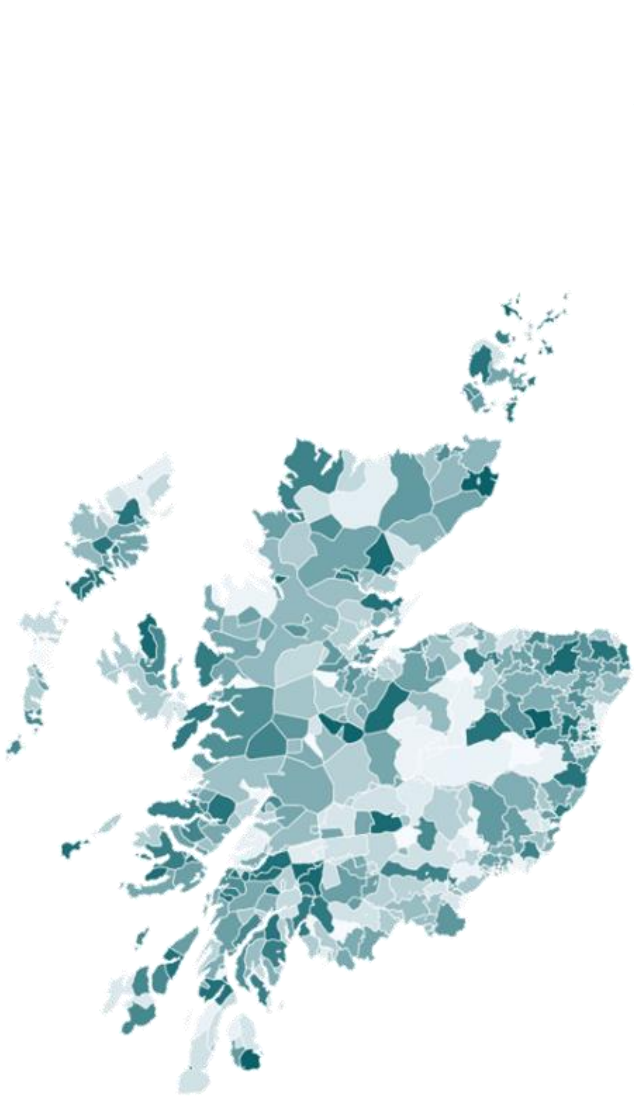
SSEN DISTRIBUTION FUTURE ENERGY SCENARIOS 2023

Results and methodology report for the North of Scotland licence area

March 2024



About Regen

Regen is an independent centre of energy expertise with a mission to accelerate the transition to a zero-carbon energy system. We have nearly 20 years of experience in transforming the energy system for net zero, delivering expert advice and market insight on the systemic challenges of decarbonising power, heat and transport.

Regen is also a membership organisation, managing the Regen members network and the Electricity Storage Network (ESN) – the voice of the UK storage industry. We have over 150 members who share our mission, including clean energy developers, businesses, local authorities, community energy groups, academic institutions and research organisations across the energy sector.

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Contents

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.

We deliver a critical role in the decarbonisation of the sector. 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, while we work to deliver the infrastructure to create a net zero tomorrow. This 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 have embraced the UK and Scottish Governments' commitments to this transition, including their targets to decarbonise by 2050 and 2045, respectively. These commitments have changed the way we go about developing our networks. We are now taking an even more strategic approach making sure we provide the capacity when needed to help achieve Net Zero. Our strategic approach will allow us to anticipate the location and timing of new demand ensuring measures are in place to flex supply and demand to manage capacity needs, or to reinforce the network. You can read more about our Net Zero strategic development process in our Distribution Networks Options Assessment methodology (DNOA).

The work that Regen has undertaken here and for previous reports underpins this process. Our future proposals draw on DFES figures to establish the building blocks that must be put in place to facilitate Net Zero. As a result in our current price control, we'll invest at least £3.5bn in our network, 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 8 GW of distributed generation and storage. This is being supported by development of new market models to allow consumers to interact with the energy system and manage their own usage and costs. This ensures we are only investing in our networks when it is most efficient.

