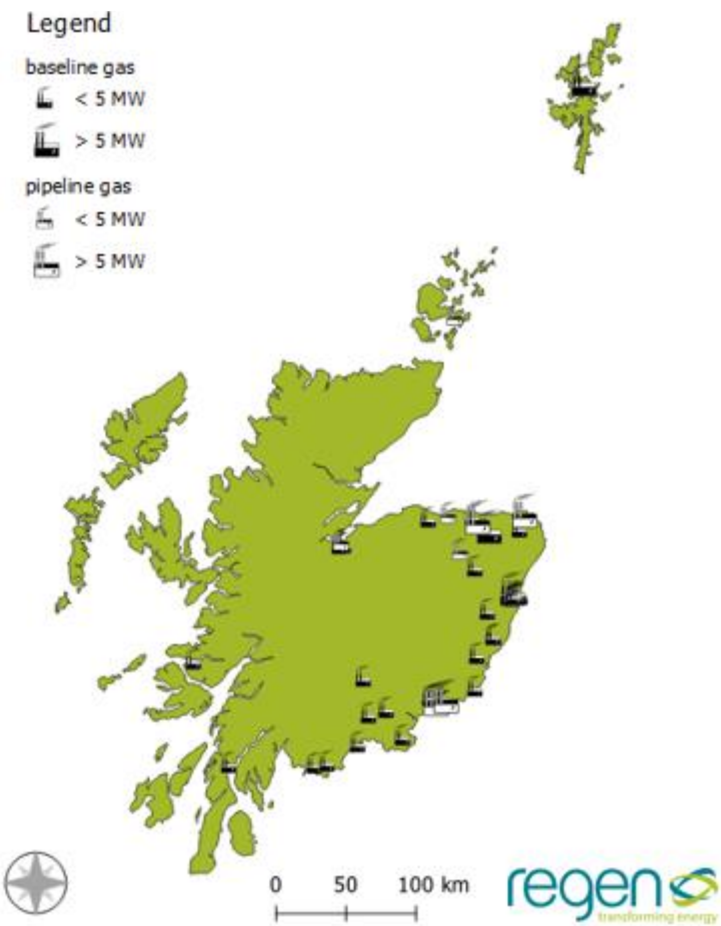
Data summary for gas fired generation in the North of Scotland licence area:

Installed power capacity (MW)		Baseline	2025	2030	2035	2040	2045	2050
CCGT	Steady Progression	--	--	--	--	--	--	--
	System Transformation		--	--	--	--	--	--
	Consumer Transformation		--	--	--	--	--	--
	Leading the Way		--	--	--	--	--	--
OCGT	Steady Progression	10	10	10	10	10	0	0
	System Transformation		10	10	0	0	0	0
	Consumer Transformation		10	10	0	0	0	0
	Leading the Way		10	0	0	0	0	0
Reciprocating engines	Steady Progression	0	76	76	76	76	76	76
	System Transformation		56	56	0	0	0	0
	Consumer Transformation		56	56	0	0	0	0
	Leading the Way		0	0	0	0	0	0
Gas CHPs	Steady Progression	31	54	54	54	31	29	23
	System Transformation		31	31	9	8	0	0
	Consumer Transformation		31	31	9	8	0	0
	Leading the Way		31	8	0	0	0	0

Overview of technology projections in the licence area:

- There is a small baseline (41 MW) of operational fossil gas-fired generation connected to the distribution network in the North of Scotland licence area.
- This baseline mainly consists of small-scale (<1 MW) gas CHPs on the mainland. There is also a larger 18 MW CHP plant on Shetland and a 10 MW OCGT located at Flotta Oil Terminal on Orkney.
- In addition to this baseline, there are eight potential new fossil gas generation sites, totalling 99 MW, in the visible pipeline. This includes:
    - Four reciprocating engine sites totalling 76 MW
    - Four gas CHPs totalling 23 MW.
- The most active development sites in the pipeline include:
    - A 20 MW site in Dundee has secured a Capacity Agreement in the T-4 2023 Capacity Market auction
    - Two additional sites totalling 36 MW have also secured planning approval
- These 3 sites have been modelled to connect in all scenarios except **Leading the Way.**
- Under the three net zero scenarios, all technology types of fossil gas generation see a decrease in capacity connected to the distribution network in the licence area by 2050
- Under **Steady Progression**, there is a moderate increase in overall connected capacity in the medium-term, followed by a decline across the 2040s.

Figure 45: Baseline and pipeline fossil gas sites in the North of Scotland licence area



- The primary role of distribution-scale fossil gas-fired generation is to provide flexibility and back-up services to the electricity system. Whilst the installed capacity may be seen to remain constant or increase some scenarios, the annual operating hours and energy output of these types of asset decreases significantly by 2050 in all scenarios as the electricity system is heavily decarbonised.
- Following engagement workshops held with Scottish Government and representatives from the Scottish Islands in 2021, under the three net zero scenarios, all fossil gas generation is modelled to disconnect from the distribution network in the North of Scotland licence area by 2045. This reflects Scotland's broader net zero target year of 2045[l] and the Scottish islands specifically targeting a net zero target year of 2030[li].
- In practice this capacity may be transferred to new low carbon generation technologies such as hydrogen generation. At a national

level, this is reflected by an increase in hydrogen generation becoming a potentially viable source of supply-side flexibility after 2030. This results in some existing fossil gas generation sites 'repowering' to become hydrogen fuelled generation sites out to 2050.

- Hydrogen fuelled generation scenario analysis and results are outlined in a separate DFES technology summary sheet.

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- There are 39 operational fossil gas generation sites in the licence area totalling 41 MW.
- This is broken down into the following fossil gas technologies:
  - A 10 MW OCGT sited at Flotta Oil Terminal on Orkney (brought online in 1988).
  - 38 gas CHPs totalling 31 MW.
- There are no operational CCGT sites or reciprocating engines currently connected to the distribution network in the North of Scotland licence area.

Near term (2021 – 2025)

OCGT:

- As a site that has been operational for 33 years already, the 10 MW Flotta OCGT site is modelled to decommission in all scenarios. Specifically:
  - By 2030 in **Leading the Way.**
  - By 2035 in **Consumer Transformation** and **System Transformation.**
  - By 2038 in **Steady Progression** (reflecting 50 years of operation).
- This reflects a move away from fossil-fuel generation technologies that have historically provided baseload generation.

Reciprocating engines:

- There are four gas reciprocating engine sites with an accepted connection offer in the North of Scotland licence area, collectively totalling 76 MW. Of this pipeline:
  - 2 sites (36 MW) received planning approval in 2016 and 2018 respectively.
  - A 20 MW site in Dundee secured a Capacity Agreement in the T-4 2023 Capacity Market auction.
  - No development information could be found for the remaining 20 MW site.
- Gas reciprocating engines are a source of flexible, dispatchable generation that can provide a range of services to the network. As a fossil fuel however, the carbon intensity of this technology will require a longer-term reduction in capacity, or replacement by alternative low carbon technologies, in a net zero energy system.
- It is unlikely that exhaust abatement technology[lii] would be a cost-effective measure for distribution network scale assets and therefore the DFES modelling has focused on the decommissioning (or repowering as another technology) of fossil gas generation sites.
- As a result, in both the near and medium-term, the speed of switching to lower carbon sources of flexibility has been applied as a variable factor across the four scenarios.
- The development evidence of some of the known pipeline sites determined the following the near-term connected capacity across the four scenarios:
  - Under **Leading the Way**, no new sites are commissioned, and no reciprocating engine capacity remains in operation by 2050. Instead, this scenario reflects a more rapid adoption of low carbon sources of flexibility, such as bioenergy, battery storage or hydrogen generation.
  - Under **Consumer Transformation** and **System Transformation**, sites with an accepted connection offer, planning permission and positive capacity market

activity are modelled to connect within the early 2020. Gas reciprocating engine capacity reaches 56 MW by 2025 in these two scenarios.
    - Under **Steady Progression**, all sites with accepted connection offers are modelled to connect in the 2020s. Reciprocating engine capacity totals 76 MW by 2025.

Gas CHPs:

- There are four gas CHPs with an accepted connection offer in the licence area, collectively totalling 23 MW. Most of this accepted capacity originates from a proposed 22.5 MW gas CHP, to be located at Claverhouse Industrial Estate in Dundee.
- No development information could be found for any of the 4 pipeline gas CHP sites.
- Gas CHPs are a source of dispatchable onsite power and heat for occupied or industrial buildings. As a fossil fuel, only sites with positive development evidence would be modelled to connect under the net zero zeros in the near-term.
- With no such information available, the four sites are only modelled to connect in the 2020s under **Steady Progression**. By 2025, total gas CHP capacity reaches 54 MW.
- Under **Leading the Way**, **Consumer Transformation** and **System Transformation**, the 31 MW baseline continues to operate across the medium and near-term, reflecting continued operational onsite power and heat use at these sites.

Medium term (2025 – 2035)

Gas reciprocating engines:

- Under **Consumer Transformation** and **System Transformation**, the new reciprocating engine sites that came online in the 2020s are all modelled to disconnect by 2035. These sites could potentially be replaced with an alternative source of flexibility or convert to become low carbon hydrogen peaking plants, or enabled with carbon capture technology, in the 2030s/2040s.
- Under **Steady Progression**, the 76 MW of new capacity modelled to connect in the 2020s remains operational across the medium term.

Gas CHPs:

- Under **Leading the Way**, a transition to low-carbon sources of smaller-scale onsite power and heat is reflected. Therefore, all gas CHP capacity is modelled to disconnect from the distribution network in licence area by 2035.
- Under **Consumer Transformation** and **System Transformation**, some more recently installed gas CHPs continue to provide heat and power to buildings in the medium term. However, older gas CHPs in the licence area are modelled to disconnect, and overall capacity reduces to 9 MW by 2035.
- Under **Steady Progression**, all gas CHPs remain operational in the medium term.

Long term (2035 – 2050)

Gas reciprocating engines:

- The 76 MW of new reciprocating engine capacity modelled to connected in the 2020s remains operational to 2050 under **Steady Progression**.

Gas CHPs:

- The residual 8 MW of gas CHP capacity under **Consumer Transformation** and **System Transformation** is modelled to disconnect from the distribution network by 2045, reflecting Scotland's target to be net zero by 2045.
- Under **Steady Progression**, older gas CHP sites are assumed to not be replaced and, therefore, connected capacity reduces to 23 MW by 2050.

Figure 46: Open Cycle Gas Turbine (OCGT) projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections

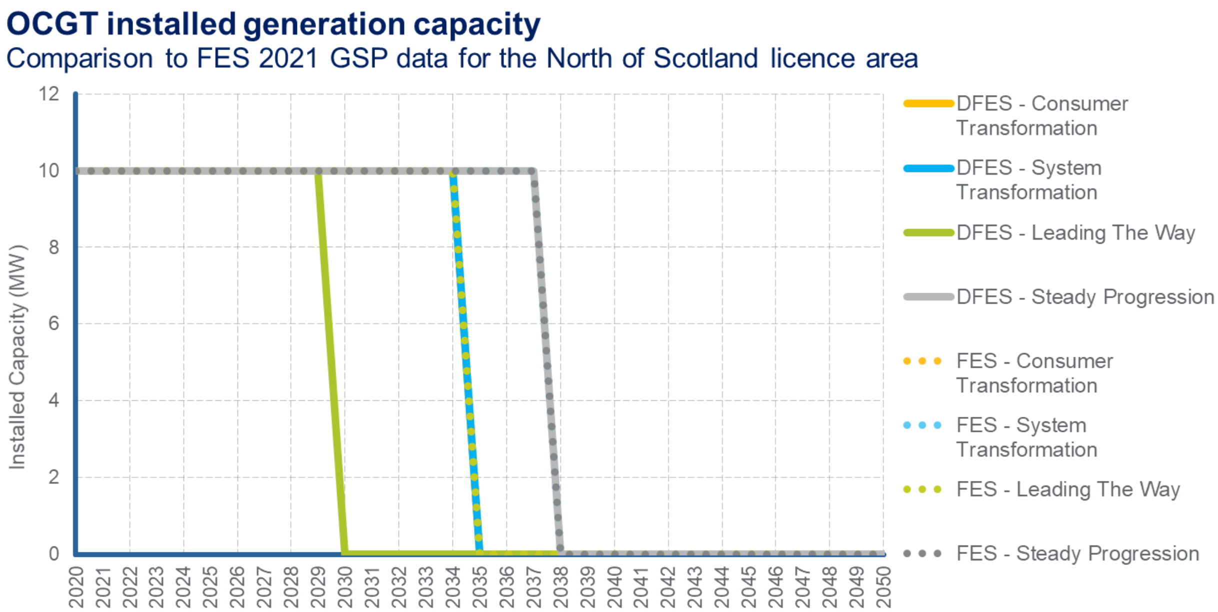


Figure 47: Fossil gas reciprocating engine projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections

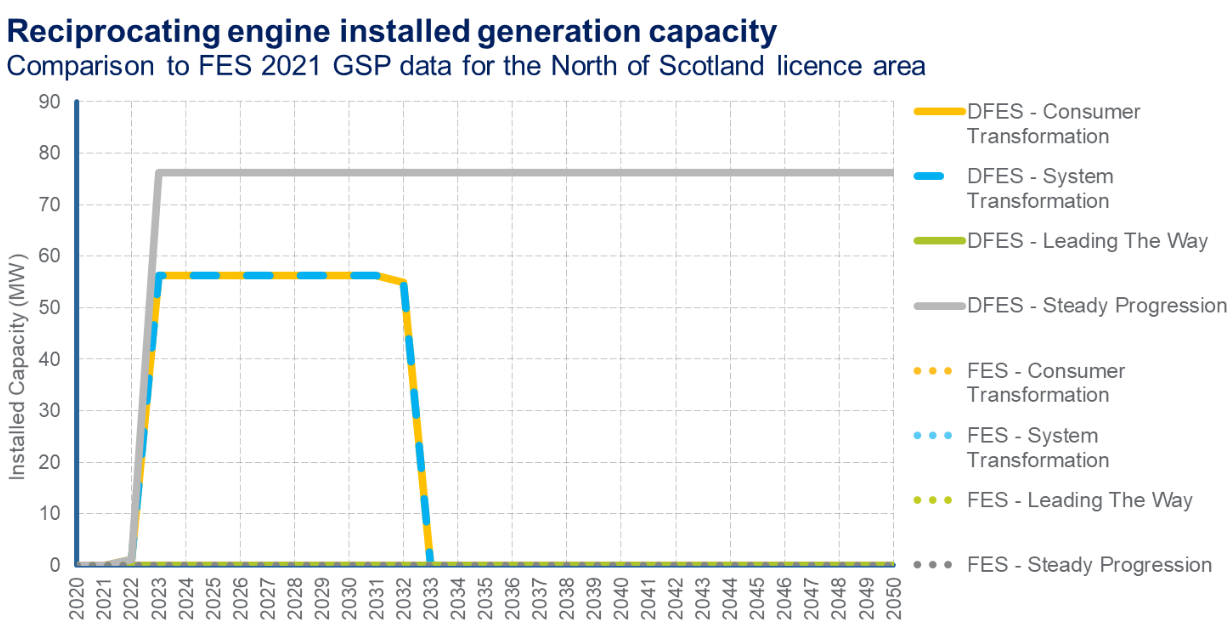
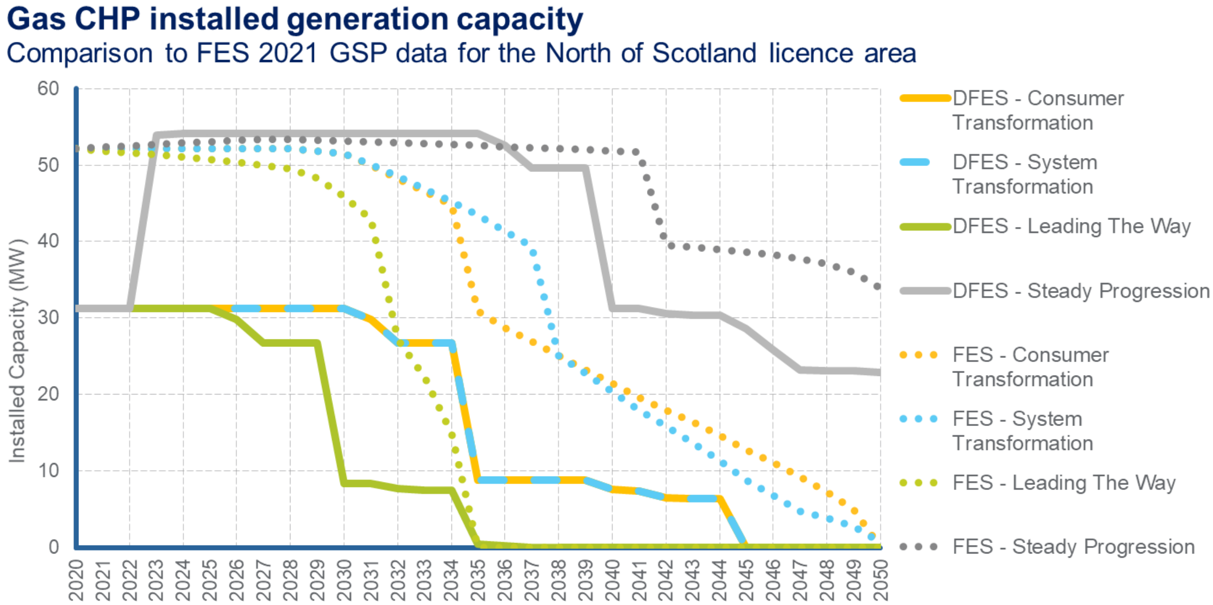


Figure 48: Fossil gas CHP projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

The DFES 21 projections have been reconciled with the FES 2021 data for the relevant GSPs within the North of Scotland licence area for the equivalent fossil gas FES building block technologies.

OCGT – [Building block Gen_BB008]

- Both the SSEN DFES 2021 and the FES 2021 GSP data has the 10 MW site at the Flotta Oil Terminal on Orkney as the only baseline OCGT site. Both the DFES and FES 2021 projections have this site decommissioning before 2050. The date of decommissioning, however, varies between DFES and FES

Decommissioning year of Flotta OCGT plant on Orkney			
Scenario	**DFES 21**	**FES 21**	**Rationale**
Leading the Way	2030	2031	Reflects Scottish Island stakeholder input and ambition to decarbonise by 2030.
Consumer Transformation	2035	2035	--
System Transformation	2035	2048	Reflects Scottish Island ambition to transition to hydrogen generation in this scenario.
Steady Progression	2048	2048	End of 50 year site operation.

Gas reciprocating engines – [Building block Gen_BB006]

- The FES 2021 GSP data has no reciprocating engine capacity in the licence area across the scenario period.
- The DFES has identified a pipeline of known reciprocating engine sites and has therefore modelled them to connect in the near-term and disconnect (in some scenarios) in the medium/long-term.

Gas CHPs – [Building block Gen_BB001]

- The FES 2021 GSP data has 21 MW more gas CHP baseline capacity in the licence area than the DFES. The reason for this is unclear but could be related to generation fuel technology classification differences between the FES and DFES.
- Under **Leading the Way**, the DFES and FES 2021 both have all gas CHP decommissioning by 2035.
- Under **Consumer Transformation** and **System Transformation**, the DFES has modelled gas CHP decommissioning by 2045, 5 years earlier than the FES 2021. This reflects Scotland achieving its net zero target year of 2045 in these scenarios.
- The DFES sees a similar trend to the FES under **Steady Progression**, with a proportion of connected capacity decommissioning by 2050, though the DFES has 11 MW less capacity still operational by 2050 than the FES. This partially relates to the lower 2020 baseline identified in the DFES.

Factors that will affect deployment at a local level:

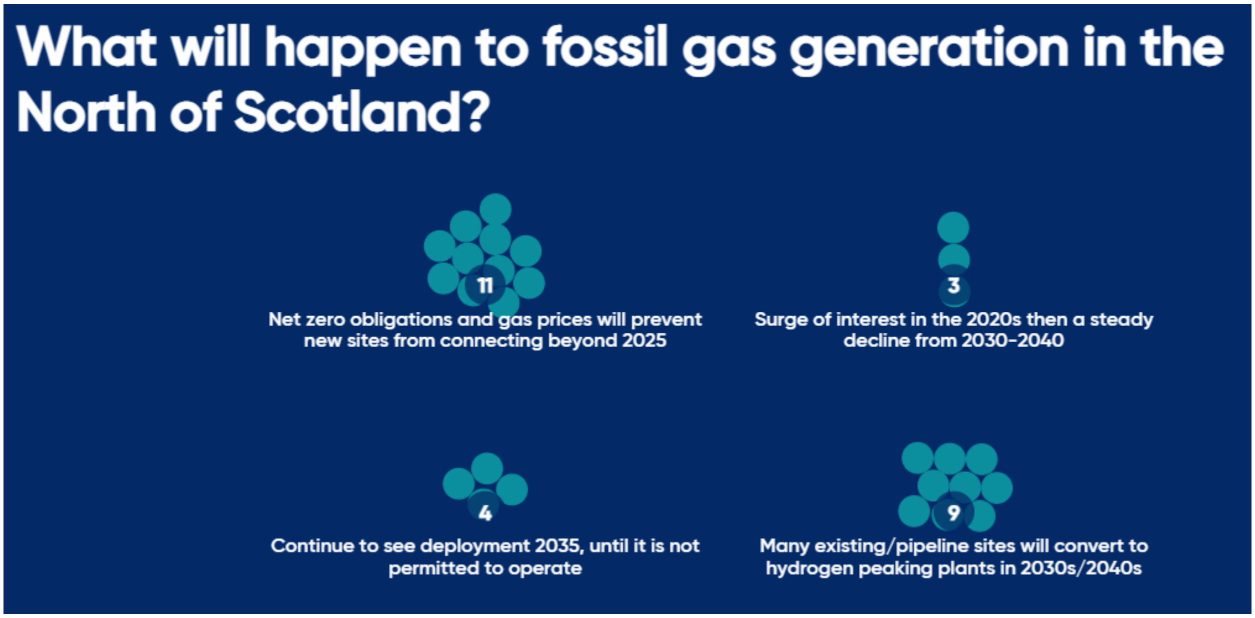
- The DFES analysis for fossil gas generation focuses predominantly on known baseline and pipeline sites to identify where capacity could increase in the near-term, and where capacity will reduce in the medium and long term.
- Therefore, the spatial distribution mostly references known site locations.
- Projections for additional reciprocating engine capacity under **Steady Progression** in the medium-term will be targeted in areas where gas network infrastructure is located.

Stakeholder feedback overview:

Fossil gas fuelled generation	
Stakeholder feedback provided	How this has influenced our analysis
A range of stakeholders were engaged through a dedicated North of Scotland DFES workshop in October 2021. Stakeholders felt that gas-fired generation will be limited in the licence area, with Scottish net zero obligations and gas prices preventing new sites from connecting beyond 2025. Some stakeholder representatives from the renewable energy and hydrogen sectors felt many of the existing/pipeline sites could convert to be hydrogen peaking plants in the 2030s and 2040s.	The net zero scenarios have modelled a range of decommissioning of the existing fossil gas generation baseline capacity. This results in no gas generation capacity operating on the distribution network by 2025 in **Leading the Way** and by 2045 in **Consumer Transformation** and **System Transformation**. This reflects Scotland's net zero target, as highlighted by stakeholders. The potential to convert to hydrogen peaking generation has been a factor influencing the decommissioning modelling. The uptake of hydrogen peaking capacity is covered in a separate technology summary sheet.

A separate workshop with Scottish Island representatives also provided valuable feedback, especially on the likely transition of island based fossil gas generators such as the Fllotta plant on Orkney to low carbon alternative technologies	The SSEN DFES 2021 has projected an early closure of the Flotta OCGT site under **Leading the Way** and an earlier transition to hydrogen generation under **System Transformation**.

Figure 49: Stakeholder responses to fossil gas question in the online engagement webinar



References:

SSEN connection offer data, DNO Embedded Capacity Registers, Regen consultation with local stakeholders in the North of Scotland licence area and workshops with Scottish Government and Scottish Island stakeholders.

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[l] See Scottish Government net zero 2045: https://www.gov.scot/news/reaching-net-zero-1/

[li] See declaration of Orkney, Shetland and Outer Hebrides Islands to transition to net zero by 2030: https://www.aemslab.org.nz/icnz_hwu_orkney

[lii] See summary of exhaust abatement systems: https://www.ebara.co.jp/en/precision/index/gas-abatement.html

Hydrogen fuelled generation

Summary of modelling assumptions and results

Technology specification:

This analysis covers hydrogen fuelled electricity generation, which has been modelled to connect to the distribution network in areas where there is the potential for hydrogen supply. The focus of the analysis has been to consider the conversion of existing fossil fuel peaking plants to low carbon hydrogen[liii]. This analysis is therefore closely linked to the DFES analysis undertaken for fossil fuel generation, including the use of fossil gas sites and diesel generators on Scottish Islands.

Larger scale, new, hydrogen turbines could also be developed. However, in the absence of a firm pipeline, it is assumed that these generation plants will connect mainly to the transmission network. This assumption will be reviewed in future DFES studies.

Technology building block: **Gen_BB023 – Hydrogen fuelled generation**

Note: hydrogen production, via electrolysis, has been modelled separately.