Your input and involvement in this process is essential to help us appropriately identify and develop the local electricity systems and grids of the future. Regen have engaged with many of you in the development of this year's DFES and I would like to thank you for your time and

effort. But our engagement does not stop here. Through innovative tools such as the Local Energy Net Zero Accelerator (LENZA) we are looking to engage with local authorities and other stakeholders through the year both to understand your needs and share our plans as well develop.

Central to this is our commitment to a just transition that leaves nobody behind. This year we have asked Regen to investigate more deeply how the transition to Net Zero is affecting vulnerable consumers, and how DFES can help us understand these impacts and suggest ways to ensure no customers are left behind.

Finally, I would 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
Distribution Systems Operations Director
Scottish and Southern Electricity Networks

Introduction

This report outlines the results from the 2023 Distribution Future Energy Scenarios (DFES) analysis for Scottish and Southern Electricity Networks' (SSEN) North of Scotland electricity distribution network licence area[1]. The DFES analysis produces high granularity forecasts for the growth (or reduction) of energy generation, demand and storage technologies connecting to SSEN's electricity distribution network.

The Future Energy Scenarios (FES) framework, published by the National Grid Electricity System Operator (ESO)[2], outlines four different scenarios for the future of the whole energy system out to 2050 and the assumptions that define these scenarios provide the foundation for the DFES analysis. A wide-ranging evidence base, extensive industry and stakeholder engagement and a thorough investigation into the pipeline of projects, either under construction or seeking development in the North of Scotland licence area, are all further inputs into the DFES.

SSEN uses the DFES analysis as part of an integrated network planning and investment appraisal process. The DFES forecasts enable SSEN to better understand how the demands on its network are likely to change over time and this facilitates the network planning teams to model and analyse future electricity demand across the North of Scotland licence area. This feeds into SSEN's Net Zero Strategic Planning process, the aim of which is to "provide the capacity on the network to deliver net zero by 2050 while retaining a clear focus on safety and reliability" [3].

This report summarises the results and scenario forecasts for the 2023 DFES analysis. It provides an overview of the DFES methodology, stakeholder engagement that was undertaken and national and local policies that influenced the analysis. In addition, this report

[1] Also known as the Scottish Hydro Electric Power Distribution (SHEPD) licence area.
[2] National Grid 2023, Future Energy Scenarios 2023 https://www.nationalgrideso.com/future-energy/future-energy-scenarios-fes
[3] SSEN 2023, Distribution Network Options Assessment (DNOA) Methodology https://www.ssen.co.uk/globalassets/about-us/dso/consultation-library/dnoa-methodology.pdf

includes detailed information for each of the energy generation, demand and storage technologies that are included in the analysis.

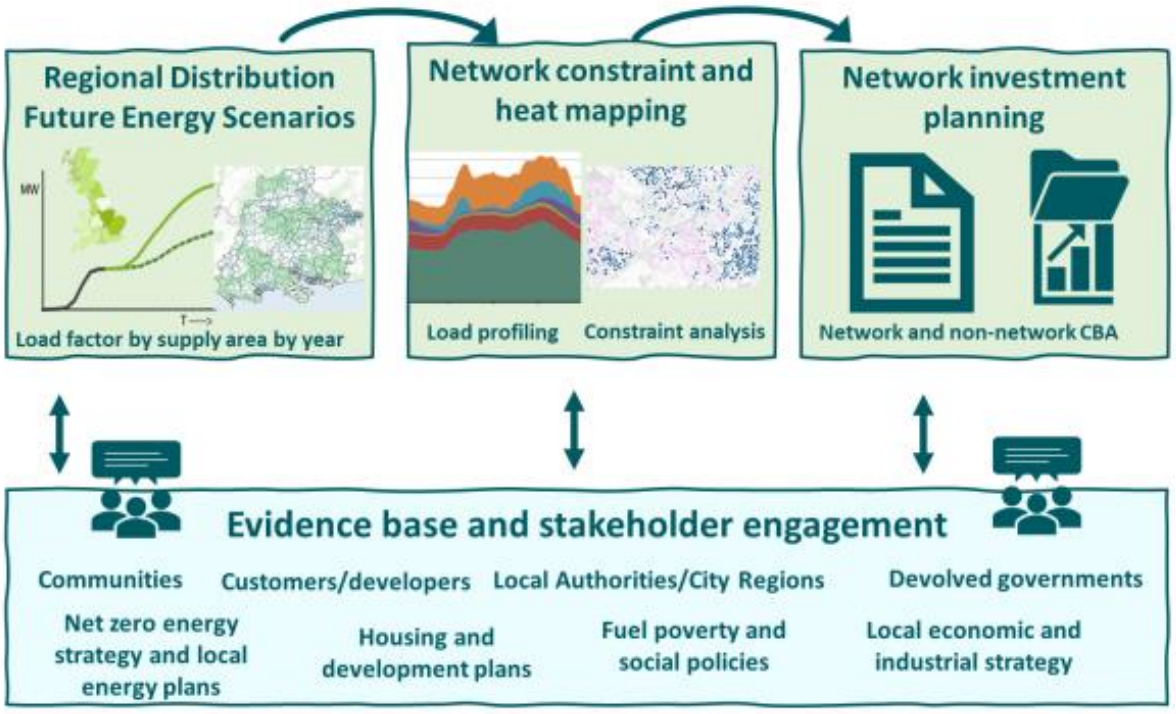


Figure 1 An overview of SSEN's network and investment planning process

SSEN's North of Scotland licence area

The North of Scotland electricity distribution licence area refers to the area served by the low voltage (LV), 11 kV and 33 kV network that is managed by SSEN 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 and includes all of the Scottish Islands groups, such as Shetland, Orkney, the Outer Hebrides and the Small Isles. The licence area covers remote and rural areas, such as the Highlands, Lochside regions, the Cairngorms and Trossachs national parks, and more urbanised areas, such as Aberdeen, Dundee, Inverness and Fort William.

The licence area comprises 14 local authority regions, either wholly or partially, including 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.

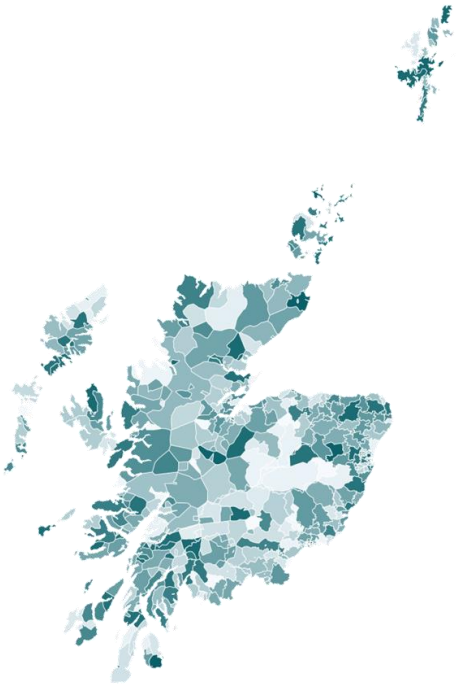


Figure 2 A map of SSEN's North of Scotland licence area and the Electricity Supply Area (ESA) boundaries

North of Scotland licence area baseline

There is currently 3.7 GW of generation and storage capacity connected to SSEN's distribution network in the North of Scotland licence area[4]. Figure 3 illustrates the geographical distribution of key baseline technologies.