Data summary for hydrogen fuelled generation in the North of Scotland licence area:

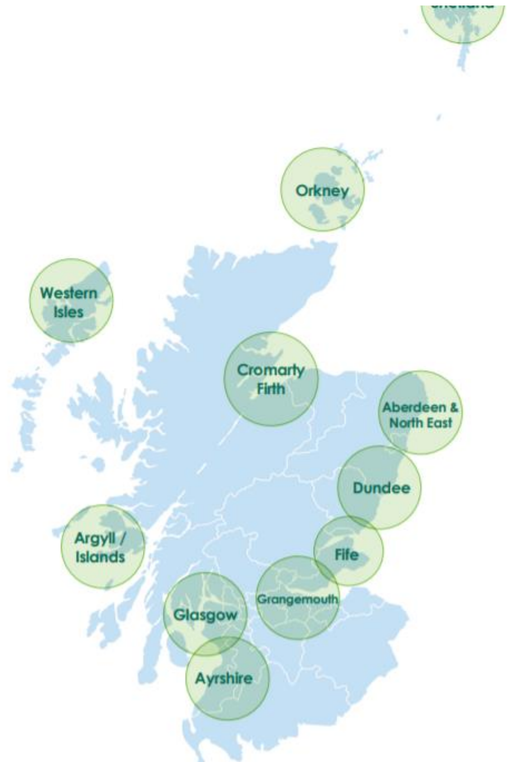
Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	0	0	0	0	0	0	0
System Transformation		0	0	141	141	196	196
Consumer Transformation		0	0	26	26	81	81
Leading the Way		0	91	158	240	240	240

Overview of technology projections in the licence area:

- The analysis of this technology considers the potential for existing fossil fuel generation sites (fossil gas and diesel) to repower their thermal generation assets to run on low carbon hydrogen.
- The conversion of these sites has been modelled in the DFES to occur in electricity supply areas of the North of Scotland licence area where hydrogen supply zones could be developed, such as in Figure 50.
- Hydrogen supply zones have been identified, in phases, through consideration of:
  - Conversion of existing gas network infrastructure
  - Hydrogen development hubs around heavy transport areas or industrial clusters such as Dundee, Aberdeen and St Fergus.
  - Scottish Islands such as Orkney, Bowmore, Stornoway and Shetland
- Baseline and pipeline gas turbines, gas reciprocating engines, gas CHPs and commercial-scale diesel generators that fall within these hydrogen supply zones are assumed to repower to be hydrogen generators under some scenarios.

- Already, a number of turbine manufacturers, including Siemens and GE, are offering hybrid hydrogen/methane turbines and have committed to providing 100% hydrogen plants in the near future[liv].
- A key advantage of hydrogen fuelled electricity generation is the potential to manufacture hydrogen during periods of high renewable generation (when electricity prices may be very low) and then store and use that hydrogen to generate electricity during periods when electricity prices are very high. This model could be applied, at a local and national level, to provide a source of system balancing and energy security.
- However, while the Scottish Government has announced a target to reach 5 GW of hydrogen production capacity by 2030[lv], it is not yet clear if, and when, hydrogen may begin to displace fossil fuel generation.
- Apart from demonstration and trial projects, the industry consensus, which is reflected in the FES 2021 scenarios, is that hydrogen for electricity peaking plant generation is unlikely to feature as a significant technology until the late 2020s and 2030s. The key considerations behind this assumption include the supply and cost of hydrogen, competing (higher value) uses for hydrogen, the availability of compatible turbines, the need for regulatory changes, the underlying carbon price and the availability of subsidy support. Fossil fuel generators may also choose an alternative decarbonisation route such as carbon capture and storage, or biomethane.
- Given this uncertainty, the scale and timing of conversion to hydrogen fuelled generation in the DFES 2021 analysis varies widely by scenario. This approach also mirrors the wide range of projections for hydrogen fuelled generation in the FES 2021.
- In terms of conversion potential, the North of Scotland licence area has 167 MW of existing operational fossil fuel generation capacity (41 MW fossil gas and 126 MW diesel). A significant number of these sites are located on the Scottish Islands.
- In addition to existing sites, the licence area has a fossil fuel generation pipeline of 133 MW (99 MW fossil gas and 34 MW diesel). This presents a moderate potential for the growth in connected capacity of hydrogen fuelled generation across the 2030s and 2040s.
- By 2050, hydrogen fuelled generation capacity ranges from none under **Steady Progression** to 240 MW under the **Leading the Way** scenario.

Figure 50: Potential Hydrogen Hubs as identified by the Scottish Government



Source: [Scottish Government, Draft Hydrogen Action Plan]

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- There is no hydrogen fuelled generation currently operating in the UK.

Near term (2021 – 2025)

- It is expected that low carbon hydrogen production will increase in response to the Scottish Government's target of 5 GW production capacity by 2030.
- There is; however, no visible pipeline of distribution connected hydrogen fuelled electricity generation projects. Note: pipeline projects may exist but may have not applied for a network connection if their plans are to use existing network connection capacity.
- Apart from demonstration and trial projects, it is unlikely that fossil fuel plants will convert to hydrogen in the very near term. This is due to a variety of factors including hydrogen turbine supply, hydrogen fuel supply and the regulatory changes that would be required.
- The cost of hydrogen fuel, absence of a subsidy framework and competing uses of available hydrogen for other, higher-value, applications are also important factors.
- In line with FES 2021, no hydrogen fuelled generation is modelled to connect to the distribution network in any scenario by 2025. This will be reviewed in future DFES studies.

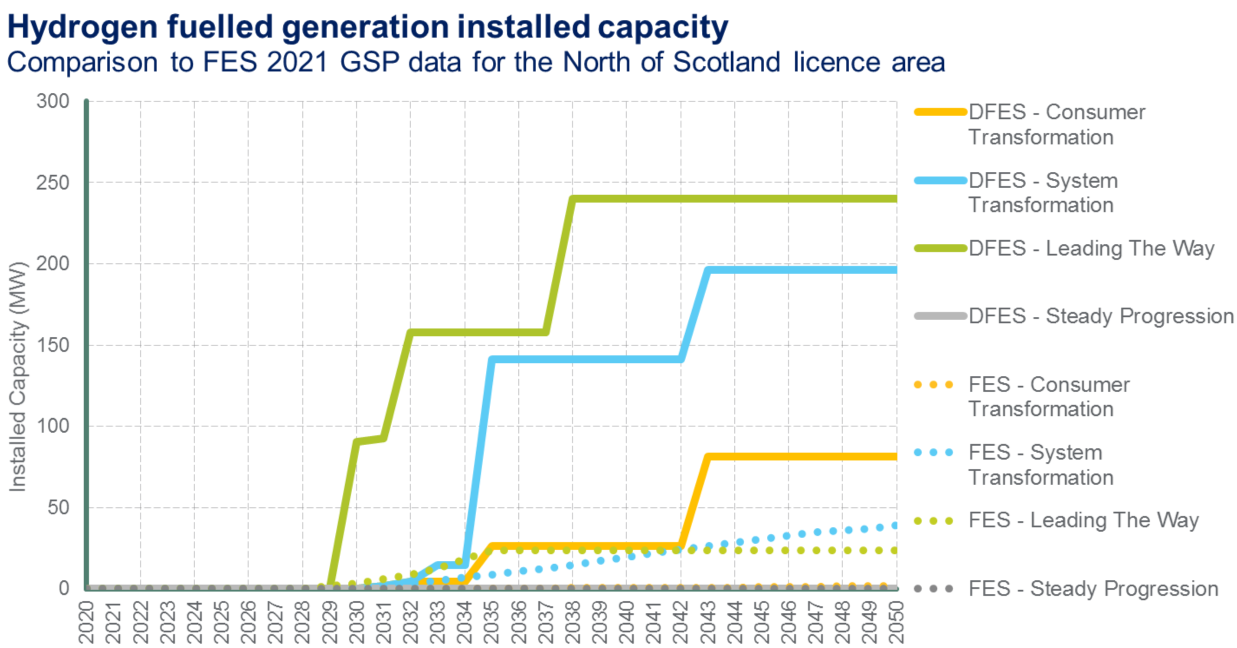
Medium term (2025 – 2035)

- With the growth of hydrogen production, it is likely that a proportion of fossil fuel generators will convert to low carbon solutions including hydrogen.
- Conversion will likely begin for generation assets within industrial clusters and in areas with high renewables and potential for hydrogen electrolysis.
- Island and highland communities that have high levels of renewable generation to meet ambitious net zero targets, but are dependent on diesel generators for supply continuity, could also be amongst the first to deploy hydrogen electrolysis and convert to hydrogen fuelled generation technology.
- From 2030, further growth in low carbon hydrogen production capacity, and rising carbon prices, could incentivise more site operators to convert their assets to run on hydrogen in the medium term.
- In the North of Scotland licence area, some key areas that could see hydrogen development might include Aberdeen[lvi], Dundee[lvii] and East Neuk[lviii]. Feedback from a workshop held with representatives from the Scottish Islands also identified a number of larger island fossil fuel sites that could convert to hydrogen, for example on Orkney, Shetland, Stornoway and Bowmore.
- The SSEN DFES 2021 has modelled the conversion of a range of existing and pipeline fossil fuel generation sites located in identified hydrogen supply zones.
- The highest development of hydrogen fuelled generation is seen under **Leading the Way**, with connected generation capacity reaching 158 MW by 2035.
- Fewer fossil fuel generation sites are modelled to convert under **Consumer Transformation** and **System Transformation**, with capacity reaching 26 MW and 141 MW by 2035, respectively.
- Due to the slow decarbonisation of electricity supply and slow integration of flexibility systems in **Steady Progression**, fossil fuel generation continues to operate in the medium and long term. Therefore, no hydrogen fuelled generation capacity has been modelled to connect in this scenario.

Long term (2035 – 2050)

- Under the three net zero scenarios, assuming hydrogen becomes a significant net zero fuel, it is likely that hydrogen will play a role in electricity generation.
- Depending on the cost of hydrogen and the future carbon price, hydrogen fuelled generation is likely to be limited to backup and peaking functions, for security of supply and to balance variable renewable generation in periods of very high electricity prices.
- In DFES 2021, this has been modelled by including additional areas for hydrogen conversion under **Leading the Way** and **System Transformation** out to 2050.
- Under **Leading the Way**, medium-scale fossil fuel generation sites (< 50 MW) are modelled to repower as hydrogen fuelled generators with 50% more capacity. This represents the most ambitious scenario for hydrogen fuelled generation on the distribution network.
- Under **System Transformation**, it is assumed that a proportion of fossil fuel sites currently on the distribution network convert to hydrogen at the same capacity. A significant hydrogen fuelled generation capacity is also expected on the transmission network in this scenario.
- By 2050, hydrogen fuelled generation capacity on the distribution network reaches:
    - 240 MW under **Leading the Way**
    - 196 MW under **System Transformation**
    - 81 MW under **Consumer Transformation**
    - No hydrogen generation has been modelled under **Steady Progression**.

Figure 51: Hydrogen fuelled generation projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

The DFES 2021 has been reconciled to the FES 2021 data for the relevant GSPs within the North of Scotland licence area for technology building block Gen_BB023.

- There is no baseline of hydrogen fuelled generation in the DFES 2021 or FES 2021.
- Both DFES and FES do not model any hydrogen fuelled generation deployment until the late 2020s. This will be reviewed in future DFES studies, as the sector progresses.
- In the medium- and long-term the SSEN DFES 2021 projections have modelled a notably higher uptake of hydrogen fuelled generation in the North of Scotland licence area than the FES 2021 GSP regional data.
- The DFES 2021 has projected the highest uptake of distribution connected hydrogen fuelled generation in the **Leading the Way** scenario. This is consistent with the FES 2021 national scenario projections for decentralised hydrogen fuelled generation.
- The DFES has modelled a high-growth scenario (**Leading the Way**) of 240 MW by 2050, representing c.80% of the fossil fuel baseline and pipeline capacity. The FES 2021 GSP data has a much smaller high-growth scenario (**System Transformation**) of 39 MW by 2050, which represents c.13% of the fossil fuel baseline and pipeline, equivalent to only one or two baseline sites converting to hydrogen across the licence area.
- The main rationale for a higher capacity of hydrogen fuelled generation in the SSEN DFES 2021 is the occurrence of diesel and gas peaking plants in the region, including critical support generators on the Scottish Islands, that would need to be decarbonised to meet Scottish and local net zero targets.
- The more ambitious projections under the DFES also reflect Scottish Government's broader commitment to support the development of a hydrogen economy in Scotland.
- It should be noted that, for both DFES and FES projections, there is a high degree of uncertainty regarding the potential role that hydrogen fuelled generation will play.

Factors that will affect deployment at a local level:

- To model the connection of hydrogen fuelled generation in the 2030s and 2040s, a spatial analysis of potential hydrogen supply areas was completed and compared to commercial baseline and pipeline fossil fuel peaking plants.
- The identification of these hydrogen supply areas considered the location of:
    - existing hydrogen trials
    - large industrial clusters
    - proximity to the gas network
    - proximity to major roads and motorways
    - potential hydrogen storage facilities.
- The location of projected hydrogen fuelled generation sites is based on the location of existing and pipeline fossil fuel peaking plants, including Scottish Island-based diesel and fossil gas generators.
- Engagement with National Grid ESO identified that most of the dedicated hydrogen fuelled generation will be new build, albeit located at existing sites.

References:

SSEN connection offer data, Regen consultation with local stakeholders in the North of Scotland licence area, including Scottish Island stakeholders.

[liii] The standards for low carbon hydrogen are the subject of consultation but are assumed to include hydrogen produced via electrolysis (using renewable electricity) and methane reformations (using an efficient CCUS process)

[liv] GE Hydrogen Turbines and Siemens Hydrogen Turbines

[lv] See Draft Scottish Government Hydrogen Action Plan, Nov 2021: https://www.gov.scot/publications/draft-hydrogen-action-plan/

[lvi] See *Aberdeen Hydrogen Hub*: https://www.aberdeencity.gov.uk/services/environment/aberdeen-hydrogen-hub

[lvii] See *Dundee Hydrogen Bus Development Project*: https://h2-accelerator.org/projects/dundee/

[lviii] See SGN's *East Neuk Power-to-Hydrogen* initiative: https://sgn.co.uk/about-us/future-of-gas/hydrogen/east-neuk-power-hydrogen

Other generation

Summary of modelling assumptions and results

Technology specification:

The ‘other generation’ technology category covers unidentified connections - *this class does not have a corresponding technology building block.*

Data summary for other generation in the North of Scotland licence area:

Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
All Scenarios	0.56	0.56	0.56	0.56	0.56	0.56	0.56

Overview of technology projections in the licence area:

- There are eight sites of unidentified generation technology in the North of Scotland Licence area totalling 560 kW of installed capacity. This is a significant decrease since DFES 2020 (4.5 MW) due to investigative analysis of sites using satellite imagery, developer outreach, news articles and in-depth desk research to identify the technologies.
- At an average capacity of 69 kW, these sites are predominantly micro CHP plants within schools, hotels, farms and recreational centres; however, the fuel type is uncertain, hence these sites cannot be allocated a technology. The largest site is 152 kW.
- There are no pipeline projects, as two sites marked as capacity increases have been assumed to have connected in 2020, as per their anticipated date of connection, and included in the baseline.
- Other generation is not projected beyond the baseline and pipeline, and there is no variance between the scenarios for this technology.

Factors that will affect deployment at a local level:

- Distribution is entirely based on the location of baseline and pipeline sites as referenced in the SSEN connections database.

References:

SSEN connection offer data, developer outreach, various news articles and project pages, Grid Reference Finder, Renewable Energy Planning Database

Battery storage

Summary of modelling assumptions and results

Technology specification:

Battery-based storage projects (solid-state and flow-state) connected to the distribution in the North of Scotland licence area, covering four business models:

1. **Standalone network services –** Typically multiple megawatt scale projects that provide balancing, flexibility and support services to the electricity network.
2. **Generation co-location –** Typically multiple megawatt scale projects, sited alongside renewable energy (or occasionally fossil fuel) generation projects.
3. **Behind-the-meter high energy user –** typically single megawatt or smaller scale projects, sited at large energy-user operational sites to support on-site energy management or to avoid high electricity cost periods.

These 3 business models or storage asset classes combine to align to the technology building block: **Batteries Srg_BB001**

4. **Domestic batteries –** typically 5-20 kW scale batteries that households buy to operate alongside domestic-scale rooftop PV or to provide backup services to the home.

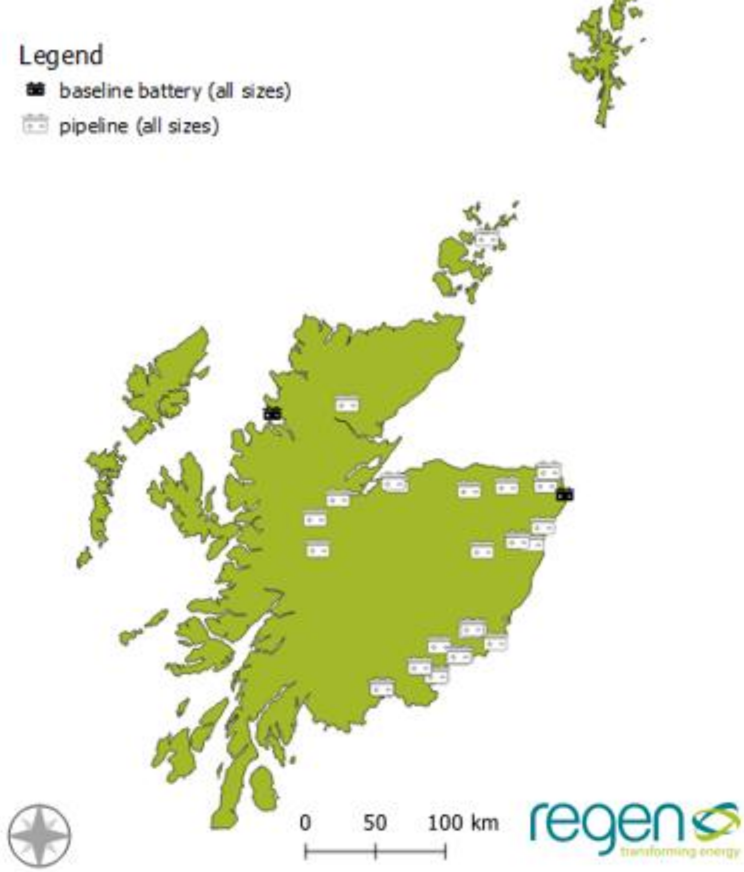
This business model aligns to technology building block: **Domestic Batteries(G98) Srg_BB002**

Data summary for battery storage in the North of Scotland licence area:

Installed power capacity (MW)		Baseline	2025	2030	2035	2040	2045	2050
Standalone network services	Steady Progression	0	50	264	290	319	335	338
	System Transformation		154	313	345	379	398	406
	Consumer Transformation		403	464	475	499	524	534
	Leading the Way		501	565	579	608	638	651
Generation co-location	Steady Progression	0	0	39	50	53	146	150
	System Transformation		35	69	86	116	168	175
	Consumer Transformation		35	93	111	180	207	216
	Leading the Way		35	114	142	176	203	214
Behind-the-meter high energy user	Steady Progression	0	13	18	20	20	21	22
	System Transformation		27	36	39	41	43	44
	Consumer Transformation		40	53	59	102	107	111
	Leading the Way		53	89	98	102	107	111
Domestic batteries	Steady Progression	0	1	1	2	3	8	19
	System Transformation		0.5	8	11	14	33	39
	Consumer Transformation		2	20	35	57	94	168
	Leading the Way		7	24	44	73	122	219

Overview of technology projections in the licence area:

Figure 52: Baseline and pipeline battery storage sites in the North of Scotland licence area



- Scotland largely missed out on the first wave of battery storage projects, which were focused more on the provision of frequency response services, however there has been a big uplift in storage projects in the region aiming to co-locate with renewables and to provide balancing services.
- The North of Scotland licence area has significant potential for long term growth in connected storage capacity. This is due to:
- Amongst the best onshore wind resource the UK and thus strong potential for significant battery storage co-location.
- Targeted network services, such as phase two of National Grid ESO's stability pathfinder tender, which could prompt notable development of standalone battery projects adjacent to network substations in Scotland[lix].
- The growth of price arbitrage and balancing services business models.
- A number of commercial and industrial premises with the potential for behind-the-meter batteries, including industrial areas in Dundee and Aberdeen.
- There is 1.2 MW of battery storage connected in the North of Scotland licence area.
- There is, however, a large pipeline of potential new battery projects, 47 sites totalling a little over 1.7 GW.
- Within this identified pipeline, a number of projects have secured planning approval, while others have positive bid activity in recent Capacity Market auctions.
- Engagement with project developers, has confirmed that a significant number of projects are very likely to progress to construction in the early-to-mid 2020s.
- As a result, a high number of projects have been modelled to come online in the near-term in the **Leading the Way** and **Consumer Transformation** scenarios.
- Overall battery storage across the four business models in 2050 in the North of Scotland licence area ranges from 509 MW in **Steady Progression** to 1.3 GW in **Leading the Way**.
- The DFES analysis has focused on the MW power rating of battery storage, the analysis however also shows that battery storage capacity duration (MWh) is also increasing with progressively more 2-4 hour duration storage in the pipeline.

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- There are no operational batteries connected in the North of Scotland licence area as of the end of 2020.
- There are four small batteries co-located with renewable energy projects on the islands of Eigg, Muck, Rum and Horse Island. But these are not connected to SSEN's distribution network and are instead on on-island microgrids.
- A 1 MW project is also co-located with the HyWind offshore wind farm in Buchan Deeps (20km off Peterhead).

Near term (2021 – 2025)

- The licence area has a large pipeline of potential new battery storage projects:
  - 34 sites (totalling 1.1 GW) have an accepted connection offer.
  - 13 sites (totalling 590 MW) have connection quotes issued not yet accepted.
  - This includes 21 sites that are individually 49 MW or greater in power capacity.
- In June 2021 a 49.9 MW standalone battery project located at a Technology Park in Dundee was brought online.
- The majority of pipeline projects, 40 sites totalling 1.6 GW, are large-scale standalone battery projects.
- There are however a number of pipeline battery projects, 7 sites totalling 150 MW, that are seeking to co-locate with renewable energy technologies (solar, wind and marine).
- Through engagement with developers and analysis of each of the remaining pipeline projects in planning and Capacity Market registers suggests:
  - Developers have advised that 3 projects (totalling 139 MW) will be progressed and operational by 2022-2024
  - 13 projects (334 MW) have recently secured planning approval
  - 2 projects (100 MW) are currently awaiting a decision on planning applications
  - 4 projects (69 MW) successfully pre-qualified in recent Capacity Market auctions
  - 2 projects (60 MW) recently (2019/2020) withdrew their planning applications
  - No development information could be found for the remaining 26 sites (1 GW).
- Planning evidence and capacity market activity are key weighting factors that determine when battery storage capacity is modelled to connect under the four scenarios.
- There are a number of regulatory reforms in motion that could affect distributed generation connection charging. Notably the Access and Forward-Looking Charges Significant Code Review and changes to transmission network (TNUoS) charges for embedded generators. For the purposes of network charging, electricity storage technologies such as batteries are treated as generation. Therefore these reforms have the potential to impact the business model for new batteries in the North of Scotland. Depending on the outcome of the code review, upfront connection charges may decrease, however, as a generation-dominated region, battery (and other distributed generation) projects in the North of Scotland could see higher ongoing network charges. This is a key uncertainty for the future development of large-scale batteries in the region.
- There is an ongoing policy discussion that batteries, located in an area with high generation and both transmission and distribution grid constraints, should face lower network charges.
- By 2025, a range of battery storage capacity connected to the distribution network in the North of Scotland licence has been modelled. This is highest (596 MW) under **Leading the Way** and lowest (64 MW) under **Steady Progression**.

Medium term (2025 – 2035)

- Across the late 2020s and early 2030s a proportion of the remaining pipeline projects are assumed to connect under both **Leading the Way** and **Consumer Transformation**.
- The characteristics of the licence area influences the development of new battery projects in a different way for each of the four business models:

Standalone network services (and arbitrage)	For the pipeline of large-scale (>50MW) standalone projects targeting low-cost and brownfield land with an easily accessible, cost-effective network connection points, is a key factor. This includes a number of projects seeking to engage with National Grid ESO's stability pathfinder, for which phase two is specifically targeting Scotland. By 2035, standalone battery capacity resultantly reaches 475 MW under **Consumer Transformation** and 579 MW under **Leading the Way**.
Generation co-location	Co-location storage with renewable generation is likely to be located in areas of high levels of generation, and in areas of grid constraint, including island communities. There is currently 2 GW of distributed connected onshore wind generation in the North of Scotland and significantly more capacity is projected to connect to the distribution network in all scenarios. Onshore wind capacity is highest under **Consumer Transformation** with 5.2 GW modelled to connect by 2035. The potential for co-located battery storage under this scenario is projected to reaching 111 MW by 2035.
Behind-the-meter high energy user	There are c.89,000 commercial and industrial properties that could potentially host behind-the-meter battery storage assets in the licence area. This includes a number of retail, port/marine and logistics premises, as well as new data storage sites. As a result, by 2035, high energy user battery capacity ranges from 20 MW under **Steady Progression** to 98 MW under **Leading the Way**.
Domestic batteries	The licence area also has c.740,000 domestic properties, and whilst solar irradiance is relatively low in the licence area compared to other parts of the UK, a potential for a future increased adoption of domestic rooftop PV remains under **Consumer Transformation** and **Leading the Way**. By 2035, domestic battery storage capacity reaches 44 MW (equivalent to c.9,000 homes) under **Leading the Way** and 2 MW (equivalent to c.500 homes) under **Steady Progression**.

Long term (2035 – 2050)

- Although there is a range of projections, the total connected capacity of battery storage increases across all four scenarios out to 2050.
- The highest increase in connected capacity, across all four business models, is seen under **Leading the Way**. Capacity reaches 1.2 GW by 2050 in this scenario.
- The lowest increase in connected capacity is seen under the **Steady Progression** scenario, reaching 529 MW by 2050. This consists of a small increase in standalone and generation co-location projects. There is also a much lower adoption of domestic and high energy user batteries, due to other methods of flexibility in homes and businesses that are favoured under this scenario.

Figure 53: Large-scale battery storage projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections

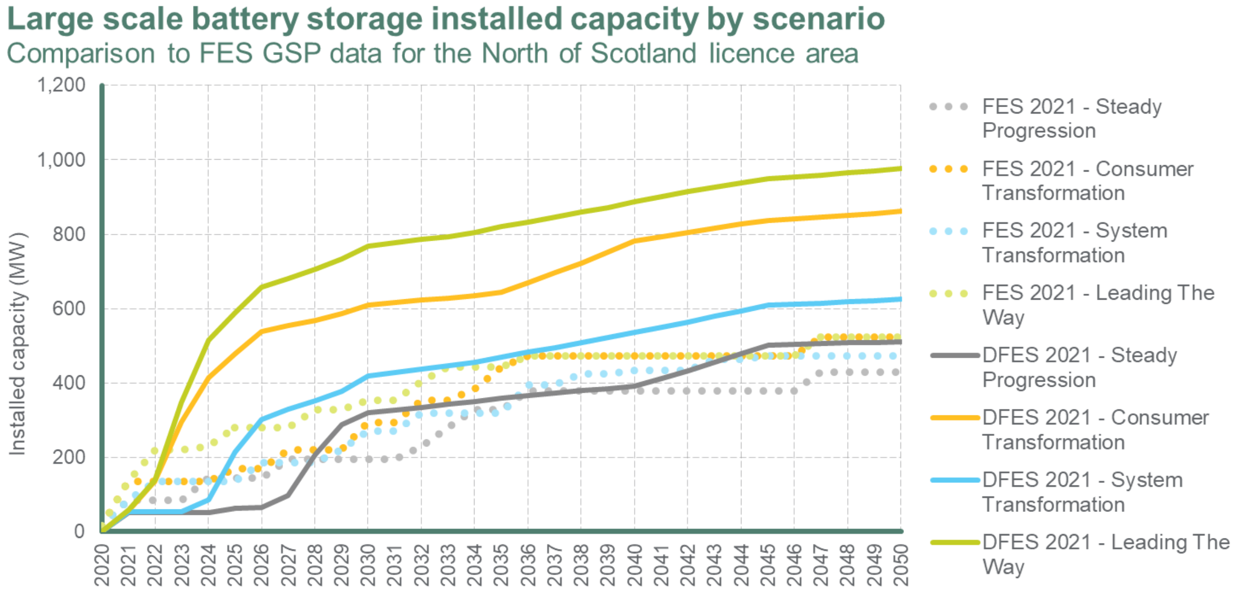
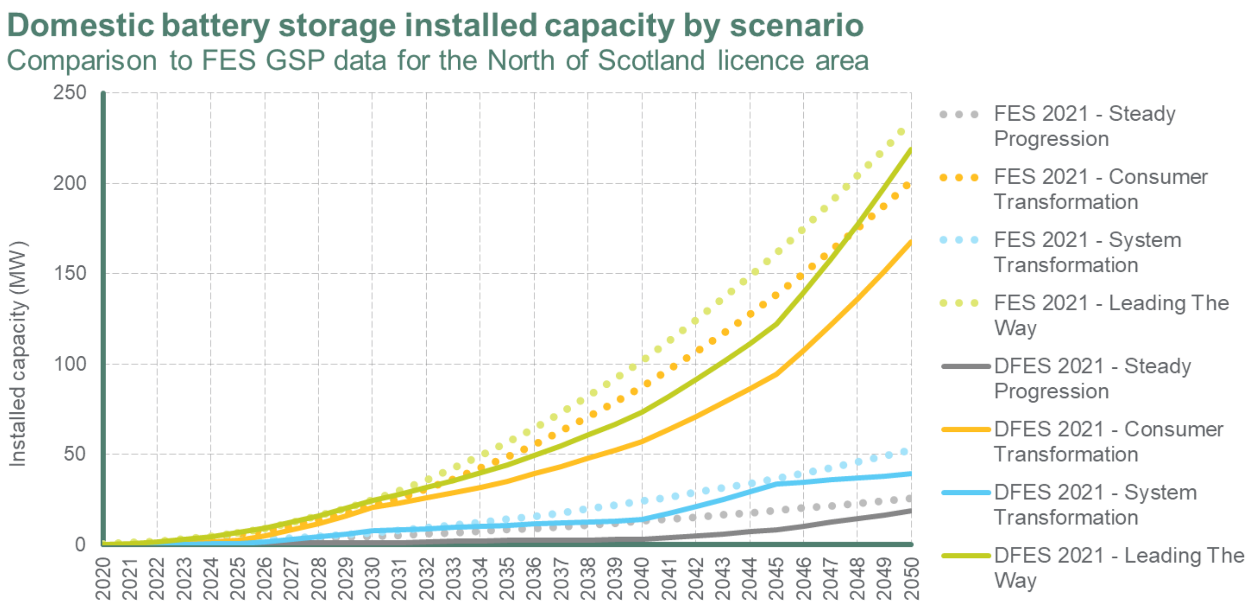


Figure 54: Domestic battery storage projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

Results in this section relate to the FES 2021 data for the relevant GSPs within the North of Scotland licence area for the battery storage building block technologies.

Batteries - [Srg_BB001]

- The FES 2021 regional projections have a slightly higher baseline than the DFES 2021. The reason for this small variance is unknown.
- Under all scenarios, the DFES 2021 shows a significantly higher increase in connected capacity in the near and medium term. This is based on the site-specific development analysis and direct engagement with project developers in the DFES, showing the potential for a much more accelerated deployment of new battery projects under all scenarios in the licence area. The variation is most significant under the **Consumer Transformation** and **Leading the Way** scenarios.
- By 2050, the variance between the FES 2021 and DFES 2021 under the **Consumer Transformation** and **Leading the Way** scenarios narrows to c.337 MW and c.450 MW respectively. The rationale for this variance is the recent very strong project pipeline and the potential for energy storage deployment to be further driven by the expected growth of renewable energy and high energy user installations.
- Under **Steady Progression** the variance between the FES 2021 and DFES 2021 is minimal by 2050, reducing from a 125 MW variance in 2030 to c.80 MW by 2050. This reflects notable pipeline project development in near-term in the DFES, reducing over time to align closer to the FES 2021 long-term projections in this scenario.

Domestic batteries - [Srg_BB002]

- The baseline, near, medium and long-term projections for domestic batteries align well across all four scenarios under the FES 2021 and DFES 2021. Both analyses showing no projects currently connected, and a range of <10 MW to c.50 MW connected by 2035.
- By 2050, a slightly higher capacity is projected in the FES 2021 than in the DFES 2021 under all scenarios, thought this minimal variance ranges from 7 MW to 34 MW. This reflects strong targets for solar PV deployment target (across all scales)[lx], and the associated potential for co-located domestic batteries – including on the Scottish Islands.

Factors that will affect deployment at a local level:

- The spatial distribution of new battery storage projects in the near and medium term is predominantly based on the location of the significant pipeline of new potential sites.
- In the longer term, spatial distribution varies according to the four battery storage business models used in the DFES 2021 modelling. These local factors are:
  - **Standalone network services:** Location of pipeline sites with no development evidence and suitable land proximate to the 33 kV and 132 kV electricity network.
  - **Generation co-location:** Proximity to existing and future onshore wind, large-scale solar PV and marine generation capacity within the licence area.
  - **Behind-the-meter high energy user:** Proximity to industrial estates and commercial buildings that could be suitable for battery storage installations.
  - **Domestic batteries:** Identified domestic dwellings with rooftop PV, as projected in the DFES 2021.

Relevant assumptions from National Grid FES 2021:

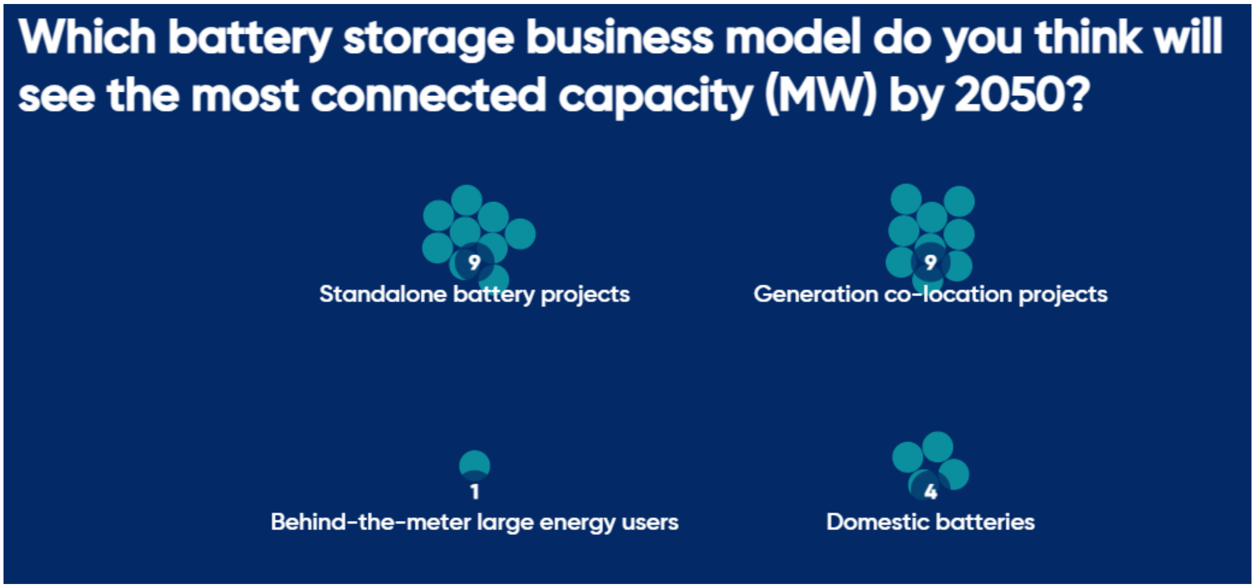
Assumption number	4.2.24 – Short duration electricity storage
Steady Progression	Moderate levels of flexibility requirements encourage new storage. Not as much deployed compared to other scenarios.
System Transformation	Not as much deployed compared to other scenarios due to high use of hydrogen within this scenario.
Consumer Transformation	High levels of variable clean generation and flexibility requirements encourage new storage technologies to emerge.
Leading the Way	Even higher levels of flexibility requirements encourage new storage technologies to emerge at distributed and transmission levels.

Assumption number	4.2.25 – Medium duration electricity storage
Steady Progression	Lower flexibility requirements means that this technology does not come forward at the volumes seen in the other scenarios.
System Transformation	Moderate levels of flexibility requirements encourage new storage. Not as much deployed compared to other scenarios due to high use of hydrogen within this scenario.
Consumer Transformation	Flexibility requirements encourage new storage.
Leading the Way	High levels of flexibility requirements encourage new storage.

Stakeholder feedback overview:

Battery storage	
Stakeholder feedback provided	How this has influenced our analysis
A range of stakeholders were engaged through a dedicated North of Scotland DFES workshop in October 2021. Stakeholders felt that standalone storage (40%) and generation co-location (40%) projects would see the most connected capacity by 2050.	The DFES has modelled these two business models separately, rather than a singular large-scale battery storage projection. Whilst a significant capacity of generation co-location storage has been modelled to connect under **Leading the Way** and **Consumer Transformation**, the majority (c.1.6 GW) of the known pipeline (c.1.8 GW) was identified to be standalone projects. Therefore, this is the business model that has the highest projection overall.
When asked what electricity storage technologies might connect in the North of Scotland by 2050, pumped hydro (57%), flow-state batteries (48%) and liquid air scored highest (48%).	The DFES battery storage analysis includes both solid-state and flow-state batteries. There is a known flow battery project seeking to co-locate with marine generation project on the Orkney Islands[lxi]. This technology could see further deployment in the longer-term in any of the three non-domestic business models. The DFES 2021 has included a separate analysis and projection of liquid air energy storage (LAES) for the first time and is summarised in a separate technology sheet. Whilst the potential for additional pumped hydro is significant in the licence area, the scale of this technology sees a focus on projects connecting to the transmission network. This is especially the case in Scotland, due to the transmission network voltages being a tier lower than the rest of the UK. Pumped hydro has therefore not been included in the SSEN DFES 2021.
Engagement with representatives from a number of the Scottish Islands highlighted that the outcome of the needs case[lxii] for a new connection to the transmission network on Orkney could influence the adoption of domestic battery storage. Islanders also fed back that co-location of storage with solar PV could be a drive to improve the economics of solar in the licence area, due to low irradiance.	The DFES 2021 has projected a broad range of domestic storage capacity deployment in the near and long term. The spatial distribution of domestic storage includes the supply areas on Orkney. Over 200 MW of storage co-located with renewable energy generation has been modelled to connect by 2050 under **Leading the Way** in the DFES. The spatial distribution factors for this business model include proximity to existing and future solar PV projects

Figure 55: Stakeholder responses to battery storage question in the online engagement webinar



References:

SSEN connection offer data, Regen consultation with local stakeholders in the North of Scotland area, workshop with Scottish Island stakeholders and direct engagement with battery storage project developers.

[lix] See NOA Stability Pathfinder – Phase 2 updates: https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-2

[lx] See Solar Energy Scotland target of 4 GW of solar PV by 2030 across Scotland: https://www.solarpowerportal.co.uk/news/solar_energy_scotland_calls_for_4gw_by_2030_target_to_realise_solars_full_p

[lxi] See EMEC press release highlighting flow battery project on Eday: https://www.emec.org.uk/flow-batteries-combine-with-tidal-power-to-produce-green-hydrogen/

[lxii] See Ofgem Orkney transmission project – conditional decision on Final Needs Case: https://www.ofgem.gov.uk/publications/orkney-transmission-project-conditional-decision-final-needs-case

Liquid air energy storage

Summary of modelling assumptions and results

Technology specification:

The analysis covers liquid air energy storage (LAES), sometimes referred to as cryogenic electricity storage, connected to the distribution network in the North of Scotland licence area. No direct equivalent technology building block currently exists, but analysis could be reconciled in part to building block: **Srg_BB004 – Other energy storage**.

Data summary for LAES in the North of Scotland licence area:

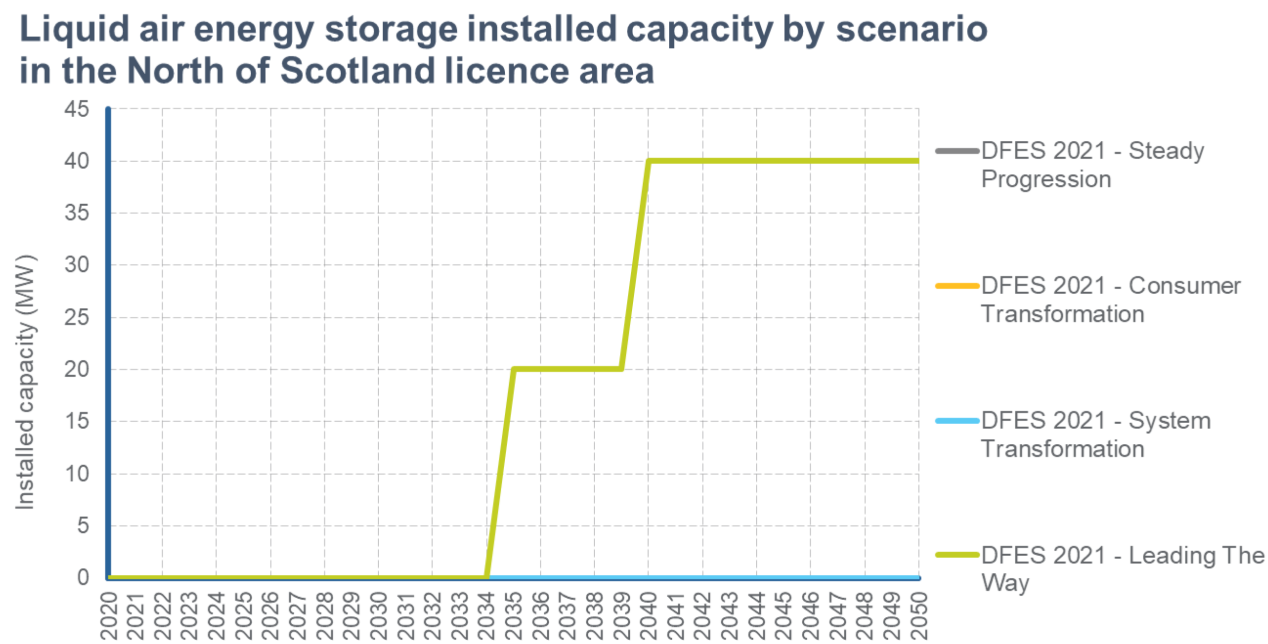
Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	0	0	0	0	0	0	0
System Transformation		0	0	0	0	0	0
Consumer Transformation		0	0	0	0	0	0
Leading the Way		0	0	20	40	40	40

Overview of technology projections in the licence area:

- Liquid air energy storage (LAES) uses electricity to power compression and refrigeration equipment to cool air until it liquefies. This liquid air is then stored in cryogenic energy storage tanks for the duration required. When electricity is required the liquid air is exposed to ambient temperature air (or waste heat from industrial processes) to convert it back to a gaseous state. This resultant expanded gas is used to turn a turbine to generate electricity.
- It is considered as one of the technologies that could provide longer duration storage services to the electricity system, with project developers looking to move from small-scale trials to full commercial-scale plants. This technology could be supported by BEIS' Long Duration Storage Competition grant funding, launched in 2021[lxiii].
- LAES is a relatively recent technology development. One of the leading developers in the UK is Highview Power, who has developed trial and pre-commercial plants in Greater Manchester[lxiv].
- At present no LAES plants are operational in the North of Scotland licence area. There are also no known pipeline projects with connection offers to connect to the distribution network in the licence area.
- However, through direct consultation with representatives from Highview Power, some business models they are considering include the potential to co-locate with renewable energy generation technology (as a source of low-cost, low-carbon input electricity). Also the National Grid ESO stability pathfinders in Scotland[lxv] could be a potential source of income for future LAES projects to target.
- As a result of this feedback and significant capacity of distributed renewable energy generation in the North of Scotland licence area, the DFES 2021 has modelled 20 MW of new LAES capacity to come online by 2035 and 40 MW by 2050, under **Leading the Way**. There is the potential for additional capacity to connect to the transmission network.

Scenario projection results:

Figure 56: Liquid air energy storage projections for the North of Scotland licence area



Reconciliation with National Grid FES 2021:

There are no equivalent projections for LAES capacity in the FES 2021 to reconcile these DFES 2021 projections against.

Factors that will affect deployment at a local level:

Based on engagement with LAES technology developers Highview Power, the location of LAES plants in the North of Scotland licence area is based on a potential to co-locate with renewable energy generation sites and proximity to distribution network infrastructure.

References:

Engagement with LAES technology developers.

[lxiii] See BEIS long duration storage competition overview: https://www.gov.uk/government/publications/longer-duration-energy-storage-demonstration

[lxiv] See Highview Power operational plants: https://highviewpower.com/plants/

[lxv] See Stability Pathfinder Phase 2 overview: https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-2

Electric vehicles

Summary of modelling assumptions and results

Technology specification:

Electric vehicles (EVs) – including non-autonomous cars covering both Battery-electric and Plug-in Hybrid cars, autonomous cars, buses and coaches, HGVs, LGVs and motorcycles.

Technology building block: Lct_BB001, Lct_BB002, Lct_BB003, Lct_BB004

Data summary for electric vehicles in the North of Scotland licence area:

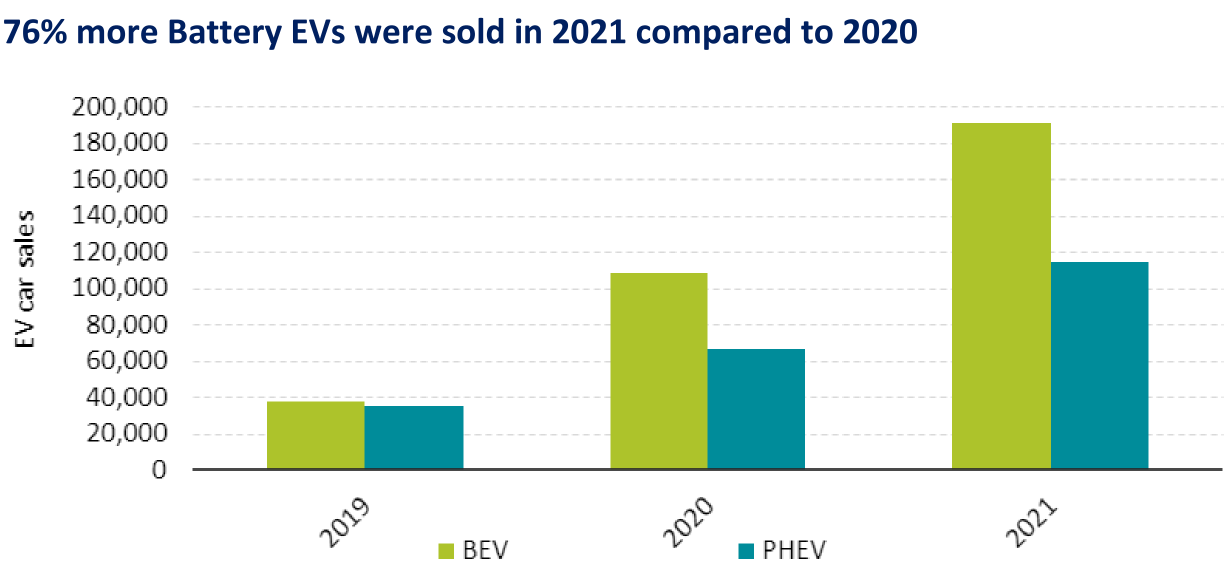
Number of EVs (total, 1000s)		Baseline	2025	2030	2035	2040	2045	2050
Battery EVs	Steady Progression	4	25	106	307	616	845	909
	System Transformation		34	159	483	816	881	828
	Consumer Transformation		73	244	554	796	850	828
	Leading the Way		62	329	743	857	796	632
Hybrid EVs	Steady Progression	3	10	26	50	67	42	9
	System Transformation		10	25	38	25	6	0
	Consumer Transformation		7	15	20	11	0	0
	Leading the Way		10	22	16	5	-	-

Overview of technology projections in the licence area:

- At present, EVs (including Battery EVs and Plug-in Hybrid EVs) represent approximately 0.8% of all vehicles in the North of Scotland licence area. The GB average is 1.4%; therefore, the area currently has a below average uptake of EVs. This is, however, representative of other predominantly rural regions in GB. More urban centres in the region, such as for Dundee and Stirling city regions, have an EV uptake more typical of GB average.
- However, as a result of Scottish Government's ambition for transport decarbonisation, North of Scotland is projected to align with the GB average uptake rate for EVs by the mid-2020s.
- Electrification is the key route to decarbonising transport in the ESO FES 2021 scenarios, with hydrogen's role focused on contributing to the decarbonisation of HGVs and buses in most scenarios. North of Scotland is projected to have a higher uptake of hydrogen vehicles compared to the national scenarios.
- The number of Plug-in Hybrid EVs in the licence area is 38% lower than the number of Battery EVs. The proportion of Plug-in Hybrid EVs compared to Battery EVs is projected to reduce further in all scenarios, as Battery EVs remain the dominant form of EV. The number of Plug-in Hybrids peaks in the 2030s in all net zero scenarios, followed by a decline to 2050.

- All scenarios in ESO FES 2021 show a more rapid EV uptake compared to the ESO FES 2020. Even the slower growth scenarios of **Steady Progression** and **System Transformation** have faster growth rates than in previous FES 2020 scenarios.
- The reduction in vehicle numbers in the long term in the ESO FES 2021 is facilitated by an increase in active and public transport use, an increase in average vehicle mileage and the introduction of autonomous vehicles (AVs) which have high average annual mileage.
- Hydrogen vehicle numbers increase throughout the 2030s, and are concentrated in HGVs, buses and LGVs in all scenarios, although **System Transformation** has significantly more hydrogen vehicles than the other scenarios, with four to five times as many hydrogen vehicles compared to other net zero scenarios and 25 times more than **Steady Progression**.
- Society of Motor Manufacturers and Traders (SMMT) data finds that 76% more Battery EVs were sold in GB in 2021 compared to 2020 and 380% greater than in 2019. In addition, that Battery EV sales now eclipse Plug-in Hybrid EVs.

Figure 57: UK annual EV sales (non-cumulative), source: SMMT, Regen analysis



2021 has seen a number of important new EV market and policy developments across the UK, whose implications have been considered for this licence area's DFES scenarios.

- Aberdeen and Dundee's Clean Air Zones are due to be implemented in early 2022.
- The Scottish Government published data that finds that over half of Scottish Government's car fleet is electric, ahead of its 2030 target date.
- The UK government has pledged that all new HGVs from 2040 will be zero-emission, and potentially sooner for smaller HGVs[lxvi].
- The UK government has consulted on phasing out non-zero emission buses from between 2025 and 2032[lxvii].
- The UK government has announced changes to the EV grant scheme, which will now provide grants of up to £1,500 for electric cars priced under £32,000[lxviii].

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- In the North of Scotland licence area, there is currently slower uptake across most of the highlands and islands, but a more rapid uptake in urban areas such as Aberdeen, Dundee and Stirling. An exception is some of the island communities, such as Orkney, which have seen rapid adoption of EVs.
- There are a total of 4,263 Battery EVs in the North of Scotland licence area, representing a 40% increase in Battery EVs compared to the DFES 2020 study.
- There are a total of 2,689 Plug-in Hybrid EVs in the North of Scotland licence area, representing a 7% reduction in Plug-in Hybrid EVs compared to the DFES 2020 study.
- Around 96% of Battery and Plug-in Hybrid EVs are cars, while HGVs, LGVs, buses and coaches and motorcycles make up the remaining EV numbers.

Near term (2021 – 2025)

- Across all scenarios, the uptake of EVs is expected to accelerate significantly in the mid-2020s. The overwhelming majority of this uptake is from electric cars, with electric vans, buses and other vehicles growing at a slower rate.
- It is projected that by 2025, there could be between c. 25,000 Battery EVs in **Steady Progression** to c. 62,000 in **Consumer Transformation** – potentially over a fourteen-fold increase by 2025. The dramatic increase in EV numbers reflects high Scottish Government ambition for EV uptake, resulting in the licence area not remaining behind the GB average for EV uptake beyond the early- to mid-2020s.
- Local initiatives to lower air quality or expand access to charging are expected to increase local uptake. 'Clean Air Zones' have been proposed in areas including Dundee and Aberdeen and are assumed to go ahead in all net zero scenarios in the near term.