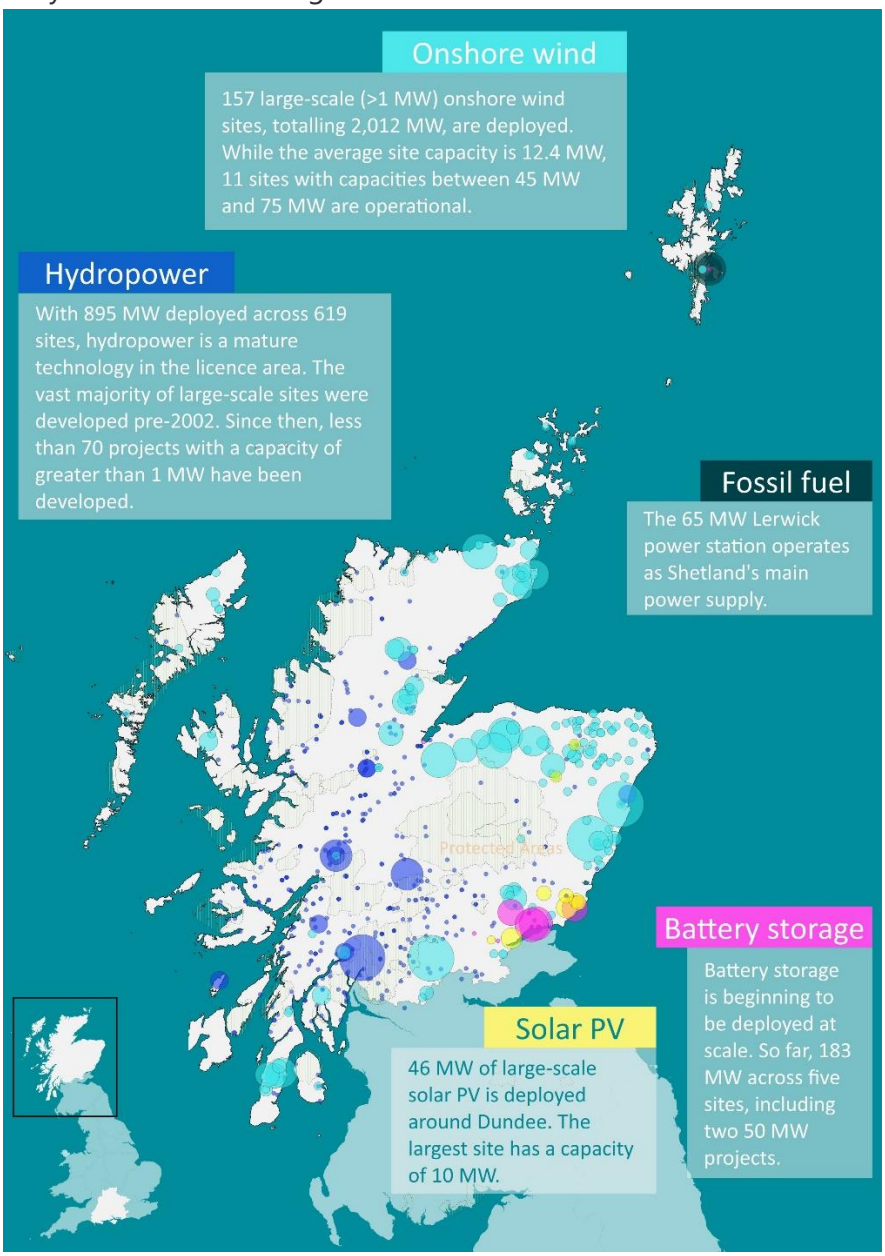


Figure 3 A map of the North of Scotland licence area and location of key baseline technologies

[4] Data correct as of August 2023 according to SSEN's connections database

North of Scotland licence area pipeline

There is 13 GW of generation and storage capacity that either has a connection agreement or an offer to connect to SSEN's distribution network[5]. Figure 4 illustrates the geographical distribution of key pipeline technologies.