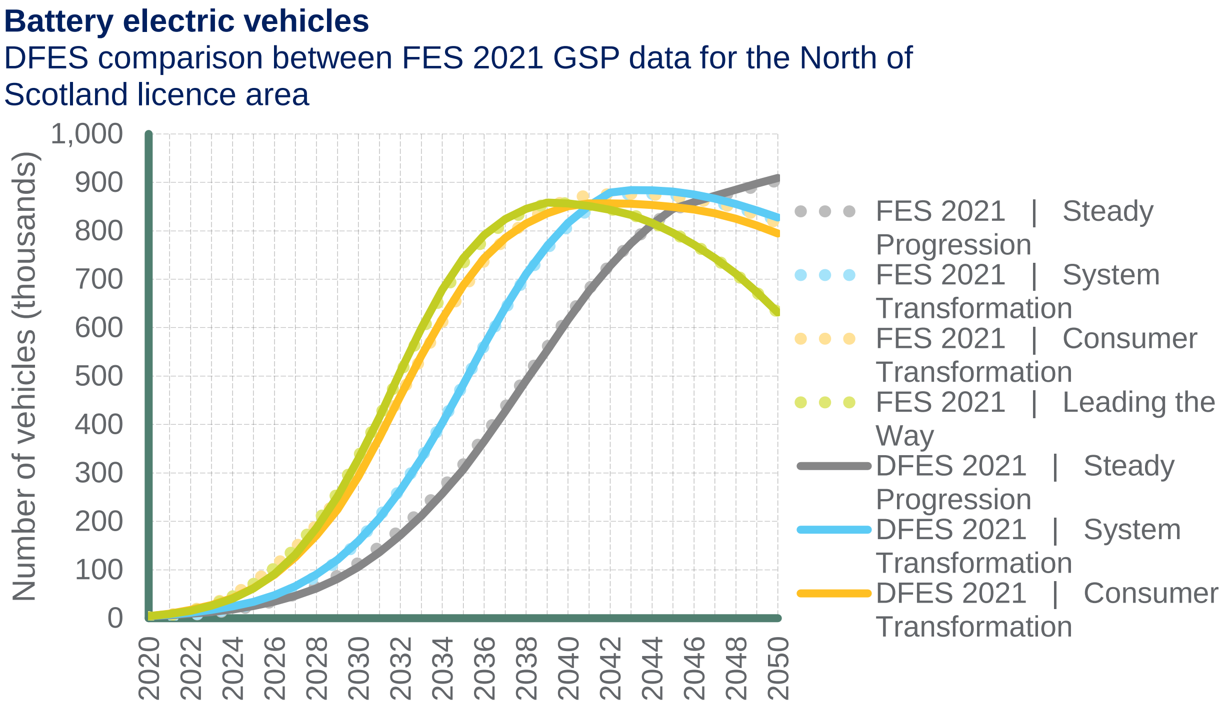
Medium term (2025 – 2035)

- The uptake of EVs is expected to accelerate between 2025 and 2035 in all scenarios.
- **Steady Progression** is the scenario with the fewest estimated Battery EVs in 2035, reaching c.307,000. **Leading the Way** remains the scenario with the most, with 743,000 Battery EVs modelled by 2035.
- EV uptake begins to slow in the mid-2030s as EV adoption approaches saturation and only the hardest-to-electrify vehicles such as HGVs, remain fuelled by petrol or diesel.
- Other factors also contribute to uptake slowing, including a reduction in the total number of vehicles, increased use of AVs and increased use of public transport and active travel.
- The uptake of plug-in hybrids slows and then reduces in **Leading the Way**, as a result of the assumed restriction on their sale in the early 2030s.

Long term (2035 – 2050)

- The uptake of EVs continues to increase in **Steady Progression**, right up until 2050 when Battery EVs total 909,000. In **System Transformation**, the uptake of Battery EVs flattens and then marginally reduces from the mid-2040s as a result of an increase in the number of hydrogen cars.
- In **Leading the Way** and **Consumer Transformation**, the numbers of EVs reduces from the late 2030s and mid-2040s, respectively. This is the result of societal change and technological development including increased use of public and active travel and the rising number of AVs.
- Many homes opt to have one or no car at all, which results in a decrease in the number of company and private vehicles.
- The number of Battery EVs and total vehicles in **Leading the Way** reduces substantially in the long term, peaking at 857,000 before reducing to 632,000 in 2050.

Figure 58: EV projections for the North of Scotland licence area, compared to National Grid FES 2021 regional projections



Reconciliation with National Grid FES 2021:

- The SSEN DFES 2021 projections are broadly in line in the near term with the FES 2021 projections for this licence area, as reported for the Building Block ID numbers Lct_BB001, Lct_BB002, Lct_BB003 and Lct_BB004.
- In order to reflect Scottish ambition for the decarbonisation of transport, the SSEN DFES 2021 projections considered analysis carried out by Transport Scotland, that showed how EVs can contribute to the Scottish Government's ambition to phase out the need for petrol and diesel cars by 2032. This has influenced the scenarios in the following ways:
    - **Consumer Transformation** has adopted the Scottish Government's ambition to have no petrol and diesel vehicles of any archetype by 2045.
    - Scottish Government's higher ambition for the uptake of electric buses, LGVs and HGVs when compared to the FES 2020 scenarios has been adopted in the **Consumer Transformation** and **Leading the Way** scenarios.
    - Scottish Government's high ambition for hydrogen vehicles has been adopted into the **Consumer Transformation** scenario.
- Interim assumptions have been made as to the uptake and distribution of AVs in the absence of other information. The spatial distribution of AV uptake is treated the same as non-autonomous EVs due to a lack of information about their future uptake. It is assumed that the uptake of AVs in on- and off-street settings is the same as for non-autonomous EVs. The uptake and distribution of AVs is an area that needs to be considered for future analysis when more evidence is available.
- Scottish Government has, through the publication of its Climate Change Plan Update and 'Covid-19 green recovery', committed to a number of actions, targets and ambitions around the decarbonisation of transport.
    - The 2030 phase-out of petrol and diesel cars, that includes a commitment to reduce

car kilometres by 20% by 2030
    - £120 million for zero-emission buses, driving forward a fully decarbonised future for Scotland's bus fleet
    - An aim for Scotland's rail services to be fully decarbonised by 2035
    - An investment of £50 million to create Active Freeways.
- The launch of Scottish Government's Hydrogen Policy Statement and Hydrogen Action Plan highlights a strategy to scale up the opportunities for hydrogen in Scotland, including the creation of the Hydrogen Accelerator programme. City region strategies for Aberdeen and Dundee seek to harness opportunities that hydrogen can bring to transport, fleet and city decarbonisation plans, such as the Aberdeen Hydrogen Hub. This ambition for hydrogen is incorporated into the **Consumer Transformation** scenario and is assumed to be within the FES 2021 **System Transformation** scenario envelope.
- The FES 2021 scenarios incorporate the latest UK and Scottish government announcements for ending the sale of petrol and diesel cars. This contributes to EV uptake rates being higher compared to FES 2020 and DFES 2020.

Factors that will affect deployment at a local level:

- The spatial distribution of EVs in the near term is based on affluence, rurality, existing vehicle baselines and the distribution of on- and off-street parking. However, the significance of these factors reduces until the late 2020s when under all net zero scenarios, EV uptake is assumed to be ubiquitous and almost all consumers are assumed to have the same likelihood of adopting an EV. However, the distribution will necessarily be weighted towards those customers who have yet to purchase an EV.

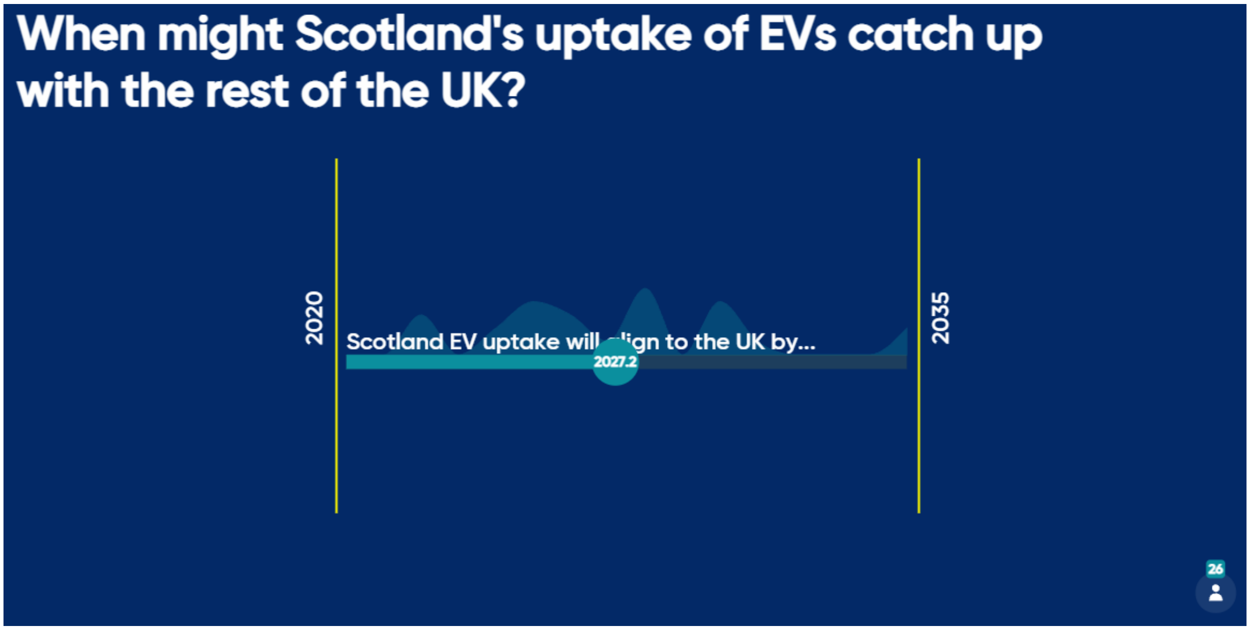
Relevant assumptions from National Grid FES 2021:

Assumption number	3.3.5 - Uptake of Battery electric vehicles 4.1.25 - The rate of uptake of Plug-in Hybrid electric vehicles
Steady Progression	BEV adoption is slow and doesn't meet policy ambitions. Sales ban of petrol & diesel cars is pushed back to 2035, and vans to 2040, to protect UK car industry sales. Low uptake of BEVs in the bus and HGV sectors out to 2050. Availability from manufacturers to meet EU emissions standards is met from demand by fleets looking to gradually reduce emissions (through PHEVs) and drivers who are unwilling to shift to BEVs. New PHEV sales banned in 2040.
System Transformation	The right conditions are not fully achieved to create the consumer confidence needed for the market to achieve the government's 2030 ban on petrol & diesel cars and vans. The bans for cars and vans are pushed back to 2032 and 2035, respectively. Uptake in (BEV) HGV and bus sector is limited by strong Hydrogen Fuel Cell Vehicle uptake. Higher demand for PHEVs as a transitional vehicle due to a higher proportion of consumers reluctant to transition to BEVs. New (PHEV) sales banned in 2035.
Consumer Transformation	The government target to ban sales of petrol & diesel cars and vans by 2030 is met. There's a significant uptake in the bus sector and across suitable HGVs. Subsidy environment, falling battery costs and increased consumer willingness to accept BEVs limits PHEV growth. New (PHEV) sales banned in 2035.
Leading the Way	The government target to ban sales of petrol & diesel cars and vans by 2030 is met. Uptake in the HGV sector is limited by strong Hydrogen Fuel Cell Vehicle uptake. There's a significant uptake in the bus sector. Subsidy environment, falling battery costs and increased consumer willingness to accept BEVs limit PHEV growth. New (PHEV) sales banned in 2035.

Stakeholder feedback overview:

Electric Vehicles	
Stakeholder feedback provided	How this has influenced our analysis
When asked "when might the North of Scotland licence area's EV uptake align with the rest of the UK", stakeholders had mixed views with little discernible trend emerging. The majority of views were that EV uptake in the licence area would align with the GB average before 2030, with the average at 2027.	EV uptake rates in the North of Scotland licence area remain behind the national average until the mid-2020s, in doing so also reflecting Scottish Government ambition for high EV uptake.
For the uptake of EVs, other feedback was received at a stakeholder workshop focused on the Isle of Wight. The outcome of this for EVs confirmed initial assumptions in the modelling such as the ambition of the net zero scenarios and distribution models.	Confirmed existing assumptions.
In addition to other feedback that confirmed existing assumptions, the Scottish Government provided feedback that public procurement of EVs to decarbonise fleets is ambitious and above average nationally.	The suitability of the scenarios in representing the uptake of fleet vehicles in Scotland was reviewed.
Feedback from industry stakeholders highlighted that the ambitious growth of the net zero scenarios was dependant on the supply of EVs, and that presently supply is not meeting demand as a result of chip shortages, manufacturing limitations and other factors. Furthermore, an additional challenge for the UK is to secure sufficient imports of EVs against the backdrop of high global demand for EVs.	The deliverability and progress achieved towards the scenarios will be reviewed annually. FES 2021 conducted this analysis and found that EV uptake seen last year fell well within the credible range of scenarios.

Figure 59: Stakeholder responses to EV question in the online engagement webinar



References:

Department for Transport data, Climate Emergency declaration data, Regen consultation with local stakeholders, Census 2011.

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lxvi https://www.gov.uk/government/news/uk-confirms-pledge-for-zero-emission-hgvs-by-2040-and-unveils-new-chargepoint-design

lxvii https://www.gov.uk/government/consultations/ending-the-sale-of-new-diesel-buses

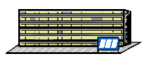
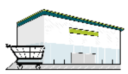
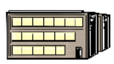
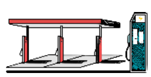
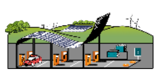
lxviii https://www.gov.uk/government/news/government-funding-targeted-at-more-affordable-zero-emission-vehicles-as-market-charges-ahead-in-shift-towards-an-electric-future

Electric vehicle chargers

Summary of modelling assumptions and results

Technology specification:

The uptake of the following EV charger archetypes are modelled:

Off-street domestic		Homes with somewhere to park a private vehicle off-street
On-street residential		Charging at roadside car parking spaces
Car parks		Charging at areas provided for parking only, hence excludes supermarkets
Destination		Supermarkets, hotels and other destinations where parking is provided
Workplace		Parking for commuters, at places of work
Fleet/depot		Charging for vehicles that return to a depot to park
En-route local		Charging service stations excluding motorway or A-road services
En-route national		Motorway or A-road charging stations outside of urban areas

FES 2021 does not publish EV charger projections and so the DFES 2021 projections cannot be reconciled against a specific FES technology building block or dataset.

Data summary for electric vehicle chargers in the North of Scotland licence area:

Note that the projection units for domestic and non-domestic EV chargers in the following table are different. To illustrate the scale of EV charger uptake, domestic off-street EV chargers are displayed in numbers, while non-domestic EV chargers are displayed in total connected capacity (MW).

For non-domestic EV chargers, different numbers of chargers could be required to deliver the same amount of energy, making capacity a better indicator of future uptake and network impact. While this is also true of domestic chargers, since there is assumed to be less variability in their individual capacity, the number of chargers is considered a more useful indicator of the scale of future uptake, as it enables comparisons of chargers on a per household and per EV basis.

<table>
<tr><th colspan="2">EV chargers</th><th>Baseline</th><th>2025</th><th>2030</th><th>2035</th><th>2040</th><th>2045</th><th>2050</th></tr>
<tr><td rowspan="4">Domestic off-street EV chargers
(Total, numbers, thousands)</td><td>Steady Progression</td><td rowspan="4">3</td><td>15</td><td>58</td><td>137</td><td>320</td><td>404</td><td>420</td></tr>
<tr><td>System Transformation</td><td>21</td><td>69</td><td>205</td><td>393</td><td>417</td><td>425</td></tr>
<tr><td>Consumer Transformation</td><td>54</td><td>149</td><td>361</td><td>417</td><td>427</td><td>437</td></tr>
<tr><td>Leading the Way</td><td>43</td><td>187</td><td>394</td><td>421</td><td>432</td><td>442</td></tr>
<tr><td rowspan="4">Non-domestic EV chargers
(Total, MW)</td><td>Steady Progression</td><td rowspan="4">48</td><td>70</td><td>119</td><td>231</td><td>441</td><td>620</td><td>649</td></tr>
<tr><td>System Transformation</td><td>75</td><td>144</td><td>333</td><td>599</td><td>691</td><td>717</td></tr>
<tr><td>Consumer Transformation</td><td>135</td><td>326</td><td>564</td><td>687</td><td>693</td><td>698</td></tr>
<tr><td>Leading the Way</td><td>121</td><td>318</td><td>619</td><td>759</td><td>765</td><td>769</td></tr>
</table>

Overview of technology projections in the licence area:

- At present, the installation of public EV chargers per EV in the North of Scotland licence area is significantly above the GB average. The density of chargers is less if compared to the geographical size of the region. This reflects Chargeplace Scotland's active participation in the Scottish EV charger market and broader support from Scottish Government. This trend is expected to continue in the near term until demand for charging increases.
- There is significant uncertainty regarding the shape and size of a future EV charger network; in particular the split between off-street home charging versus public charging, as well as the market share between ultra-fast charging hubs versus lower voltage on-street, neighbourhood and municipal charging. The DFES projections, therefore, aim to represent the envelope of the possible spread and rate of deployment of EV chargers in the licence area.
- Although it is not within the scope of the DFES study, the utilisation profile of chargers is also likely to change over time.
- 2021 has seen a number of important new EV charging market and policy developments across the UK. These have been considered for the DFES analysis in the licence area:
    - The Scottish Government consulted on the installation of EV charge points in

residential and non-residential buildings, both new and existing[lxix].
  - Ofgem has announced which projects proposed by DNOs have received funding from the £300 million green recovery scheme, designed to support network capacity investment for 'shovel-ready' net zero projects (such as EV charging hubs and solar farms)[lxx]. Around 40% of the investment proposals support increasing network capacity at Motorway Service Areas (MSAs), working alongside OZEV's Project RAPID to allow an estimated 1,800 ultra-rapid charge points to be installed (c.948 are installed at present).
  - This year has seen the rise of the EV forecourt, dedicated rapid and ultra-rapid EV charger-only forecourts and an expanded rollout of EV chargers at existing petrol stations.
- Compared to the DFES 2020 report and FES 2021, the uptake rate of EV chargers is higher and the scenario envelope of charger capacity in 2050 has narrowed.
- Hot spots for public charger deployment include urban areas, particularly Perth, Aberdeen and Dundee, as well as some of the Scottish Islands and tourist destinations.
  - Aberdeen and Dundee's Clean Air Zones are due to be implemented in early 2022, which may drive the uptake of EVs in these locations, increasing demand for EV chargers.
- By 2050, total EV charger capacity is highest under **Leading the Way**, with c.769 MW of non-domestic charger capacity and c.382,000 domestic EV chargers operating.

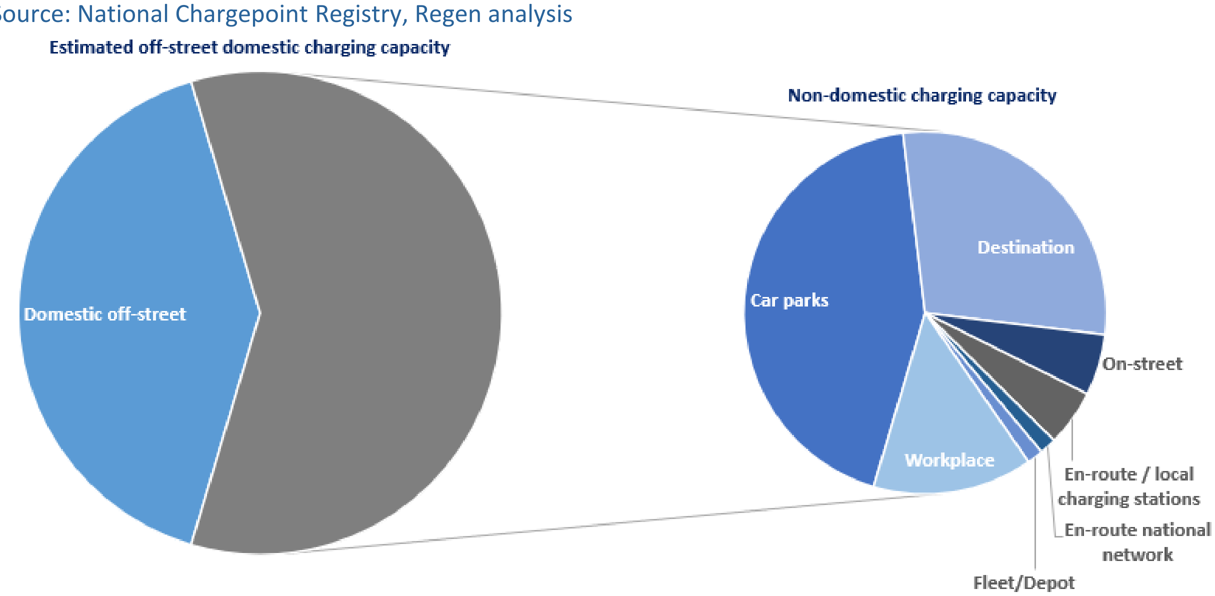
Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- There are a total of 1,016 public EV chargers in the North of Scotland licence area, totalling an estimated 35 MW of public charger capacity[lxxi]. This is above the GB average for the number of vehicles in the area, predominantly due to Chargeplace Scotland's high installation rate.
- This represents a 19% increase in EV charger capacity since DFES 2020. This is a significant increase but is still less than the growth of EVs, which has increased by 40% over the same analysis period. It is estimated that there are approximately 3,400 domestic EV chargers in the North of Scotland licence area.

Figure 60: North of Scotland licence area 2020 charger capacity

Source: National Chargepoint Registry, Regen analysis



Near term (2021 – 2025)

- In all scenarios, the uptake of EV chargers is expected to increase rapidly in the near term supported by ongoing investment by the public sector and Chargeplace Scotland. However, as the rate of EV uptake increases, more private charging operators are expected to enter the market.
- In **Consumer Transformation,** more localised charger points, including residential on-street chargers, are projected. **System Transformation** delivers lower charger capacity, in the short term, and is weighted more towards larger commercial charging sites.
- Network access and charging reforms[lxxii] may encourage rapid deployment of chargers from 2023 onwards.
- Early uptake of electric cars and LGVs by people with off-street parking is expected. It is projected that by 2025, there could be between 15,000 domestic off-street chargers in **Steady Progression** and 54,000 in **Consumer Transformation**.
- In addition, it is projected that by 2025, there could be between 70 MW of non-domestic off-street chargers in **Steady Progression** and 135 MW in **Consumer Transformation**.

Medium term (2025 – 2035)

- EV charger installation rates are expected to accelerate between 2025 and 2035 across all scenarios.
- Public charging, including on-street charging in residential areas and rapid charging hubs, is expected to increase substantially as EV usage increases, range increases and more households without access to off-street parking begin to adopt EVs.
- By 2035, **Leading the Way** has the highest EV charger capacity, with around 394,000 domestic EV chargers and 610 MW of non-domestic capacity.
- **Steady Progression** has the lowest estimated EV charger capacity in 2035, with c.137,000 domestic EV chargers and 219 MW of non-domestic capacity.
- The rate of EV car uptake begins to slow in the mid-2030s as EV car adoption approaches saturation. Therefore, the installation rate of EV chargers equivalently slows.
- As the market matures, it is likely that the growth in the number of EV charger locations may flatten and even fall, although the capacity and utilisation of existing charge stations are likely to increase.

Long term (2035 – 2050)

- In some of the FES 2021 scenarios, notably **Leading the Way**, the uptake of electric cars slows and then reduces significantly as consumers adopt new transport methods including public transport, shared vehicles and Autonomous Vehicles (AVs). However, while the number of EV cars may reduce, utilisation and milage per AV increase significantly. Therefore, the reduction in overall energy demand is less significant.
- The uptake of EVs and EV chargers continues to increase in **Steady Progression** up until 2050 when there are over 420,000 domestic EV chargers in operation.
- In **Leading the Way** and **Consumer Transformation**, the total capacity of EV chargers is static from the late 2030s.
- The amount of EV charging capacity across the scenarios converges in the long term, as the total amount of energy EVs require aligns. However, the scenarios maintain variation in the amount of centralised and decentralised charging capacity.

Figure 62: Summarising scenario projection graph for non-domestic EV chargers for the North of Scotland licence area

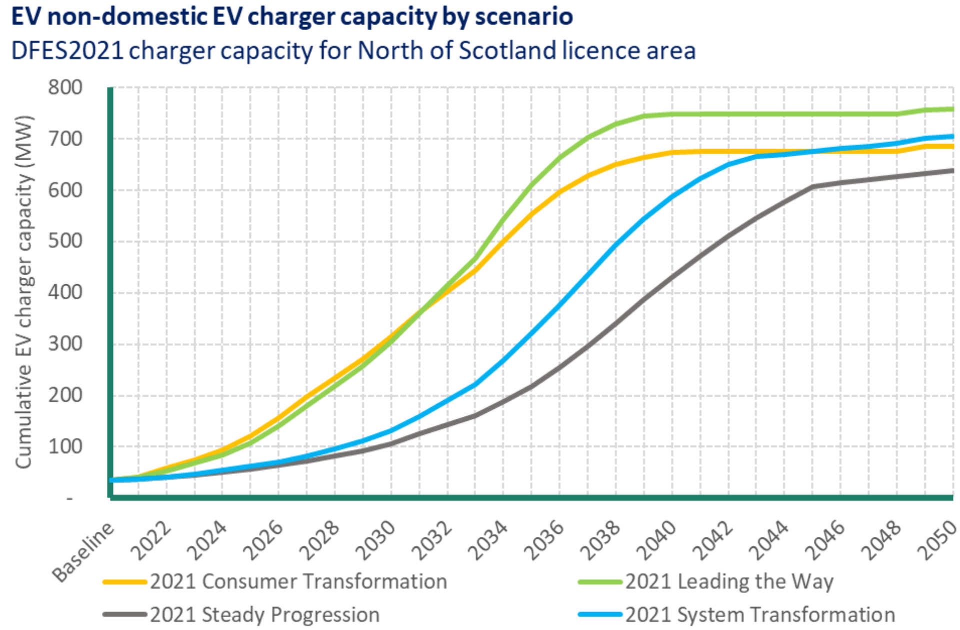


Figure 61: Summarising projection graph for public EV charger archetypes for the North of Scotland licence area, by scenario

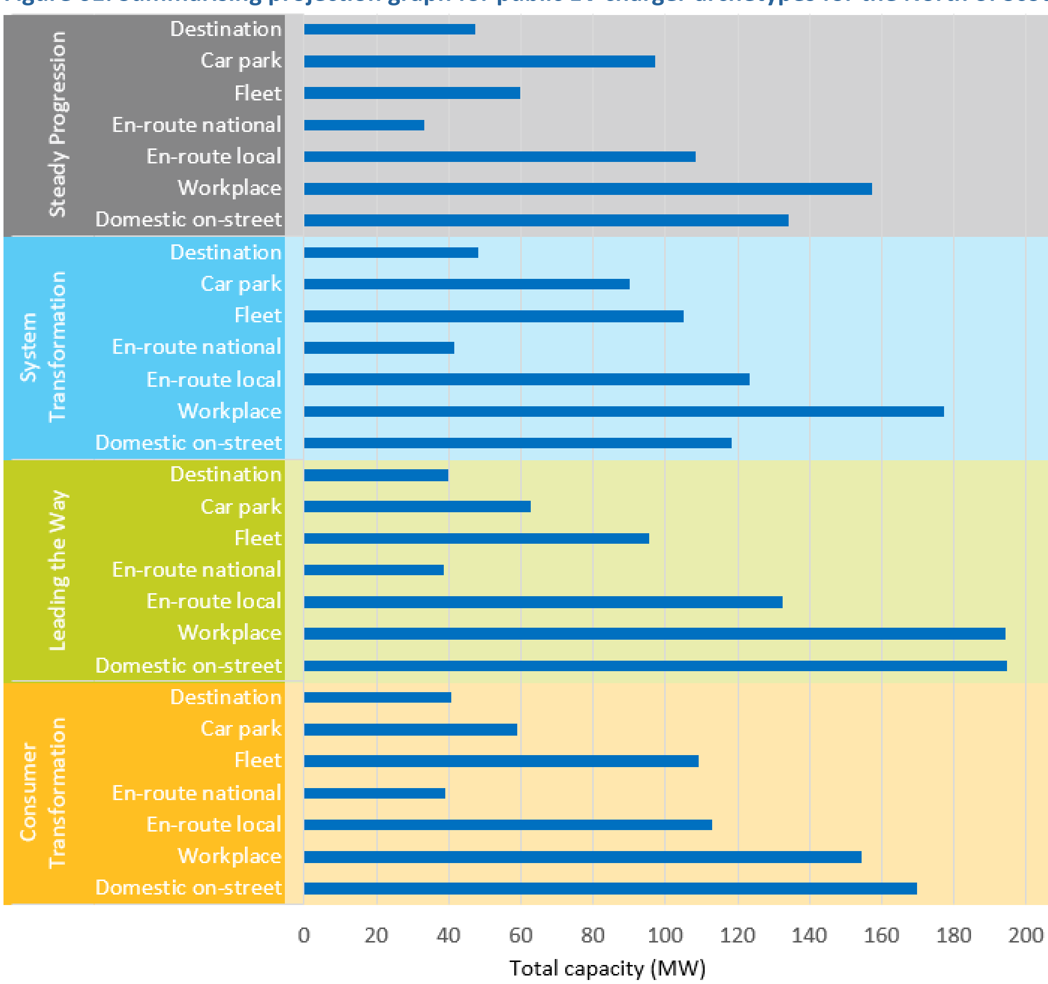
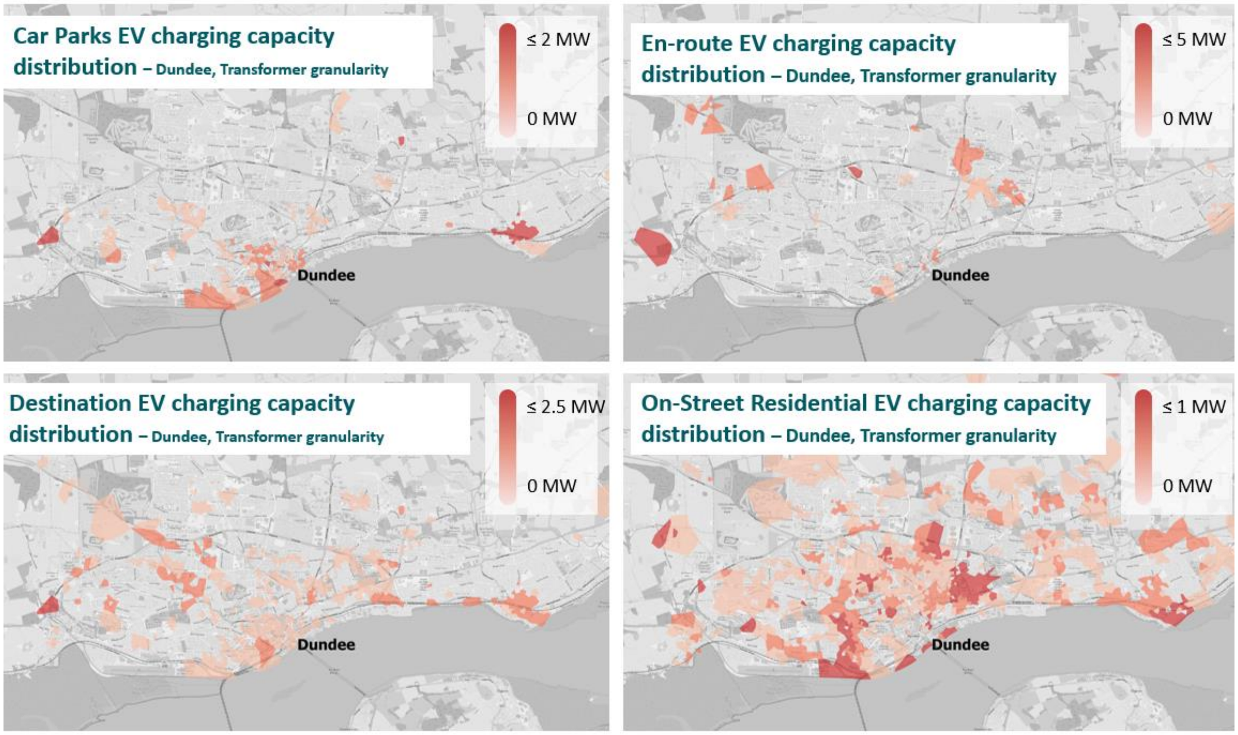


Figure 63: Map of illustrative Dundee EV charger capacity distribution results in 2050, under Consumer Transformation



Reconciliation with National Grid FES 2020:

- The FES 2021 data does not provide sufficient regional or GSP level information to reconcile DFES EV charger projections with.
- Factors that will affect EV charging infrastructure which are available in the FES 2021 assumptions and data workbooks are used where it is possible to do so, including:
  - Projections of vehicle numbers
  - Projections of EV average annual mileage trends
  - Projections of EV and EV charger efficiencies.
- Although there have been a number of trial projects, and new data is becoming available, there is still a lack of evidence of future consumer charging behaviour, charger utilisation rates and vehicle ownership trends. This results in uncertainty in the assumptions that must be made for the projection of future EV charging requirements.
- Assumptions that have been made include:
  - What proportion of annual EV energy requirements will be delivered at different locations (including for which EV charger archetypes)
  - EV charger utilisation rates at different locations.
- These assumptions have been made using industry input and Regen analysis. As more behavioural data and other evidence become available, these assumptions will be further refined for future DFES analysis.
- Some assumptions have been made around the behaviour of AV cars, including:
  - The proportion of AVs that are private or shared in absence of further information.
  - AV charging behaviour is similar to EV cars, the key difference being an increase in fleet/depot charging.
  - AVs are associated to on and off-street houses and charge at the same rate as EV cars.
- The uptake and distribution of chargers associated with AVs is an area that needs to be considered and developed for future DFES analysis.

Reconciliation with DFES 2020:

- FES 2021 has updated its assumed EV efficiencies (miles driven per kWh consumed) compared to FES 2020. These differences are outlined in the table below, alongside the equivalent DFES 2020 and 2021 assumptions.

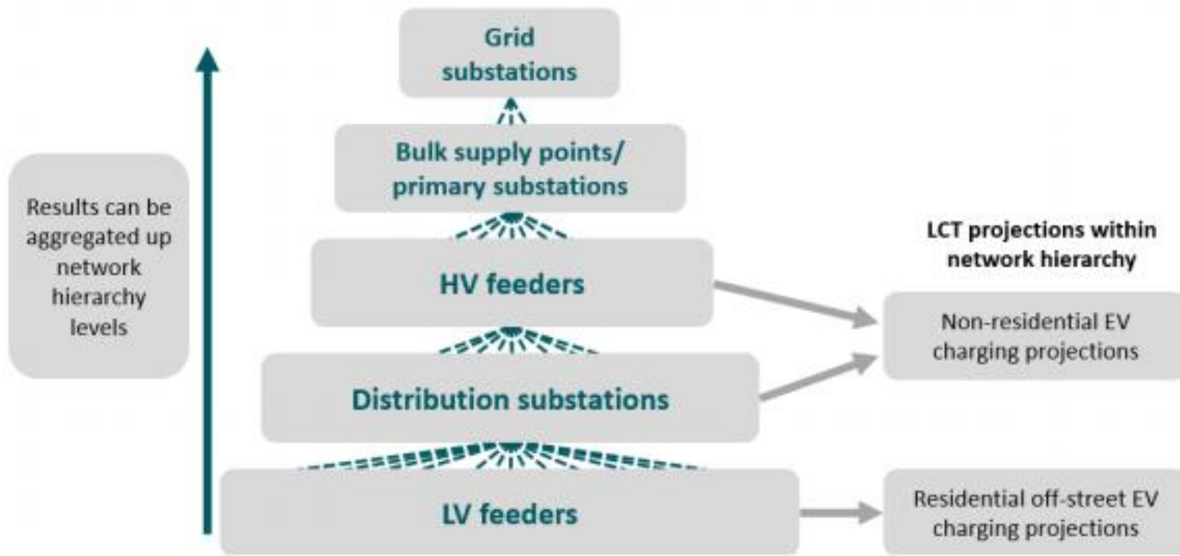
Year	FES EV car efficiency (miles/kwh)		DFES EV car efficiency (miles/kwh)	
	2020	2021	2020	2021
2020	4.1	3.1	3.1	3.1
2050	5.1	3.9	5.1	3.9

- In summary:
  - The FES 2021 EV car energy to mileage efficiency assumptions have reduced significantly
  - In the short term, this has brought the FES and DFES into alignment and has not, therefore, had an impact on the overall energy demand
  - In the long term, both the FES and DFES efficiency assumptions have been reduced, increasing the energy required per vehicle mile.
- Impact on charger capacity:
  - In the short term, the impact has been minimal
  - Over the long term, a reduction in vehicle efficiency has led to increased energy demand and, other things being equal, an increase in the EV charger capacity (number and power capacity) required to meet that demand
  - Capacity charger increases, caused by a reduction in EV efficiency assumptions, is mitigated to some extent by an assumption that charger utilisation will also increase.
- The uncertainty regarding EV energy efficiency is one example of a factor that could significantly change the requirements for EV chargers in the future.
- The FES 2021 EV energy to mileage efficiency assumptions for HGVs, LGVs, motorcycles and buses have also changed, though these changes have less impact on total EV charger capacity than cars.

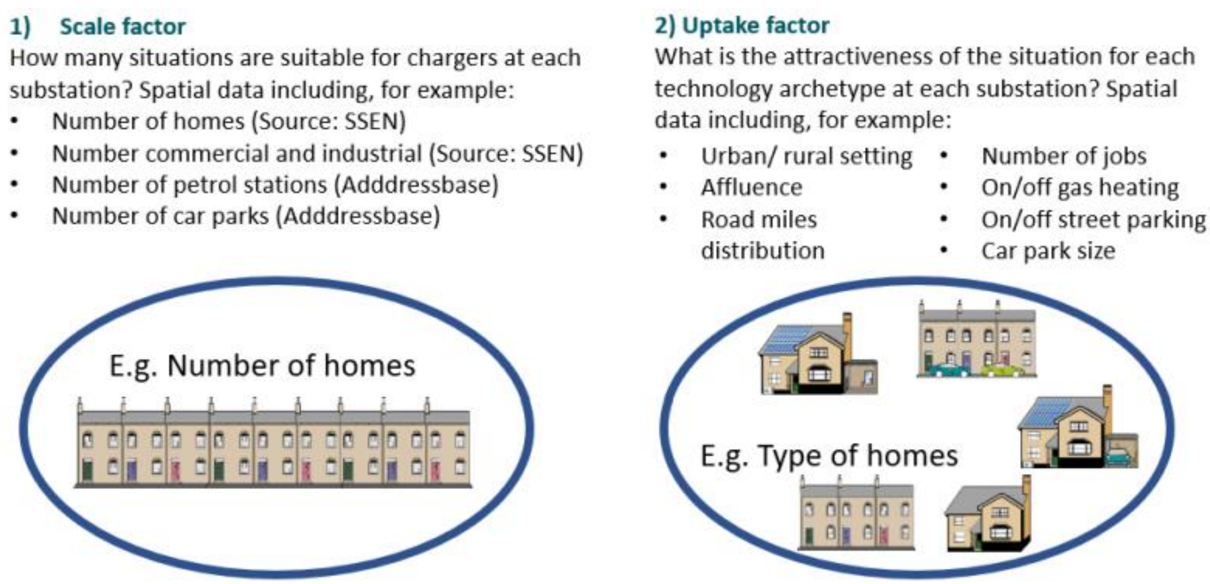
Factors that will affect deployment at a local level:

- The uptake of EV chargers was evaluated to a much higher granularity than ESAs. The uptake of domestic and on-street residential EV chargers was evaluated to SSEN's 400,000 individual feeders, equivalent to street-level forecasts, while non-domestic and public chargers were evaluated to SSEN's 100,000 distribution substations. Where feeders and distribution substations sit in SSEN's network hierarchy is illustrated in the graphic below.
- A wide variety of datasets were used to analyse specific regional and feeder specific demographic and technical attributes, geographical characteristics and local resources. For example, in order to evaluate the number of commercial and industrial sites connected to a feeder, SSEN connectivity data was used to identify individual sites which were then classified by type of commercial and industrial activity using Ordnance Survey Addressbase data. While not perfect, owing to data limitations, this allowed a much more granular assessment of commercial and industrial activity connected to the network.

Simplified electricity network hierachy



Assigning data to individual substations and technology archetypes



- The uptake of home EV chargers is distributed in the near term towards more urban, sub-urban and affluent areas and those where there are high levels of off-street parking.
- The spatial distribution of non-domestic chargers was produced differently for each archetype.
  - En-route local and national charging locations were distributed based on the density of local housing, the volume of local traffic, the distribution of existing petrol stations and the road classification on where the site is located
  - Car parks, workplace and fleet depot locations were identified from Ordnance Survey data
  - The on street residential analysis was undertaken in parallel with the off-street parking analysis to identify vehicles associated with on-street parking.

- The distribution analysis uses affluence as one of the key factors driving the uptake of EV chargers in the near term. For the more ambitious scenarios, from mid- to late-2020s, the underlying assumption is that EV cars will become ubiquitous. Therefore, the growth in demand for EV cars in both on- and off-street areas and lower and higher affluence areas begins to increase at equivalent rates.
- In order to evaluate the distribution of chargers to a feeder level, the above factors were interpolated down to individual feeders from the highest granularity of publicly accessible datasets that are available. In addition, Ordnance Survey Addressbase data has been used to identify the locations at which EV chargers could be located.

Scottish Government policy context

- It is estimated that 85% of all public EV chargers are operated by Chargeplace Scotland, a national network of EV chargers that is funded by the Scottish Government. This has resulted in a baseline with more chargers in public locations such as car parks, public estates, and local charging infrastructure relative to other licence areas. The proportion of chargers that are estimated to be operated by Chargeplace Scotland has reduced slightly on last year, potentially indicating an increasing number of private EV chargers in the area.
- Chargeplace Scotland's dominant market position and strategy of chargers in predominantly public and centralised locations is expected to continue in the short term. However, as demand for EV charging increases it is expected that charging infrastructure will become increasingly distributed, particularly as the number of privately operated chargers increases.
- The Scottish Government consulted on the installation of electric vehicle charge points in residential and non-residential buildings, both new and existing[lxix]. Therefore, the modelling assumes a high uptake of EV chargers associated with new buildings and in the car parks of residential and non-residential buildings.

Relevant assumptions from National Grid FES 2021:

Assumption number	4.2.13 - Level of home charging and other stated assumptions
Steady Progression	Charging at home is limited by a lack of viable solutions for those without off-street parking.
System Transformation	Emphasis on public rollout of fast chargers to allow rapid charging. More rapid and fast public charging is demanded from consumers.
Consumer Transformation	Charging predominately happens at home. Emphasis on home chargers, taking advantage of consumer engagement levels in flexibility. Leads to some disruption (e.g. reinforcing local networks).
Leading the Way	Charging happens similarly to how it happens today, with various types receiving investment to support an accelerated uptake of electric vehicles. Accelerated rollout of charging infrastructure at home and in public places. BEV cars smart charge at home or at the office, frequently pairing with on-site PV and batteries to encourage self-consumption.

Stakeholder feedback overview:

At the North of Scotland stakeholder engagement event, stakeholders gave their views on the future of EV charging infrastructure in SSEN's North of Scotland licence area.

There was a split view as to whether local charging for households without off-street/home charging would, in the future, be provided by:

a) widely distributed on-street charging, directly outside people's homes, or in residential parking areas, and very likely connected to the nearest low voltage distribution feeder/substation

Or

b) larger charging hubs, with more rapid chargers, located in public (or private) spaces such as car parks, school car parks, industrial estates, leisure centres etc. These could connect to primary distribution feeders or even HV networks.

The consensus in the workshop was that both types of charger infrastructure will likely be needed depending on local factors; however, in the near term the priority of Chargeplace Scotland has been towards local charging hubs in public areas, with proportionally less on-street residential chargers (compared to what is currently happening in England).

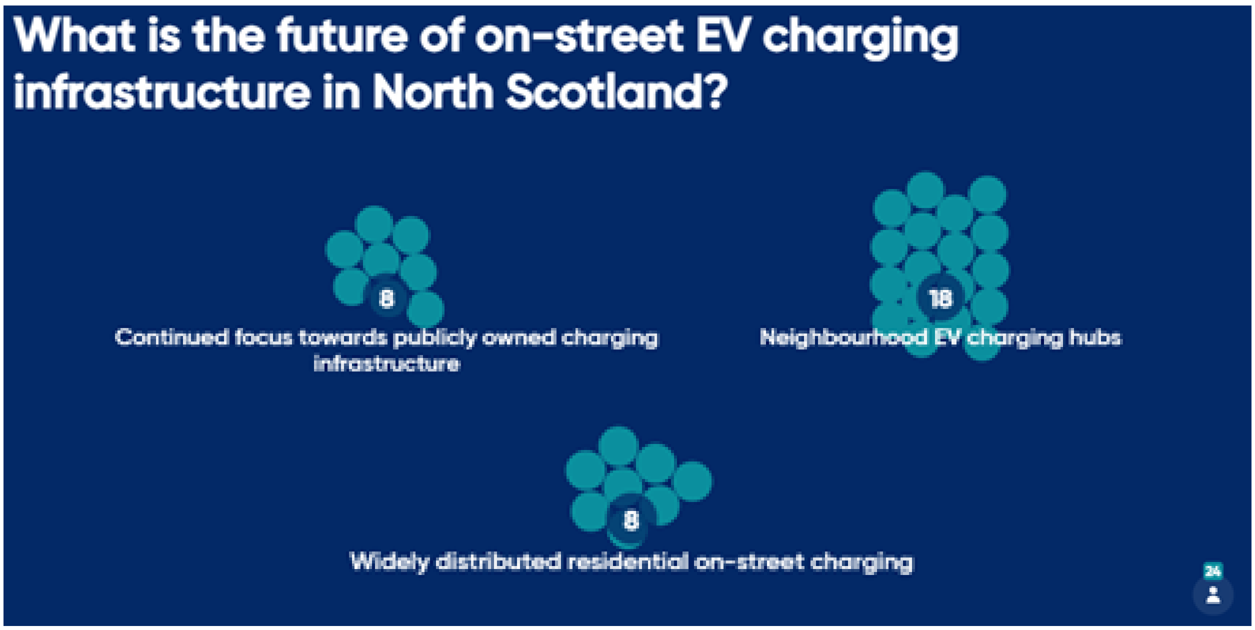
There was also a discussion about whether the rollout of charging in Scotland will continue to be led by public investment, through programmes like Chargeplace Scotland, or by private charger networks as seen elsewhere in the UK. The consensus was that, although there will be a shift to privately operated chargers in the future, especially in urban areas and along main transport routes, the Scottish model would continue to be led by publicly funded investment. This is partly to ensure that Scotland has an appropriate level of charger coverage, especially in rural and remote areas which may not be supported if left to private network operators.

This input has contributed to the future charging scenario assumptions in this study including the definition of the **Consumer Transformation** scenario, which features more localised and residential on-street charging, and **System Transformation** which has fewer, larger and faster chargers which are located at road networks and other hub locations.

EV chargers	
Stakeholder feedback provided	How this has influenced our analysis
Scottish Government and other stakeholders highlighted the impact of potential upcoming distribution network charging changes.	Regen modelled a moderate pause and then acceleration in the uptake of EV charger capacity before and after April 2023. As the changes to network charges are presently only a minded-to decision, this impact is only modelled in **Leading the Way**.
Scottish Government highlighted that public procurement is ambitious in Scotland and above the national average.	We have ensured that the modelling keeps pace with the uptake of electric buses and fleet vehicles.
Engagement with the Scottish island stakeholders identified that a notable energy demand associated with the islands is shipping. Shipping is currently excluded from the DFES analysis but could contribute	The inclusion of future electricity demand from shipping will be reviewed for future iterations of the SSEN DFES analysis.

significantly to local energy vector shifts.	
For the uptake of EV chargers, feedback was received by the Scottish Islands and other stakeholders which confirmed initial assumptions in the modelling such as the types of suitable charging locations and the focus on public vs private charging infrastructure.	This feedback has been directly reflected in the scenario projections for the Scottish Island supply areas.

Figure 64: Stakeholder responses to EV charger question in the online engagement webinar



References:

SSEN connection data, National Chargepoint Registry, Department for Transport data, Regen consultation with local stakeholders, Census 2011 data.

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lxix Scottish Government, *Building regulations - energy standards and associated topics - proposed changes: consultation*, July 2021: https://www.gov.scot/publications/scottish-building-regulations-proposed-changes-energy-standards-associated-topics/pages/7/

lxx Ofgem, *Decision on the RIIO-ED1 Green Recover Scheme*, May 2021: https://www.ofgem.gov.uk/publications/decision-riio-ed1-green-recovery-scheme

lxxi The charger baseline is derived by analysing National Chargepoint Registry and SSEN connections data.

lxxii https://www.ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/network-charging-and-access-reform

Heat pumps and resistive electric heating

Summary of modelling assumptions and results

Technology specification:

The analysis covers all variants of electrically fuelled heating technologies within the scope of the SSEN DFES 2021. This includes electric heat pump systems providing space heating and hot water to domestic and non-domestic buildings, and direct electric heating systems using electricity to provide primary space heat and hot water to domestic buildings, typically via a night storage or direct radiant electric heater.

This technology is divided into five sub-categories:

- Domestic non-hybrid heat pumps – **technology building block Lct_BB005**
- Domestic hybrid heat pumps – **technology building block Lct_BB006**
- Non-domestic non-hybrid heat pumps – **technology building block Lct_BB007**
- Non-domestic hybrid heat pumps – **technology building block Lct_BB008**
- Domestic resistive electric heating – **No corresponding network building block ID**.

Data summary for domestic heat pumps in the North of Scotland licence area:

Number of homes (thousands)		Baseline	2025	2030	2035	2040	2045	2050
Non-hybrid heat pumps	Steady Progression	22	33	78	144	218	257	286
	System Transformation		37	62	100	151	200	222
	Consumer Transformation		46	248	392	530	607	642
	Leading the Way		84	287	407	474	510	530
Hybrid heat pumps	Steady Progression	0	0	3	8	14	14	14
	System Transformation		1	2	12	47	85	121
	Consumer Transformation		1	4	15	29	39	46
	Leading the Way		1	11	25	47	60	68

Data summary for non-domestic heat pumps in the North of Scotland licence area:

Number of non-domestic properties (thousands)		Baseline	2025	2030	2035	2040	2045	2050
Non-hybrid heat pumps	Steady Progression	3	4	7	9	11	12	13
	System Transformation		6	12	17	20	22	23
	Consumer Transformation		7	21	26	28	29	30
	Leading the Way		6	16	22	24	26	26
Hybrid heat pumps	Steady Progression	0	0	0	0	0	1	1
	System Transformation		0	1	2	4	6	6
	Consumer Transformation		0	0	1	2	2	2
	Leading the Way		0	1	2	2	3	4

Data summary for domestic resistive electric heating in the North of Scotland licence area:

Number of homes (thousands)		Baseline	2025	2030	2035	2040	2045	2050
Resistive electric heating	Steady Progression	138	129	108	91	76	60	52
	System Transformation		133	112	93	61	28	16
	Consumer Transformation		135	107	88	64	37	29
	Leading the Way		116	96	70	57	57	61

Overview of technology projections in the licence area:

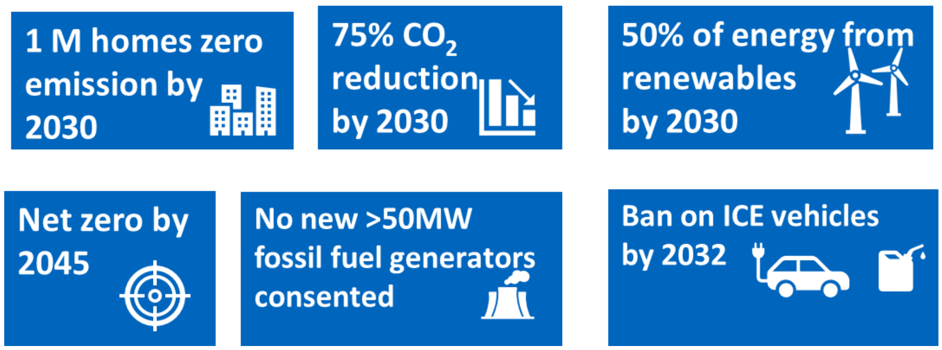
- The majority of homes in the North of Scotland licence area use fossil fuel heating systems. These will require conversion to a low carbon form of heating in the next 25 years, if the UK and Scotland are to meet their carbon reduction targets.
- Several announcements, research papers and strategies were published in towards the end of 2021, setting out how the UK plans to reduce carbon emissions over the coming decades.
- Consultations regarding the development of specific policy measures discussed in these strategies are underway, but the strategies themselves provide many of the principles for future decarbonisation, including context for future heat decarbonisation:

- The UK's Net Zero Strategy was published, bringing together all national decarbonisation policy, moving towards identifying and understanding the dependencies between departments and sectors.[lxxiii]
    - The UK's Heat and Buildings Strategy was published, setting out how the UK will look to decarbonise residential, commercial, industrial and public sector buildings.[lxxiv]
    - Consultations on heat network zoning, transparency of carbon content in energy products, phasing out the installation of fossil fuel heating in homes not connected to the gas grid, and the development of a market based mechanism for low carbon heat are underway or awaiting results.
- The findings of these consultations, and subsequent policy measures, will be revealed in the coming months. The envelope of scenarios in the DFES reflects the range of potential upcoming policy measures. As more specific policies, ambitions and actions are unveiled, future DFES studies are likely to see a narrower range of scenario pathways for the decarbonisation of heat.
- Penetration of the gas grid throughout Scotland is however highly variable. Nearly 30% of Scottish homes are off gas grid as an average, but this rises to more than 90% in some of the regions especially in the highlands and islands. Electricity (night storage heaters and direct resistive heating) is the most common form of off-gas heating.
- SSEN DFES 21 broadly follows the scenario framework and assumptions that have been made for the national FES 2021, but has been tailored for a Scottish context. The **Consumer Transformation** scenario has been specifically aligned with the Scottish Government's net zero commitments and plans for heat decarbonisation.
- In line with potential options for decarbonising heat at a national level, there is a dramatic shift to low carbon heating in the licence area in all three of the net zero scenarios. Under **Consumer Transformation** and **Leading the Way**, this results in heat pumps becoming the predominant domestic heating technology in Scotland by 2050.
- Under **System Transformation**, the decarbonisation of heat on a UK level is driven by hydrogen, either through standalone boilers or hybrid heat pumps. However, since a higher than average proportion of homes in the licence area are off-gas homes, there is a higher uptake of non-hybrid heat pumps, as availability of hydrogen from domestic heating is assumed to be in-line with the current availability of fossil gas heating.
- Resistive electric heating, both direct electric and night storage heating, reduces in all scenarios. Despite being a zero emissions heating technology, the high running costs of resistive electric heating means that it is replaced by heat pumps or district heating in many cases.
- Non-domestic properties see a similar uptake of low carbon heating technologies, with heat pumps and hydrogen heating becoming common heating technologies alongside resistive electric heating.

Implementation of Scottish Government Policies in the DFES 2021 analysis

The **Consumer Transformation** and **Leading the Way** scenarios have been aligned with the Scottish Government's net zero commitments and plans for heat decarbonisation.

The Scottish Government has set a number of ambitious targets that are intended to drive its policies and interventions to achieve net zero. This includes a number of targets and policy commitments which are set out in the **Scottish Government's Heat in Buildings Strategy**[lxxv] including a target that over one million homes will be converted to zero emissions heating systems by 2030.



Policies outlined in the **Hydrogen Policy Statement**[lxxvi] may also have implications for heat decarbonisation in the longer term. At a local level, heat decarbonisation is being led by Scottish local authorities, and is expected to be supported by the rollout of Local Heat and Energy Efficiency Strategies[lxxvii] (LHEES).

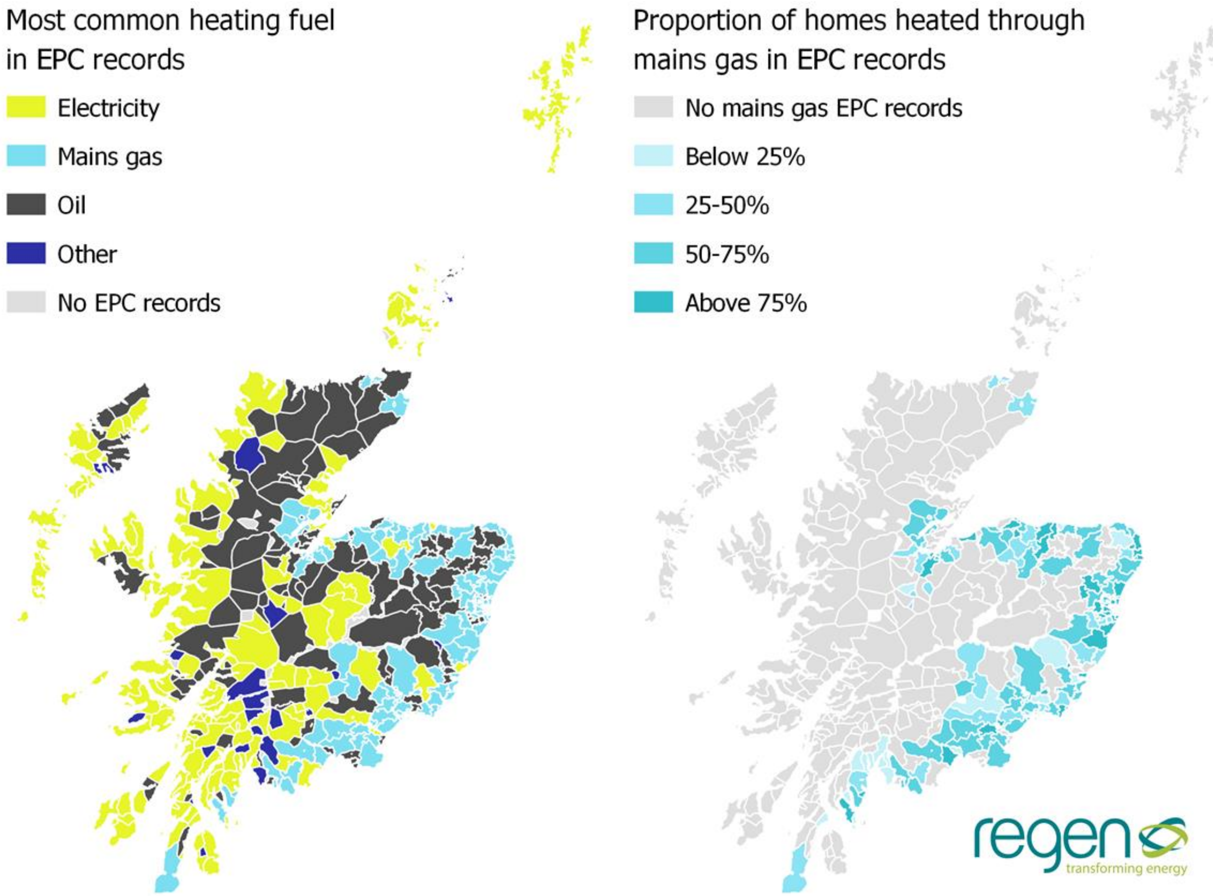
Zero emissions heating in Scotland will be delivered by a combination of low carbon technologies; the most cost-effective pathway will require a considered and strategic response using more than one technology solution. The key low carbon heating solution available today and to meet the 2030 targets is heat pumps. However, this solution could come at a high capital cost to individual consumers, unless the rollout is bolstered through government support.

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- The North of Scotland licence area has an estimated 21,800 homes heated by a non-hybrid heat pump, of which 85% are air source and the remaining 15% are ground source. There are no domestic hybrid heat pumps in the baseline.
- The heat pump baseline represents 3.1% of homes, dramatically above the GB average of 0.6%. This is expected, due to the much higher proportion of off-gas homes in the licence area and subsequent prevalence of electrically heated homes.
- An estimated 2,700 non-domestic properties are heated by a non-hybrid heat pump. As with domestic properties, there are no hybrid heat pumps in the baseline.
- The baseline is composed of RHI data augmented with EPC data, aiming to capture heat pump installations that were not accredited for the RHI scheme. There may be a small number of homes with heat pumps that are not captured by EPC or RHI data.
- 138,000 homes in the licence area are heated primarily by resistive electric heating, based on analysis of EPC and Census 2011 data.
- 26% of homes in the licence area are heated via electricity, compared to the GB average of 11%. This is mainly due to the high proportion of off-gas homes across the licence area, and the cost of non-electric off-gas fuels such as oil and LPG in the more remote areas of the licence area, such as the Highlands and Islands.

Figure 65: Current primary heating fuels for homes in the North of Scotland licence area, showing the higher levels of mains gas connection along the east of the licence area following major population centres, comapred to high levels of oil and electric heating in rural and island communities.



Near term (2021 – 2025)

- Heat pump uptake increases in all scenarios in the near term, but remains low in all scenarios except **Leading the Way**. Uptake of heat pumps is supported by the domestic RHI and its upcoming successor, the Boiler Upgrade Scheme.
- Under **Leading the Way**, very high levels of consumer engagement and green ambition results in high levels of heat pump deployment in the near term.
- The Scottish government's Heat in Buildings Strategy includes the New Build Zero Emissions from Heat Standard[lxxviii], which requires all new buildings to have zero direct emissions heating systems from 2024. There are also proposals for a £1.8 billion Heat in Building Fund. These policies are assumed to be implemented under **Consumer Transformation** and **Leading the Way**, resulting in a significant increase in heat pump deployment in both new and existing build homes.

Medium term (2025 – 2035)

- 2025 sees a step change in heat pump uptake in all scenarios, most notably under **Consumer Transformation** and **Leading the Way**. This reflects Scottish government ambitions to achieve at least 124,000 zero emissions heating system installations between 2021 and 2026, over 200,000 installations per annum by the late-2020s, and over one million homes converted to zero emissions heating by 2030.
- This coincides with a wider GB government ambition to increase heat pump adoption to 600,000 heat pumps per year by 2028, however, uptake in Scotland is above and beyond the GB average due to greater Scottish government ambition.
- Heat pump uptake under **System Transformation** and **Steady Progression** also increase, however Scottish and UK government targets are not met in these scenarios.
- Hybrid heat pump uptake is limited in the 2020s and early 2030s, due to not meeting the criteria for zero emissions heating. By 2035, hybrids make up less than 7% of all heat pumps installations in every scenario except **System Transformation**, under which 11% of heat pumps are hybrid.
- As a common factor in fuel poverty due to high costs, resistive electric heating reduces in all four scenarios in favour of heat pumps, heat networks, gas network expansion and other more affordable heating systems. However, some installations occur in energy efficient new build properties, especially smaller homes such as flats.

Long term (2035 – 2050)

- Under the **Consumer Transformation** and **Leading the Way** scenarios, the high levels of heat pump uptake seen in the 2030s continues to 2045, as Scotland achieves its 2045 Net Zero goal. By 2050, over 80% of homes are electrically under these scenarios, with the remainder heated via low carbon district heat (which may be driven by a heat pump), biofuels or hydrogen. Similarly, the vast majority of non-domestic properties are electrically heated in these scenarios.
- Under **System Transformation**, heat pump uptake slows and is replaced by the emergence of hydrogen boilers for domestic heating, which becomes the heating technology for majority of homes that are currently on-gas. However, the high cost of hydrogen also encourages the uptake of hybrid heat pumps with hydrogen boiler back-ups.
- Under **Steady Progression**, heat pump uptake remains low as Scotland and GB fail to meet their decarbonisation targets. 40% of North of Scotland homes are heated by a heat pump or resistive electric heating by 2050, higher than the GB average, due to increased Scottish government ambitions and the higher proportion of off-gas homes in the licence area.
- Resistive electric heating remains an option for a minority of homes, but continues to decline under **Consumer Transformation**, **System Transformation** and **Steady Progression** as less costly forms of heating continue to be adopted.
- Under **Leading the Way**, high levels of societal engagement, energy efficiency and technological advances in smart, phase-change storage heating results in next-generation storage heating becoming a more affordable form of domestic heating in the longer term, and a source of demand-side response flexibility through smart heaters and Time Of Use Tariffs. As a result, this scenario sees an uptick in resistive electric heating in the latter years of the scenario timeframe, replacing many of the remaining fossil fuelled heating systems present in the licence area.

Figure 66: Domestic heat pumps (non-hybrid and hybrid) in the North of Scotland licence area, compared to National Grid FES 2021 regional projections

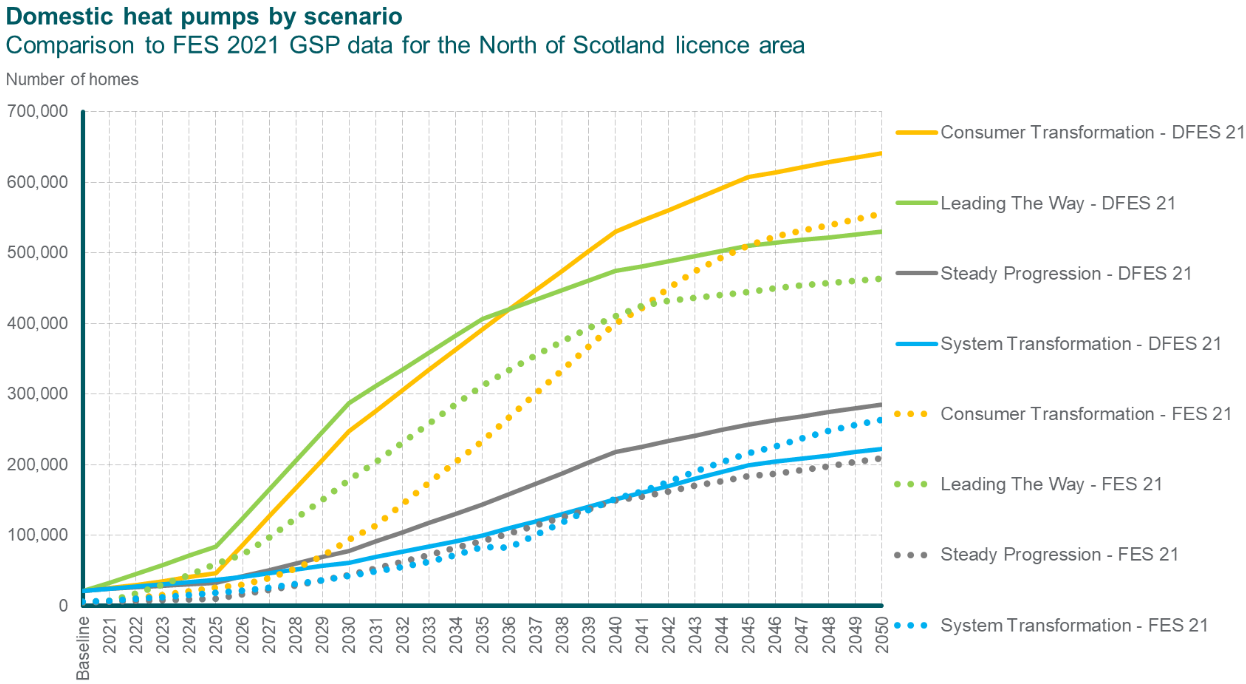


Figure 67: Non-domestic heat pumps (non-hybrid and hybrid) in the North of Scotland licence area, compared to National Grid FES 2021 regional projections

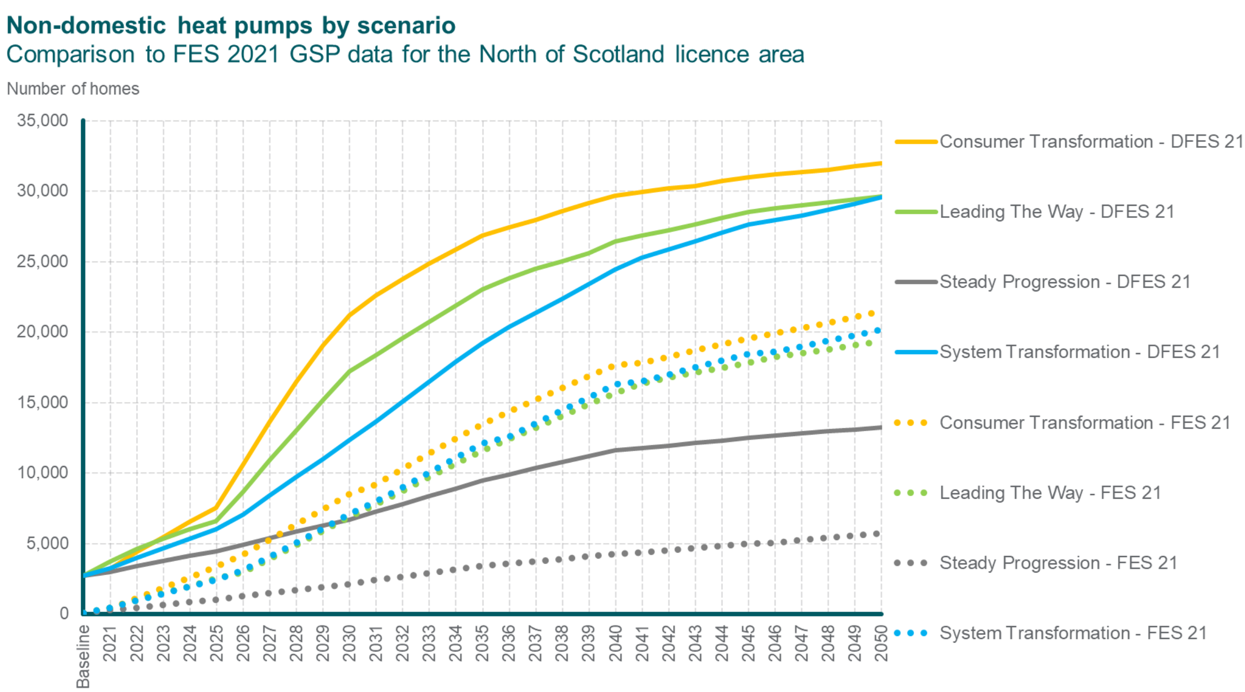
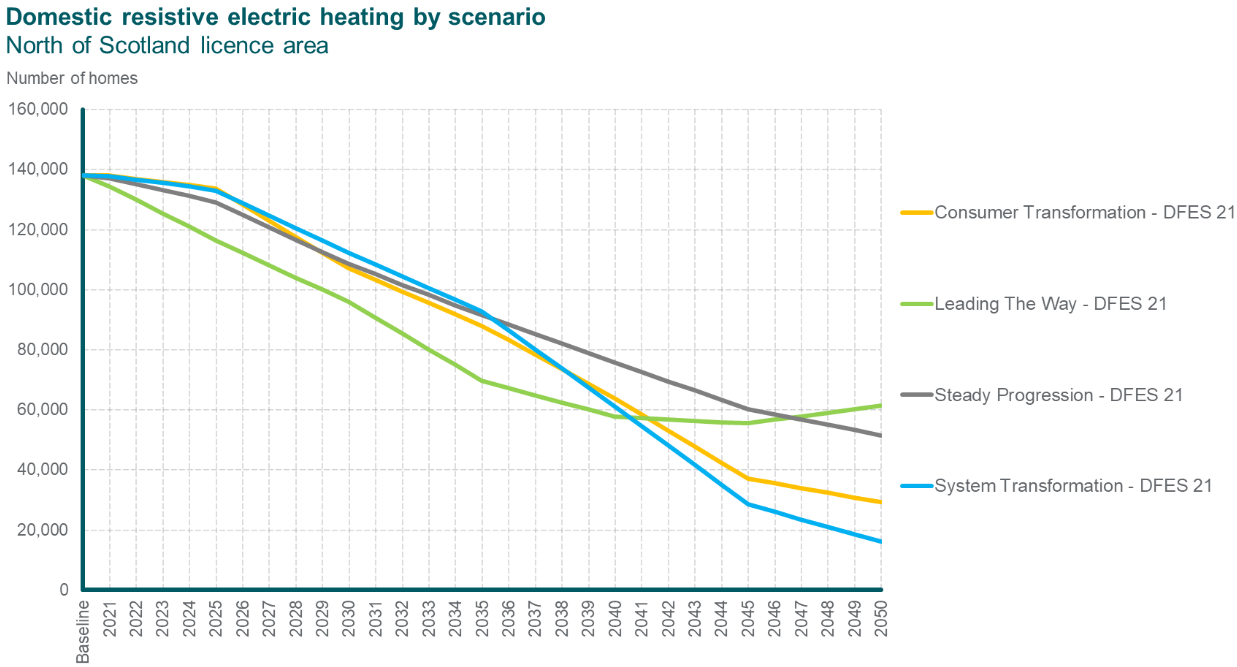


Figure 68: Domestic resistive electric heating in the North of Scotland licence area



Reconciliation with National Grid FES 2021:

The SSEN DFES 2021 analysis has been reconciled to the FES 2021 data for the relevant GSPs within the North of Scotland licence area.

The Building Block data provided in the FES 2021 classifies an 'ASHP with a resistive heating element' as a hybrid heat pump (Lct_BB006), whereas the DFES analysis considers this is to be a variation of a non-hybrid heat pump (Lct_BB005). Accordingly, the reconciliation has been undertaken using combined figures for both non-hybrid and hybrid heat pumps, as this specific form of heat pump cannot be accurately disaggregated from the FES data at a GSP level.

- In the near and medium term, domestic heat pump uptake in the North of Scotland licence area is substantially above the FES 2021 regional projections, particularly under **Consumer Transformation** and **Leading the Way**. This is due to these scenarios aligning with Scottish government ambitions for zero carbon heating system deployment, which are significantly above the UK's ambitions.
- In the longer term, the North of Scotland projections for total domestic heat pumps are broadly aligned with the FES 2021 regional projections. However, due to the high proportion of off-gas homes in the licence area, a greater proportion of homes are projected to be non-hybrid heat pumps rather than hybrid heat pumps, compared to the FES 2021 results. This is particularly noticeable in the **System Transformation** and **Steady Progression** scenarios.
- Non-domestic heat pump uptake is significantly higher in the DFES outputs compared to FES 2021 in all scenarios. This is assumed to be due to differences in the total number of heated non-domestic buildings considered in each analysis. The DFES building stock is modelled based on Scottish government data, Ordnance Survey Addressbase data and Non-Domestic EPC and Display Energy Certificate data.
- Other differences between the DFES and FES outputs for non-domestic heat pumps are based on the same factors as domestic heat pumps, namely Scottish government

ambitions and targets, and the high proportion of off-gas properties limiting hybrid uptake, particularly hydrogen and fossil gas hybrids under **System Transformation** and **Steady Progression**.

- There is no regional FES 2021 data for resistive electric heating. The scenario projections for the North of Scotland licence area are based on national FES trends, with consideration for the increased rate of heat pump deployment in the near and medium term in the licence area.

Factors that will affect deployment at a local level:

- The uptake of heat pumps is modelled to a very high level of granularity within the SSEN low voltage network. Domestic heat pump uptake was evaluated across over 400,000 individual feeders across SSEN's licence areas, while non-domestic heat pumps were evaluated across over 100,000 distribution substations.
- Various data were used to model local uptake of heating technologies, such as socio-demographic graphics, building attributes, and geographical characteristics.
- Key factors for the uptake of heat pumps are gas network connectivity, household information evaluated from EPC data such as energy efficiency and building type, affluence and tenure.
- As levels of heat pump deployment increase, especially under **Consumer Transformation** and **Leading the Way**, uptake is assumed to become more evenly distributed across all types of homes and non-domestic buildings. In the longer term, as heat pumps become the most common heating technology in these scenarios, uptake is inevitably seen in areas that did not see high levels of heat pump deployment in the near and medium term.

Relevant assumptions from National Grid FES 2021:

Assumption number	3.1.3 – Heat pump adoption rates
Steady Progression	Low disposable income and low willingness to change lifestyle means consumers buy similar appliances to today
System Transformation	Medium disposable income, an increase in energy prices relative to today through carbon price but low willingness to change lifestyle and consumer preference is to minimise disruption to existing technologies
Consumer Transformation	Medium disposable income, high energy prices relative to today through carbon price incentives and a change in zeitgeist drive behavioural change to adopt new heating technologies
Leading the Way	High disposable income, high energy prices relative to today through carbon price incentives and a change in zeitgeist drive behavioural change to rapidly adopt and experiment with new heating technologies

Assumption number	4.2.27 – Uptake of hybrid heating system units*
Steady Progression	Gas boilers still dominant and very low levels of hybridisation
System Transformation	Hydrogen boilers dominant and very low levels of hybridisation
Consumer Transformation	Moderate levels of heating hybridisation. Even in a highly electrified heat landscape the availability of other fuels makes hybridisation cost optimal in certain localities
Leading the Way	The drive to get to net zero early means taking the best from each fuel source and each technology to achieve optimum overall outcome for individual consumers and the system at large

* Note that this assumption relates to the National Grid FES definition of hybrid heat pumps. This includes ASHPs with a resistive electric back-up heater, which are considered as non-hybrid heat pumps in the DFES.

Stakeholder feedback overview:

Regional stakeholders were consulted on various aspects of low carbon heat as part of a wider stakeholder engagement webinar. Stakeholders were presented information about the current heating technologies present in the licence area, then canvassed for opinions on where heat pumps may be prioritised in the near term, the use cases of hydrogen, and the potential low carbon heating solutions for Scottish islands.

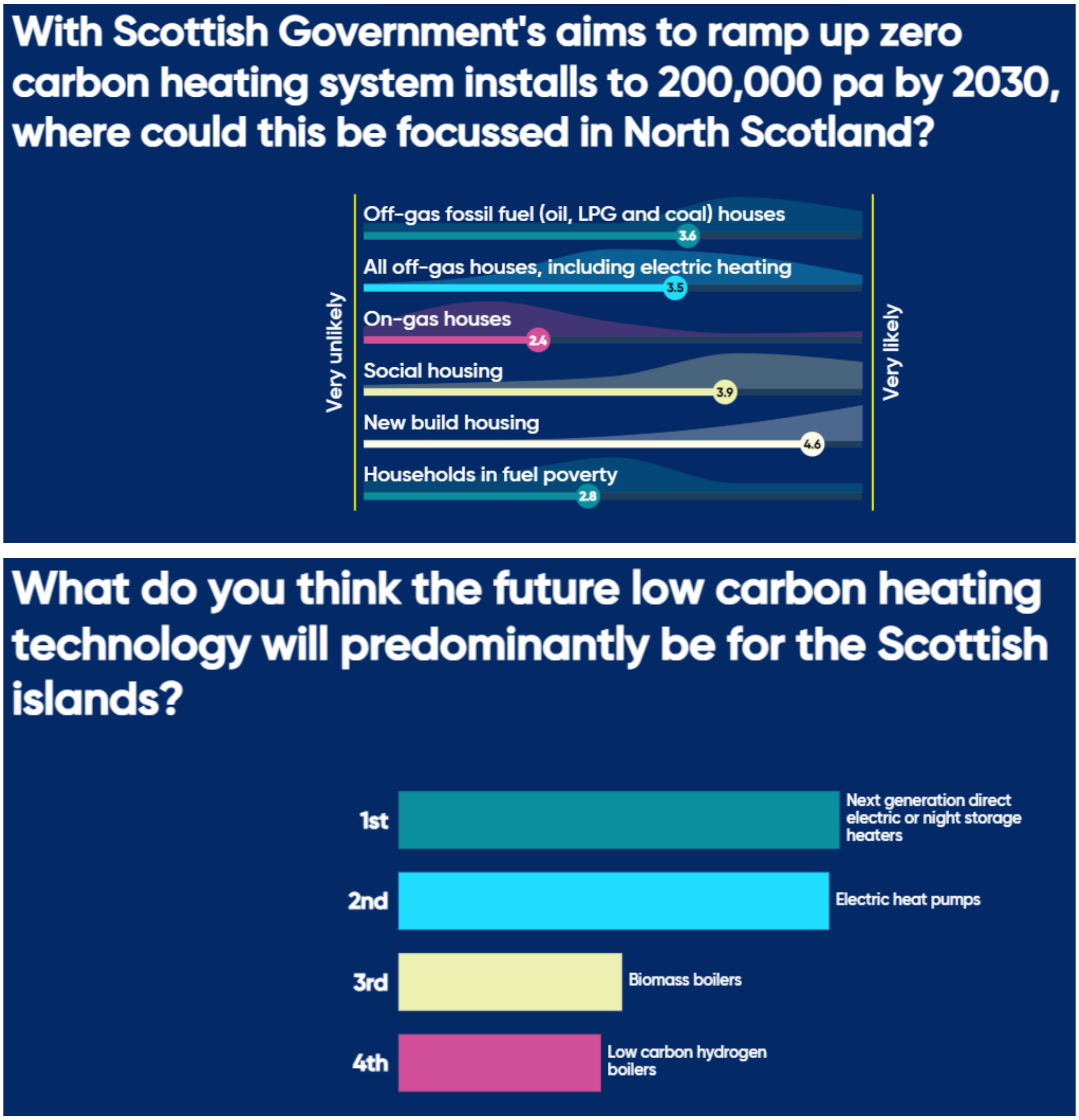
Reflecting the unique energy circumstances of the island communities in the licence area, a workshop was held with stakeholders from the Highlands and Islands, including the Isle of Lewis, Orkney, Shetland and the Isle of Skye, alongside the SSEN and Regen team. This included discussion around the decarbonisation of heat on these island communities, highlighting that the current building stock is predominantly heated by resistive electricity and off-gas fossil fuels, and that poor energy efficiency and high rates of fuel poverty are key considerations, alongside the potential production and usage of hydrogen for heating.

To ensure that Scottish Government policies and ambitions were accurately reflected in the DFES scenarios, a workshop was held with Scottish government to discuss decarbonisation technologies, including electrified heat and hydrogen. The **Consumer Transformation** and **Leading the Way** scenarios have been aligned with the Scottish Government's net zero commitments and plans for heat decarbonisation, based on the outputs of this workshop and published information.

The table below summaries the key areas where stakeholder feedback has influenced the DFES analysis for electrified heat:

Heat pumps and resistive electric heating	
Stakeholder feedback provided	How this has influenced our analysis
In the context of Scottish government's 2030 target for zero carbon heating uptake, stakeholders thought that heat pump deployment would be focussed in new homes, off-gas homes and social housing.	Heat pump uptake is weighted towards these housing types and demographics in the near and medium term.
Local authorities were engaged to understand which authorities had a low carbon heat strategy established or in development. However, this formed a minority of local authorities.	Heat pump uptake is weighted towards local authorities with low carbon heat strategies in the near term.
Scottish government's Heat in Buildings Strategy policy commitments, targets and projections, alongside workshop engagement and other published low carbon heat documents.	Scottish government targets and ambitions for low carbon heating are reflected in all scenarios, and explicitly met in the **Consumer Transformation** and **Leading the Way** scenarios.
Islands in the North of Scotland licence area were specifically consulted around their unique heating challenges and drivers. Fuel poverty, energy efficiency and the lack of mains gas were raised as key drivers in the electrification of heat. Hydrogen for heating is also being explored on Shetland and Stornoway.	Heat pump uptake on the islands is high in every scenario, due to being dominantly off-gas. However, uptake may be tempered by high heat demands and poor energy efficiency of the housing stock. This is reflected through the range of the four future scenarios in the analysis.

Figure 69: Stakeholder responses to heat technology questions in the online engagement webinar



References:

EPC data, Census 2011, RHI data, Scottish Household Survey, Regen consultation with local stakeholders.

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lxxiii https://www.gov.uk/government/publications/net-zero-strategy
lxxiv https://www.gov.uk/government/publications/heat-and-buildings-strategy
lxxv Scottish Government Heat in Buildings Strategy https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/
lxxvi Hydrogen Policy Statement https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/
lxxvii LHEES https://www.gov.scot/publications/local-heat-energy-efficiency-strategies-lhees-phase-2-pilots-evaluation/
lxxviii New Build Zero Emissions from Heat Standard https://consult.gov.scot/energy-and-climate-change-directorate/new-build-heat-standard/

Domestic air conditioning

Summary of modelling assumptions and results

Technology specification:

The analysis covers the number of domestic air conditioning (A/C) units, based on a typical portable or window-mounted air conditioner.

Technology building block: **Lct_BB014 (A/C domestic units)**

Data summary for domestic air conditioning in the North of Scotland licence area:

A/C units (thousands)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	1.4	2.5	4.9	11.0	22.5	48.2	96.9
System Transformation		2.3	4.1	7.0	13.9	25.7	45.7
Consumer Transformation		2.3	4.1	7.0	13.9	25.7	45.8
Leading the Way		1.5	1.5	1.5	1.5	1.5	1.5

Overview of technology projections in the licence area:

- Air conditioning is currently uncommon in UK homes, with just over 1% of homes currently containing an A/C unit.
- While regional data is not available for domestic A/C, the North of Scotland licence area is modelled to have units in around 0.2% of homes. This is based on analysis showing fewer days requiring cooling and lower building density of homes in the licence area.
- However, increasing temperatures and falling costs of A/C units could result in increased uptake over the coming decades.
- With a minimal baseline and high levels of uncertainty around future cooling demand, as well as cooling methods, there is a wide range of scenario outcomes for A/C units.
- This range results in minimal uptake under **Leading the Way** and A/C becoming more commonplace by 2050 under **Steady Progression**.

Scenario projection analysis and assumptions:

Baseline (up to end of 2020)

- There is limited data on domestic A/C in the UK, and no available data at a regional level. A 2016 report by Tyndall Manchester[lxxix] suggested that 1-3% of UK households had A/C in some form.
- The analysis is aligned with National Grid FES 2021 A/C demand data, from which a UK baseline of c.300,000 domestic air conditioner units has been derived.
- Using regional temperature data and the characteristics of the licence area's building stock, this national figure was disaggregated to determine a regional baseline.
- This results in a modelled baseline of 1,400 domestic A/C units in the North of Scotland licence area.

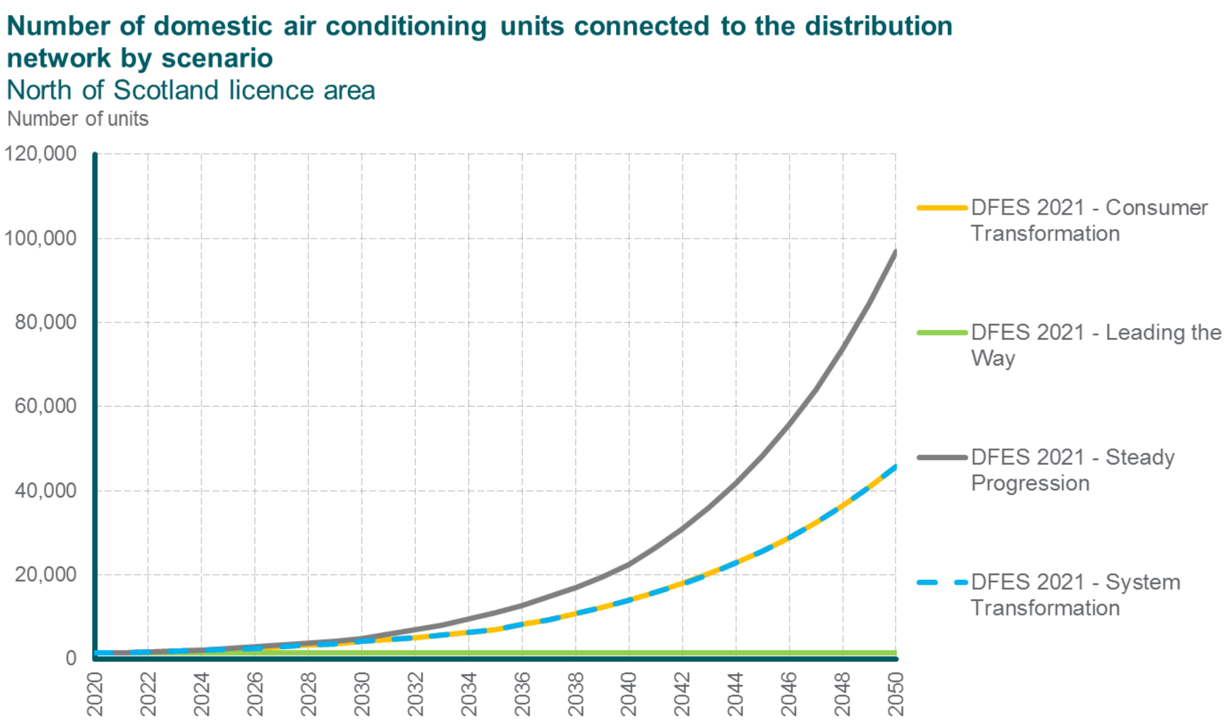
Near term (2021 – 2025)

- Near-term uptake of domestic A/C is limited in all scenarios. Domestic A/C is associated with high upfront and running costs and is not seen as necessary in most homes.

Medium and long term (2025 – 2050)

- The uptake of A/C accelerates in the medium term in all scenarios.
- Under **Steady Progression**, increasing summer temperatures and limited deployment of passive cooling measures lead to accelerated uptake of domestic A/C. By 2050, 14% of current homes in the licence area (c.97,000) have an A/C unit in this scenario.
- Under **Consumer Transformation** and **System Transformation**, uptake of domestic A/C also accelerates, especially in urban 'heat island' areas. However, increased deployment of passive cooling measures limits uptake. In these scenarios, 6% of homes in the licence area (c.46,000) have an A/C unit by 2050.
- Under **Leading the Way**, domestic A/C remains rare, with cooling requirements met through more sustainable methods, including high levels of passive cooling deployment, coupled with behaviour change of homeowners. Throughout the scenario timeframe, less than 1% of homes in the licence area (c.1,500) have an A/C unit.

Figure 70: Domestic air conditioning projections for the North of Scotland licence area



Reconciliation with National Grid FES 2021:

- The FES 2021 does not directly detail numbers of domestic A/C units, thus direct comparison is not possible. However, annual electricity demand for domestic A/C is provided at a national level, alongside typical consumption values for domestic A/C units. This allows for reconciliation against national figures, at a high level.
- Temperature data shows that the North of Scotland licence area has far fewer cooling degree days at or above 18.5°C than the national average.
- Housing density in the licence area is also lower than the national average.

A/C uptake is anticipated to be focused in dense urban ‘heat islands’, which are more common in other parts of the UK.
- As a result, the proportion of homes with an A/C unit in the North of Scotland licence area is significantly below the FES 2021 national average in every scenario.

Factors that will affect deployment at a local level:

- Affluence is a key factor in the distribution of domestic A/C, given the high upfront and running costs of units. This is weighted most strongly in the near term, where A/C is an uncommon ‘luxury’ in all scenarios.
- Property tenure is also a significant factor in the near term, due to the greater likelihood of homeowners to invest in relatively expensive home improvements such as A/C, compared to tenants that are renting properties or landlords.
- Urban ‘heat island’ areas are seen as drivers in the uptake of domestic A/C in the medium and long term. Urban areas also contain higher proportions of flats, which have a lower ratio of external surface area to floorspace, which prevents heat from escaping effectively at high temperatures.

Relevant assumptions from National Grid FES 2021:

Assumption number	3.1.2 - Uptake of residential air conditioning
Steady Progression	Low willingness to change means society takes the easiest route to maintain comfort levels, therefore increasing levels of air conditioning.
System Transformation	Medium uptake as society takes a mix of actions to maintain comfort levels (mix of air conditioning, tolerance of higher temperatures, changes to building design).
Consumer Transformation	Medium uptake as society takes a mix of actions to maintain comfort levels (mix of air conditioning, tolerance of higher temperatures, changes to building design).
Leading the Way	Low uptake as society changes to minimise uptake (e.g. personal tolerance of higher temperatures, changes to building design).

References:

National Grid ESO FES 2021 data, UK cooling degree days data, Census 2011.

[lxxix] See *Air conditioning demand assessment* report by Tyndall Manchester, May 2016: https://www.enwl.co.uk/globalassets/innovation/enwl001-demand-scenarios--atlas/enwl001-closedown-report/appendix-3---tyndall-uom---air-conditioning-demand-report-may2016.pdf

Hydrogen electrolysis

Summary of modelling assumptions and results

Technology specification:

The analysis covers the capacity of hydrogen electrolysers connected to the distribution network in the North of Scotland licence area. The analysis does not include electrolysers that are directly powered by renewable energy without a dedicated grid connection ('behind-the-meter') or large-scale electrolysers connected to the transmission network. Nor does it include CCUS-enabled hydrogen produced via the reformation of natural gas or other fossil fuels.

Technology building block: **Dem_BB009 (hydrogen electrolysis)**

Due to a lack of GSP level data for this building block, SSEN DFES 2021 projections have been compared to FES 2021 figures at a national level.

Data summary for hydrogen electrolysis in the North of Scotland licence area:

Installed power capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Steady Progression	1.4	11	31	163	163	163	163
System Transformation		20	72	241	409	698	903
Consumer Transformation		27	68	618	856	1,473	2,012
Leading the Way		46	203	574	844	1,259	1,549

Overview of technology projections in the licence area:

- There is significant uncertainty around the development of hydrogen electrolysis as an emerging technology. The main sources of uncertainty are:
    - The split of capacity that may connect to the distribution network or transmission network
    - The contribution of hydrogen electrolysis to national hydrogen aims, compared to CCUS-enabled hydrogen (i.e. blue hydrogen produced via methane reformation)
    - The types of connection arrangements for hydrogen electrolysers, including behind-the-meter co-location with renewable generation
    - The range of end-uses for hydrogen, including transport, industrial processes, aviation and shipping, power generation and heating
    - Major government policy decisions regarding revenue support that are still to be finalised
    - How far and how quickly hydrogen costs will fall.
- Ofgem's announcement of their minded-to decisions related to the Network Access and Charging Significant Code Review could be beneficial for hydrogen electrolysers, if it leads to reduced network connection charges. This is modelled to be a factor under **Leading the Way** and **Consumer Transformation**.
- In the Scottish Government's Draft Hydrogen Action Plan[lxxx], a clear ambition is set out of 5 GW installed hydrogen production capacity by 2030, and 25 GW by 2045. This capacity will come from a mix of hydrogen electrolysis and CCUS-enabled hydrogen, as well as being split over the transmission and distribution networks and non-networked arrangements.

- The Scottish Government's commitment[lxxxi] to provide policy and regulatory support for hydrogen production and use is expected to accelerate the deployment of hydrogen electrolysers connecting in Scotland.
- The North of Scotland licence area is likely to be a centre of hydrogen electrolysis development, with dedicated hydrogen hubs in Aberdeen, Dundee, Cromarty Firth, Orkney and the Western Isles.
- The potential for both onshore and offshore wind generation in the North of Scotland is also a key opportunity for hydrogen production.
- The largest capacity of distribution-connected hydrogen electrolysers in 2050 in the North of Scotland licence area is modelled under **Consumer Transformation** (2 GW) and **Leading the Way** (1.5 GW). This reflects a focus on hydrogen as a widespread zero carbon fuel in these scenarios, for use in transport, industrial processes, shipping and heating.
- In contrast, the least capacity is modelled under **Steady Progression** (163 MW) reflecting limited government policy support for this technology/fuel sector and the assumption that high construction, production and commodity costs limit the rollout of electrolysis.

Scenario projection analysis and assumptions:

Baseline (up to the end of 2020)

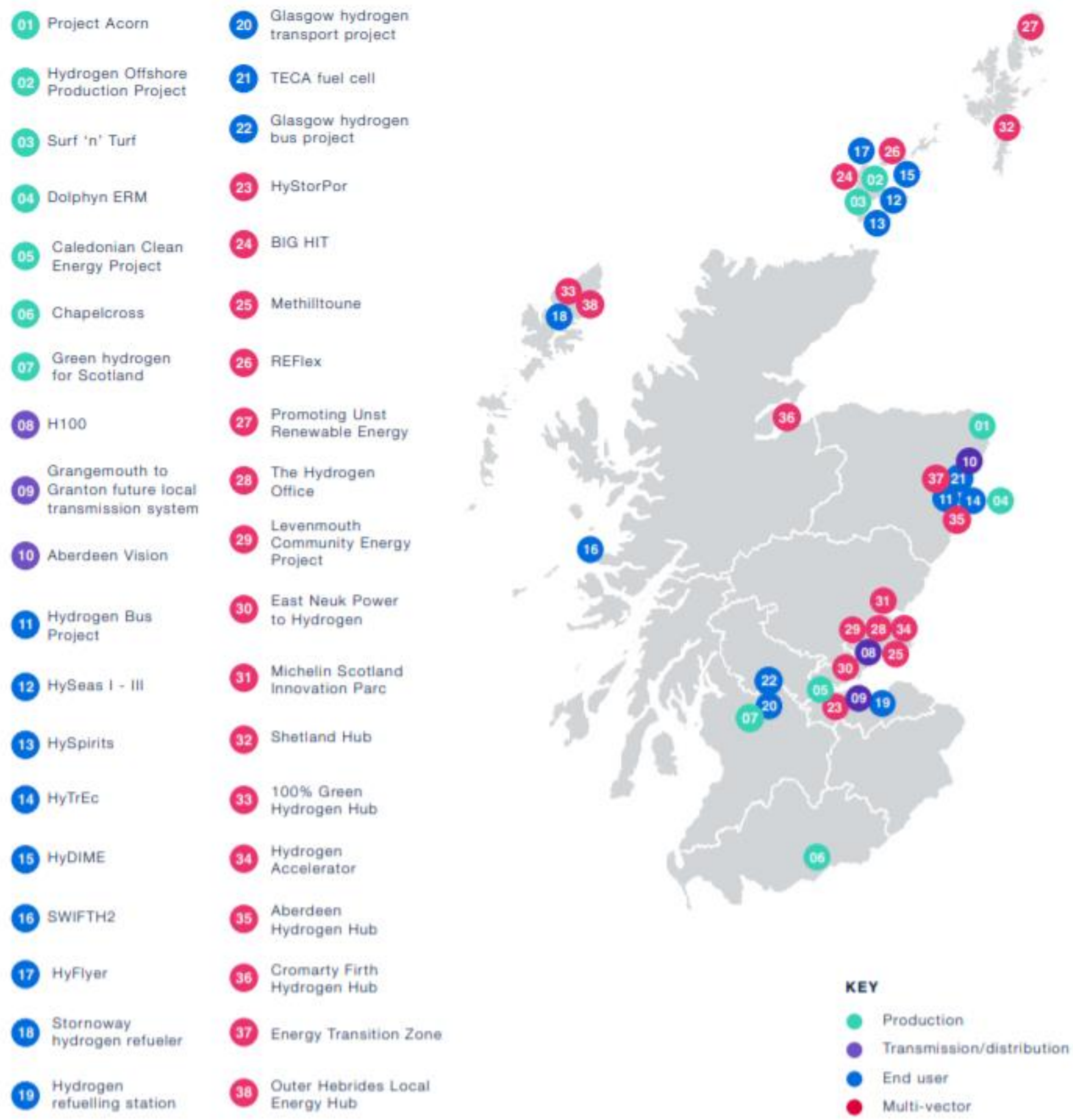
- There is 1.4 MW of hydrogen electrolysers connected to the distribution network in the North of Scotland licence area.
- This includes two hydrogen refuelling stations in Aberdeen at the Aberdeen Hydrogen Centre (0.35 MW) and the Kittybrewster refuelling station (1 MW). These have been operational since 2017 and 2015, respectively.
- The Kittybrewster bus depot has the capacity to produce 360 kg of hydrogen daily; enough for the current fleet of 10 hydrogen buses in Aberdeen[lxxxii].
- A 30 kW electrolyser is also operational at the Creed Integrated Waste Management Facility as part of the Outer Hebrides Local Energy Hub[lxxxiii]. This is a multi-sector partnership that includes The Scottish Salmon Company, Pure Energy Centre, Community Energy Scotland and Comhairle nan Eilean Siar and involves using hydrogen in a salmon hatchery in Lewis, as well as providing fuel for a hydrogen-powered bin lorry.
- There are also two electrolysers operating on Orkney (totalling 1.5 MW) as part of the BIG HIT project[lxxxiv]. However, these sites are directly connected to renewable energy generation, operating at times of curtailed wind and tidal generation, hence do not have their own grid connection and do not fall under the scope of the DFES modelling.

Near term (2021 – 2025)

- In the near term, **Leading the Way** sees the highest level of capacity growth due to strong government support for hydrogen. This is likely to be focused on transport, including the introduction of hydrogen buses and HGVs.
- There are two pipeline sites in the North of Scotland which have clear information on both capacity and targeted year of operation:
  - The North of Scotland Hydrogen Programme Distilleries Project[lxxxv] is exploring the use of green hydrogen within Scottish distilleries. Phase 1 of this project aims to install 35 MW of electrolysers by the end of 2024 in the Port of Nigg, Cromarty Firth. This has been modelled to connect in 2024 under **Leading the Way**, 2027 under **Consumer Transformation** and 2029 under **System Transformation**. It is not modelled to go ahead under **Steady Progression**.
  - Integrating Tidal Energy into the European Grid (ITEG)[lxxxvi] is looking to demonstrate the integration of tidal energy (2 MW) and hydrogen production (0.5 MW) on Orkney. This phase of the project ends in 2021. As this is a demonstration project currently on track, this is expected to connect under all scenarios in 2021.

Figure 71. Hydrogen Projects in Scotland

Source: [Scottish Government, Scottish Hydrogen Assessment]



- Aberdeen and Dundee have been identified as potential hydrogen hubs, particularly for hydrogen-powered transport. Aberdeen already has a fleet of double-decker buses powered by hydrogen[lxxxvii], but the Aberdeen Hydrogen Hub programme hopes to deliver a green hydrogen facility in the city, with first operations targeted for 2024.
- Michelin Scotland Innovation Parc in Dundee is seeking to procure a specialist company to design, build, commission, maintain and operate a hydrogen refuelling station on the Parc in 2022 to generate green hydrogen for a minimum of 12 hydrogen fuel cell electric buses.
- Hydrogen is set to be a crucial part of Scotland's broader net zero targets, and a number of future projects have been announced or are in discussion.
- Some projects that have been identified, which aim to be operational before 2025, include:
    - Eneus energy, working in conjunction with locally-owned Hammars Hill Energy and Green Cat Renewables, has identified Hammars Hill in Evie as the prime location for

    - a hydrogen production facility, which would produce both hydrogen and ammonia. The proposal, which includes the erection of two wind turbines (8.4 MW), a substation and a hydrogen production facility has received planning permission from Orkney Islands Council in January 2021. It is unclear whether the project will involve a demand connection, or whether the electrolyser will be directly powered by the wind turbines. This also may depend on the outcome of the Orkney transmission network needs case[lxxxviii].
    - The ORION project[lxxxix] aims to repurpose the infrastructure at Sullom Voe terminal and the Shetland Gas Plant towards hydrogen production. The target is to produce local wind-powered hydrogen in Shetland by 2025, with a view to producing over 10% of the estimated UK demand for hydrogen by 2050.
    - A new £20m centre at Rothesay Dock[xc], Clydebank has applied for planning permission to divert non-recyclable plastic from landfill, incineration or export overseas to produce hydrogen for buses, cars and HGVs.
    - ERM Dolphyn[xci] has developed a concept design for the production of large-scale hydrogen from offshore floating wind. The aim is to deploy 10 MW of electrolysis capacity by 2027, with a 2 MW prototype expected to be operational by summer 2024. As the electrolyser is modelled to be offshore, it is unlikely that this project will involve a distribution network connection, hence it is not included in this analysis.
    - Multiple distilleries across Scotland have expressed an interest in using hydrogen to aid decarbonisation, and many have sought funding from BEIS' Green Distilleries Competition[xcii]. Arbikie Distillery in the Highlands has received £3m in funding to combine an on-site wind turbine with a hydrogen electrolyser, storage and boiler system. Bruichladdich distillery on the Isle of Islay received £70,000 of BEIS funding to complete a feasibility study on incorporating hydrogen combustion technology into the distillery. Both of these projects have applied for planning permission.
- By the end of 2025 electrolyser capacity in the licence area ranges from 11 MW under **Steady Progression** to 46 MW under **Leading the Way**.

Medium term (2025 – 2035)

- Hydrogen produced via electrolysis will be used for transport across all scenarios, favoured over CCUS-enabled hydrogen due to its increased quality/purity.
- As a result, hydrogen electrolysis capacity is likely to increase in the medium term across all scenarios. This is driven by the uptake of hydrogen-fuelled heavy vehicle fleets and the introduction of mainstream hydrogen fuel cell public transport. This transition to low carbon heavy vehicles will be further incentivised by wider transport decarbonisation policy measures, such as the ban on the sale of new petrol and diesel cars by 2030.
- The use of hydrogen in wider transport, such as rail, has been considered, through engagement with Scottish Government and reviewing Transport Scotland's Rail Services Decarbonisation Action Plan[xciii], which aims to decarbonise Scotland's rail network by 2035.
- There is significant marine transport activity in the North of Scotland licence area, raising the potential for hydrogen electrolysis to be used to fuel ferries, boats and broader shipping.
- Further medium-term projects that have been identified in the North of Scotland include:
    - A proposed green hydrogen production and export facility on the island of Flotta in Orkney, with a view to export and blend green hydrogen, as well as drive forward an international maritime green hydrogen refuelling hub.
    - SWIFTH2 (Scottish Western Isles Ferry Transport using Hydrogen), which is planning on using wind to produce green hydrogen to power a new class of ferries operating on one of the established passenger routes between the Scottish islands and the mainland. This project is currently in the feasibility and design stage.

- Highlands and Islands Airports Limited are looking at integrating a hydrogen combustion engine at Kirkwall Airport in Orkney in 2021. During the trial, the CHP will use green hydrogen supplied by EMEC to generate electricity.

- Under **Consumer Transformation** and **Leading the Way**, it is expected that hydrogen electrolysis will achieve cost parity with CCUS-enabled hydrogen by the mid-2030s.
- From consultation with electrolyser manufacturers, 5 MW and 10 MW electrolyser units could become commercially viable in the medium term. This will allow existing and new sites to scale up their installed capacity cost effectively.
- **System Transformation** does not see electrolysis reaching cost parity in the same timeframe, so CCUS-enabled hydrogen is the favoured hydrogen production method, particularly for decarbonising industrial clusters and heating homes.
- Under **Steady Progression**, there is little policy support for hydrogen production in general.
- As a result of these sector developments, **Consumer Transformation** and **Leading the Way** see an unprecedented growth in connected capacity between 2025 and 2035, with 591 MW and 528 MW of additional capacity, respectively. This increase is in line with the Scottish Government's target of 5 GW of clean hydrogen production capacity by 2030.
- In contrast, **System Transformation** and **Steady Progression** see more limited deployment in capacity in the medium term, with 221 MW and 152 MW of additional capacity, respectively.

Long term (2035 – 2050)

- In the long term, electrolysers are expected to scale their capacity by increasing the number of modules connecting to a compressor. This means that the development of new sites is likely to slow, and instead, existing locations are likely to be expanded to cater for higher demand.
- **Leading the Way** and **Consumer Transformation** continue to experience further increased deployment of hydrogen electrolysers, seeing more than a doubling of capacity in each scenario between 2035 and 2050.
- This is due to a number of factors, including:
    - Wider hydrogen sector developments, i.e., the repurposing of large-scale storage facilities for hydrogen and a decrease in upfront costs, as hydrogen electrolyser capacity increases across the UK
    - Demand for hydrogen from a variety of sectors, including heating, industrial demand, road transport, power, shipping and aviation
    - The coupling of hydrogen electrolysis with renewable generation in high-renewable scenarios.
- In **Consumer Transformation**, electrolysers are located close to demand as a national hydrogen network is not expected. This results in a higher overall number of electrolysers connecting to the distribution network. In 2050, electrolyser capacity reaches 2 GW, the highest of the four scenarios.
- In **Leading the Way**, a national hydrogen transmission network allows production capacity to increase rapidly. This could favour transmission-scale production or large-scale production co-located with offshore wind farms. This results in 1.5 GW connected by 2050.
- **System Transformation** and **Steady Progression** have significantly lower electrolyser capacity connecting by 2050, due to a focus on CCUS-enabled hydrogen.

Key modelling assumptions:

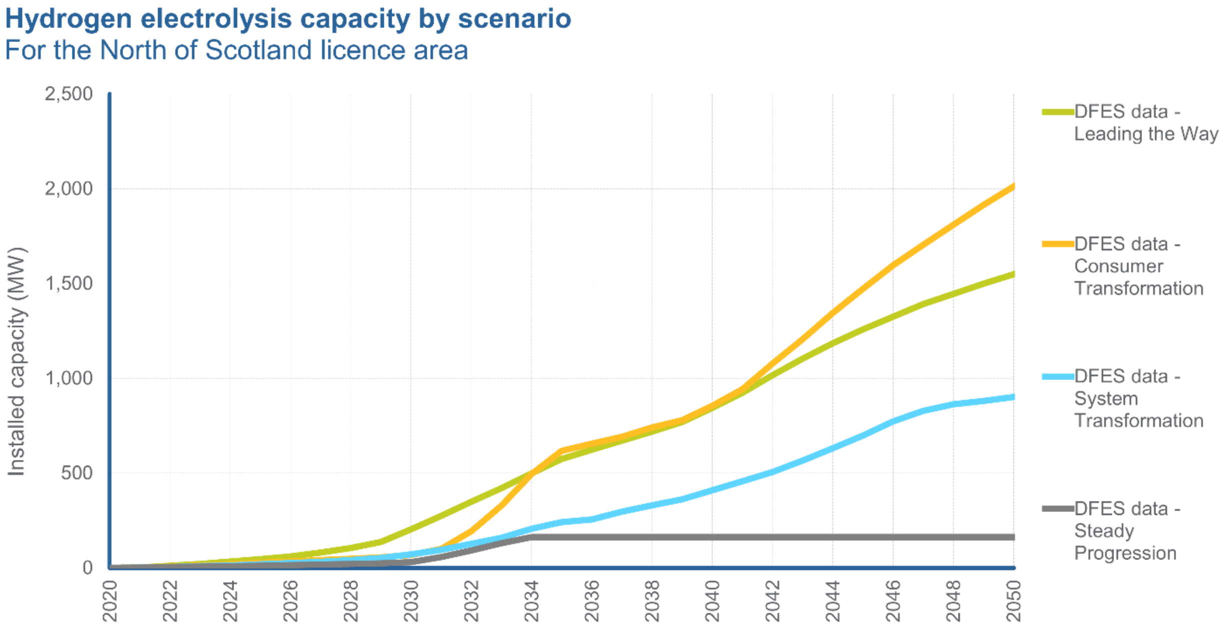
- **Leading the Way**, **Consumer Transformation** and **System Transformation** have been modelled with total GB hydrogen electrolysis capacity split between the transmission and distribution networks. Total distribution connected capacity is modelled to account for 31%, 74% and 22% of the total capacity, respectively.
- **Steady Progression** is the only scenario to have all grid-connected hydrogen electrolysis (100%) modelled on the distribution network.
- All scenarios project electrolytic hydrogen to be used in transport applications. Hydrogen refuelling infrastructure is likely to be co-located with existing petrol stations, particularly ones with high HGV fuelling demand.
- In scenarios where CCUS-enabled hydrogen is also present in the energy mix, it is assumed this is used to decarbonise existing high-carbon hydrogen production and the majority of industrial clusters.
- As a new technology, it is not clear how electrolysers co-located with renewable generation will connect to the grid. It is therefore assumed that hydrogen production co-located with renewable generation, but with its own demand connection, will connect to the same network as the renewable generation site itself.

From engaging electrolyser developers, a number of factors influencing the location of sites were identified, as seen in Table 5. These factors were weighted based on the assumptions underpinning the four FES scenarios and used to create licence area projections.

Table 5 - Locational factors used in the modelling of hydrogen electrolysis capacity, by scenario

Factor	Leading the Way	Consumer Transformation	System Transformation	Steady Progression
Industrial energy demand/clusters	X	X		
Heavy transport demand (HGVs)	X	X	X	X
Large-scale hydrogen storage options	X	X	X	
Location of major ports and maritime activity	X	X	X	
Access to the gas network	X		X	X
Distributed wind generation	X	X	X	
Distributed solar generation	X	X	X	
Rail network and associated infrastructure	X	X	X	
Existing grey hydrogen production	X	X		
Innovation/production projects	X	X	X	X

Figure 72: Hydrogen electrolysis projections for the North of Scotland licence area



Reconciliation with National Grid FES 2021:

Results in this section pertain to FES 2021 Building Block ID number Dem_BB009; however, due to a lack of GSP level data for this building block, reconciliation is difficult. Instead, the SSEN DFES 2021 projections have been calculated as the distribution network proportion of FES 2021 grid-connected hydrogen electrolysis capacity at a national level. These were calculated based on the locational factors outlined in Table 5, including the location of existing hydrogen production sites, large industrial clusters and heavy transport demand.

- As a result, hydrogen electrolysis capacity in 2050 in the North of Scotland licence area under **Leading the Way** equates to 3% of the FES 2021 national grid-connected hydrogen electrolysis capacity. **Consumer Transformation** (5%) and **System Transformation** (3%) have assumed there is capacity on both the transmission and distribution networks.
- **Steady Progression** models 13% of the FES 2021 national capacity to be connected to the distribution network in the North of Scotland licence area. This is mainly due to the number of existing and potential projects in the North of Scotland licence area.

Factors that will affect deployment at a local level:

The spatial distribution of hydrogen electrolysers is highly uncertain, due to a number of unknown factors, including:

- The potential for hydrogen electrolysers to be co-located with existing or new distributed renewable generation.
- The split of electrolysis capacity on the distribution network compared to the transmission network.
- Whether or not there will be construction of a national hydrogen network that would be able to transport hydrogen around the UK.
- The location of large-scale storage facilities, which have not currently been explored for hydrogen storage.

Relevant assumptions from National Grid FES 2021:

Assumption number	4.2.19 – Hydrogen (electrolysis exc. from nuclear)
Steady Progression	High costs limit rollout of electrolysis – used mainly in transport.
System Transformation	Competition from CCUS-enabled hydrogen limits rollout of electrolysis – used mainly in transport. Electrolysis mainly from curtailed wind. CCUS-enabled hydrogen covers heat.
Consumer Transformation	Electrolysis used to decarbonise heat, transport and some industrial and commercial – medium as rollout begins later than in **Leading the Way**.
Leading the Way	Electrolysis used to decarbonise heat, transport and industrial and commercial, but rollout starts in the mid-2020s.

Stakeholder feedback overview:

Hydrogen electrolysis Stakeholder feedback provided	How this has influenced our analysis
A range of stakeholders were engaged through a dedicated North of Scotland DFES workshop, where Menti was used to gauge stakeholders' views.	Stakeholders concluded that the best uses of hydrogen are as a fuel for shipping, ferries and large road vehicles, and for firing industrial processes. This has been included in the methodology as locational factors that influence the distribution of hydrogen electrolysis, as well as the allocation of "hydrogen hubs".
Scottish Government highlighted their ambition for hydrogen production and demand across Scotland. This was outlined in their Hydrogen Action Plan and Hydrogen Policy Statement. There is a commitment of 5 GW of hydrogen production capacity by 2030.	These documents have been used to gain a better understanding of the current activity of hydrogen electrolysis in the licence area and informed the assumptions driving the projections out to 2050, specifically under **Consumer Transformation** and **Leading the Way**.
A workshop was held with representatives from the Scottish Islands. It was noted that the islands could be hubs for the production and export of hydrogen. Multiple pipeline projects were discussed.	These pipeline projects have been included in the analysis and discussions were used to understand the scale and location of future hydrogen electrolysis capacity.

References:

IEA hydrogen project database, FES 2021 data workbook, Network Rail Traction Decarbonisation Strategy, the Renewable Energy Planning Database, Regen consultation with ITM Power, Scottish Government Draft Hydrogen Action Plan, National Atmospheric Emissions Inventory, BEIS energy consumption dataset, Department for Transport local authority vehicle miles data, UK Carbon Capture and Storage Research Centre, 2011 Census data, Regen consultation with local stakeholders and discussion with developers, Regen questionnaire and consultation with local authorities.

[lxxx] Scottish Government Draft Hydrogen Action Plan: https://www.gov.scot/publications/draft-hydrogen-action-plan/documents/

[lxxxi] See Scottish Government Hydrogen Policy Statement: https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/

[lxxxii] Kittybrewster bus depot fact sheet: https://hydrogeneast.uk/wp-content/uploads/2020/08/Case-study-Kittybrewster-Aberdeen-hydrogen-refuelling-station_tcm410-563229.pdf

[lxxxiii] Outer Hebrides Local Energy Hub: https://communityenergyscotland.org.uk/projects-innovations/ohleh/

[lxxxiv] BIG HIT: https://www.bighit.eu/

[lxxxv] North of Scotland Hydrogen Programmer Distilleries Project: Green hydrogen set for Port of Nigg - ScottishPower

[lxxxvi] Integrating Tidal Energy into the European Grid: https://www.emec.org.uk/projects/hydrogen-projects/iteg/

[lxxxvii] See Fore Court Trader article on Aberdeen hydrogen buses: https://forecourttrader.co.uk/latest-news/aberdeens-hydrogen-double-decker-buses-notch-up-100000-miles-of-operation/655579.article

[lxxxviii] See Ofgem update on Orkney transmission link: https://www.ofgem.gov.uk/publications-and-updates/ofgem-gives-go-ahead-orkney-transmission-link-subject-conditions

[lxxxix] See Orion Clean Energy project on Shetland: https://www.orioncleanenergy.com/

[xc] Rothesay Dock, Clydebank plastics to hydrogen plant: https://www.gov.scot/publications/clyde-mission-energy-masterplan/pages/16/

[xci] ERM Dolphyn: https://ermdolphyn.erm.com/p/1

[xcii] BEIS' Green Distilleries Competition: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/985896/Environmental_Resource_Management_Phase_1_Feasibility_Report.pdf

[xciii] See Transport Scotland Rail Services Decarbonisation Action Plan: https://www.transport.gov.scot/publication/rail-services-decarbonisation-action-plan/

New property developments

Summary of modelling assumptions and results.

Technology specification:

New property and industrial developments can have a significant impact on local electricity demand and therefore forecasts of new housing and commercial and industrial (C&I) builds have been included in DFES analysis.

New developments are categorised as new domestic developments (houses) and non-domestic sites (e.g. factory/warehouse, offices, retail premises, sports & leisure etc.). These correspond to the following FES technology building blocks:

- Number of domestic customers - **DFES technology building block Gen_BB001a**
- Meters squared of I&C customers - **DFES technology building block Gen_BB002b**

Data on planned domestic and non-domestic developments for the SSEN licence areas has been gathered through a data exchange process with all local authorities (LAs) in North of Scotland. The process made use of an online data portal, together with individual engagement with local authority planners and data providers. Desk based research and site investigation has helped to validate and augment the data supplied.

Alongside historic build rates, the data provided by the LAs is used to inform licence area projections for future housing numbers and non-domestic floorspace (sqm).

Summary of process and assumptions:

Figure 73: Summary of methodology for New Developments analysis

Data exchange with all LAs in the licence area: LAs review site data from on-line project database and provide updates or add additional sites.

→

Database update: LA-provided data is checked, suplemented where necessary, and added to the database. Where new data was not provided, existing data from Regen's project database was used.

→

ESA assignment: New sites were assigned ESAs based on locational data. Where locational data was not provided by the LA, new sites were located using address information, a geolocator tool and manual searches.

→

Scenario formulation: The trajectory of planned developments is delayed based on an envelope of past buildout rates to produce a Central Scenario.

Database update and ESA assignment

- Through engagement with LAs, Regen's database of new developments was updated to inform the DFES 2021 analysis.
- This database contains information on development location, size, likely use (for non-domestic), development stage and planned buildout timescale.
- Every LA within the licence area was contacted and invited to verify or update their datasheets via a SharePoint site. Over half of the LAs in the licence area provided new data through the SharePoint or directly to the project team. For the remaining LAs, Regen's existing new developments data, developed through previous DFES iterations, was used to as a starting point to inform this year's projections.
- All sites are assigned an ESA, using the following method:
    - Most could be carried over from Regen's existing project database.
    - For newly provided developments with locational data, ESAs were assigned using GIS mapping. Large sites near an ESA border were manually checked and split across the neighbouring ESAs as appropriate.
    - The remaining sites are assigned ESAs using a geolocator tool, supplemented by manual searching and investigation of individual sites.

- Some sites are provided by LAs without a buildout timeline. For these sites, an estimate of an appropriate build-out rate has been modelled based on development stage, type, and typical regional site development rates.
- For non-domestic analysis, LA provided site areas are converted into floorspace (sqm) using a conversion ratio specific to the type of development and from historic DFES data.
- The LAs were also asked about existing or draft decarbonisation strategies for renewable energy, transport, waste, and heating in their local area. The responses and supporting information provided was used to inform analysis within the wider SSEN DFES 2021.

Delay factors and historic build rates

- The timeline and build out rate of new developments is a key source of uncertainty. Developer suppled data typically comes with a high degree of "optimism bias" with almost all developments nominally scheduled for completion within a 5 year timeframe.
- Planned developments peak in the medium term; however it is likely that a proportion of these developments will be subject to delays. For the purpose of network planning, the modelling applies, scenario based, delay factors to planned buildout timescales. In this way, the location and scale of development is maintained, but the period over which the sites are built is extended.

Table 6: Domestic delay factors, the percentage of domestic developments which are completed as planned, with the remainder delayed.

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030-2040
Central Scenario	100%	80%	80%	80%	80%	80%	80%	75%	65%	90%

- The past ten years of build out data is used to define an annual average housebuilding rate.
- Government projections that forecast a levelling off in the growth of household numbers are also considered.
- These delay factors, the historic housebuilding rates and government projections are then used to define a **Central Scenario** projection for new developments.
- There is no historic build rate data or future projections available for non-domestic developments. Only delay factors are used to account for project delays and define the non-domestic **Central Scenario**.

Table 7: Non-domestic delay factors, the percentage of non-domestic developments which are completed as planned, with the remainder delayed.

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030-2040
Central Scenario	90%	45%	40%	40%	40%	40%	40%	40%	40%	40%

Residual sites and modelled development

- The domestic analysis seeks to capture all significant developments, constituting 20 homes or more. Analysis of previous new developments studies suggests this cut-off leaves about 5% of homes un-recorded, so an estimation of these residual small-scale sites is modelled and included in the **Central Scenario** projection.
- Given typical development timeframes, there is a natural reduction in the data for planned developments after 2025. Additional domestic developments are modelled post 2025, this modelled development brings the long-term trajectory in-line with the **Central Scenario**.
- There are no residual sites or modelled developments for non-domestic developments.

Scenario projection analysis and assumptions:

- For the SSEN DFES 2021 a **Central Scenario** is used rather than four FES scenarios, as the analysis is based on known property development information provided by LAs.

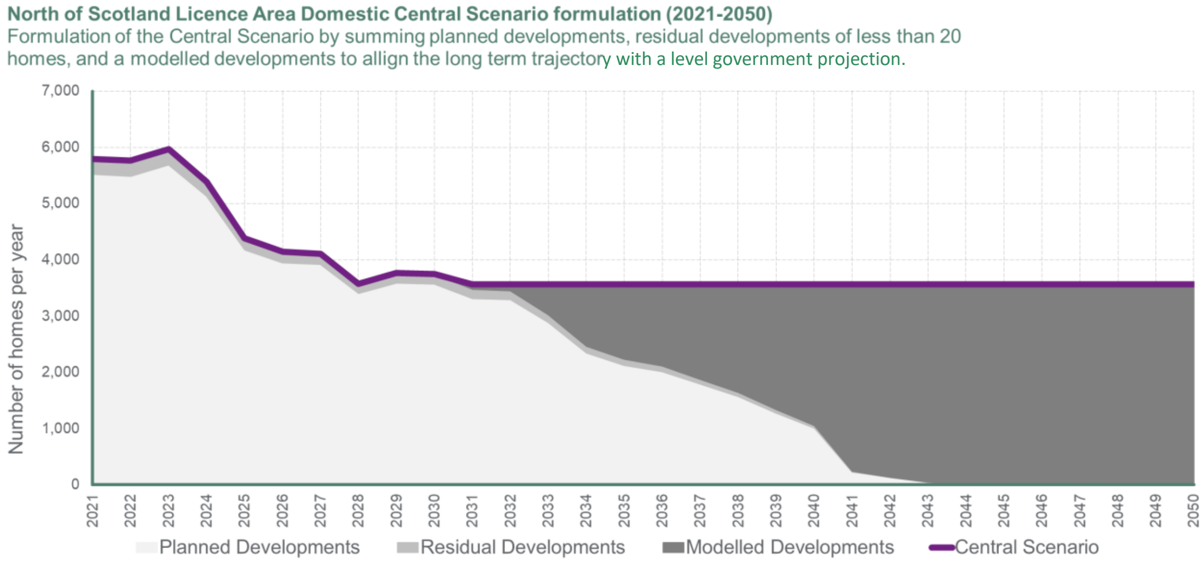
Data summary for cumulative new properties in the North of Scotland licence area

Classification of new property development	Near-term projections of known developments			Modelled projections of new developments beyond 2030		
	2025	2030	2035	2040	2045	2050
New domestic properties (number of houses)	27,302	46,636	64,468	82,300	100,132	117,964
New non-domestic development floorspace (sqm)	4,819,224	9,904,568	13,942,423	14,413,598	14,446,207	14,452,997

New domestic developments

- For the North of Scotland licence area, the **Central Scenario** projection for new domestic property developments decreases from a historic average build rate of 6,000 homes annually, before levelling off to be in line with government projections from 2030-2050.
- This equates to a cumulative total of just under 118,000 new domestic properties by 2050.

Figure 74: Domestic Central Scenario and it's formulation

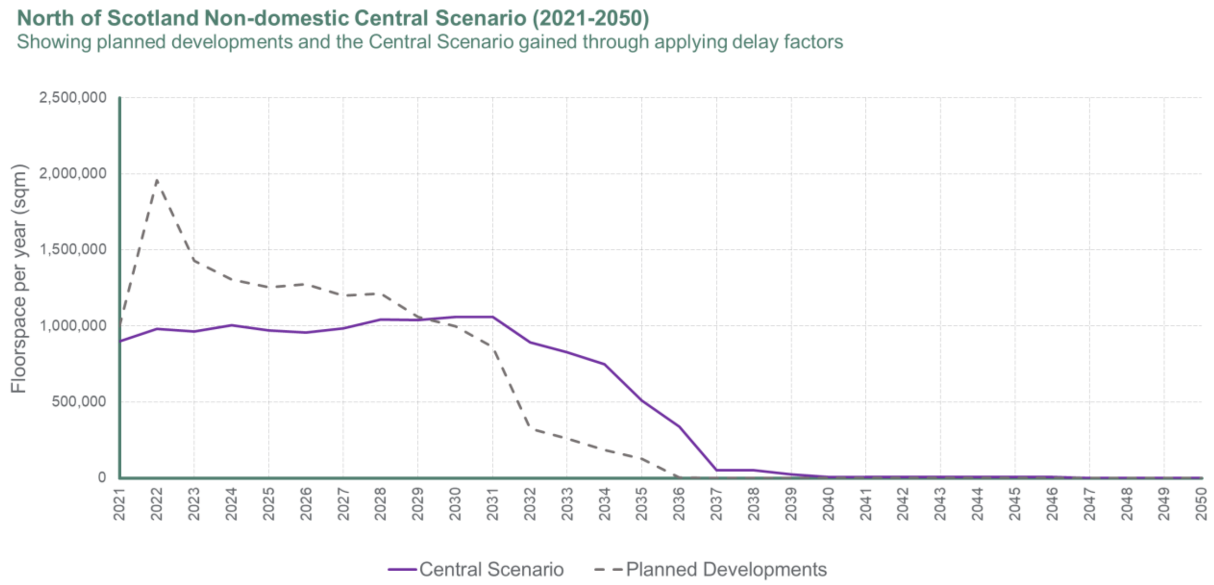


- Aberdeen City region has the highest number of homes projected to build out. This is driven by a single development of 3,434 homes at Grandhome, Old Machar, which is already under construction.
- These projections also inform the analysis of domestic technologies such as electric vehicles, heat pumps and rooftop solar PV. The spatial data from the local plans define where on the SSEN network these technologies may be located.

New non-domestic developments

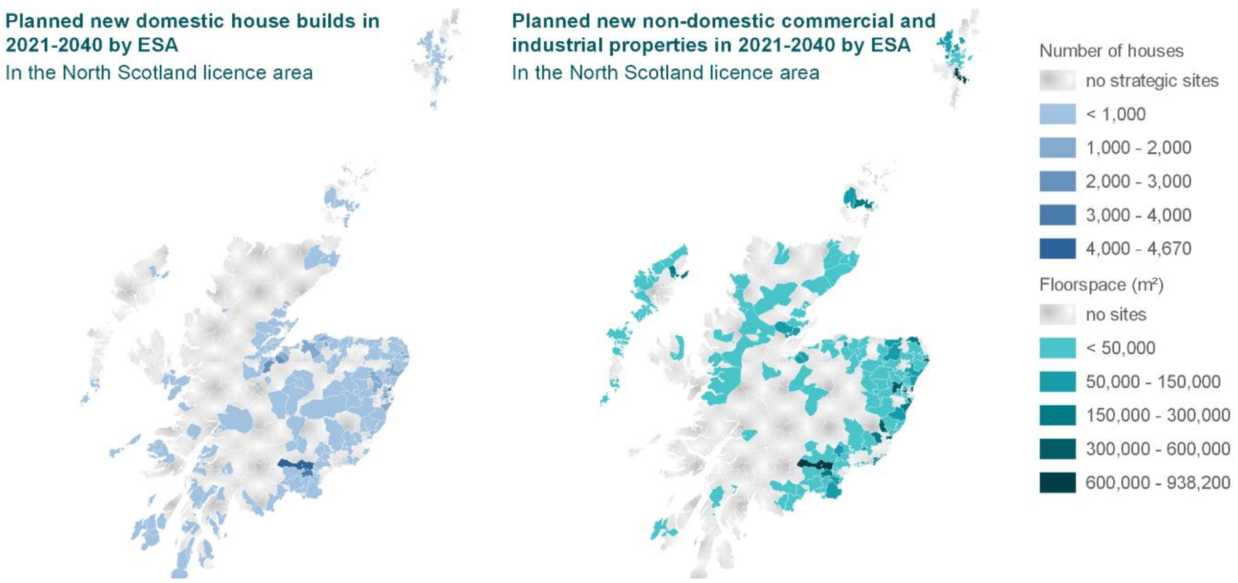
- For the North of Scotland licence area, the **Central Scenario** for non-domestic developments modelled the known developments and decreased from 800,000 sqm of floorspace added annually in the near term to just under 200,000 sqm by 2035.
- This equates to a cumulative total of just over 14.5 million sqm by 2050.

Figure 75: Non-domestic planned developments and Central Scenario



- Of the planned non-domestic developments, 47% are factory and warehouse developments and 42% is new office space.
- Shetland Islands has greatest amount of non-domestic floorspace due to be developed, totalling around 250,000 sqm. Of this, factory and warehouse accounts for 140,000 sqm. This is driven by the Staneyhill, Lerwick development which is currently under construction.

Figure 76: Distribution of planned developments across the licence area



Stakeholder engagement:

- The initial stage of this process is reliant on engagement with LAs in the licence area. Over half of LAs provided new data through a SharePoint site, or directly to the project team. For the remaining LAs, Regen's existing project database was used.
- With many LAs engaging directly with the process, the projections are based on the most accurate and up to date information available.
- Some LAs were not able to provide information within the timeframe of the project, especially due to resourcing pressures as a result of the ongoing COVID-19 pandemic.
- Regen's project database ensured that all LAs were represented with recent high granularity development data wherever possible.
- Large non-domestic developments (over 50,000 sqm floorspace) were subject to additional analysis, due to their impact on future demand. This involved further contact with LAs to confirm developments, their size, and expected buildout.
- More specifically, any site which appeared to have large open areas, including airports, spaceports, and marine parks, were highlighted and brought to the attention of the LAs.
- An additional category was considered to encompass these developments due to their distorted area/floorspace ratio. However, LAs confirmed that only two of these developments were due to build out, and the decision was made to continue using the 'other' classification with an updated floorspace.
- Alongside the new developments data exchange, the LAs were also asked about existing or draft decarbonisation strategies for energy, transport, waste, and heating in their local area. This data was used to inform analysis within the wider SSEN DFES 2021.