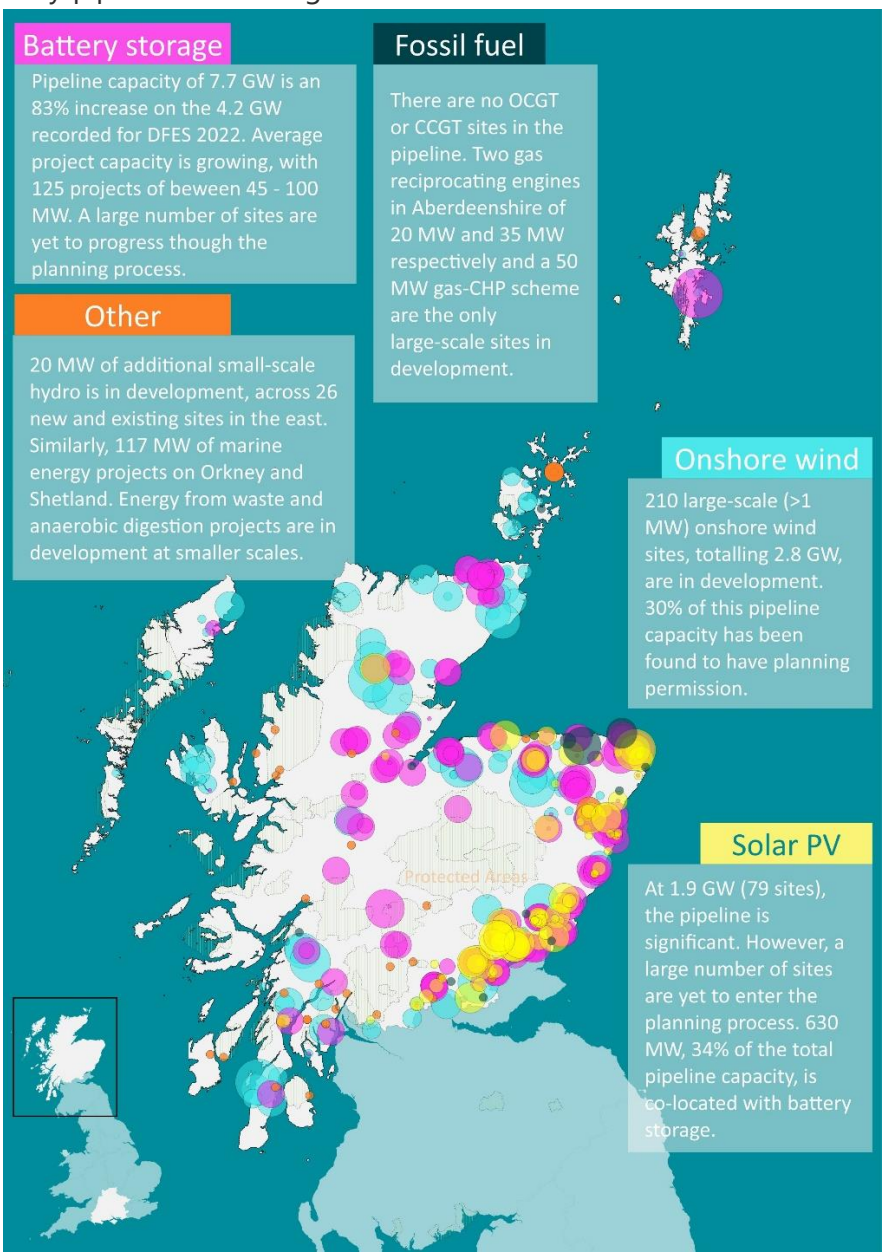


Figure 4 A map of the North of Scotland licence area and location of key pipeline technologies

[5] Data correct as of August 2023 according to SSEN's connections database

North of Scotland baseline technology summary

Renewable generation			
Solar 173 MW	**Onshore wind** 2.2 GW	**Marine** 17 MW	**Hydropower** 895 MW
2 GW of large-scale (>1 MW) onshore wind capacity is already deployed in the licence area, primarily along the east coast. 895 MW of hydropower capacity is also deployed, largely across the south east of the licence area. There is a low deployment of solar to date (<200 MW), which is currently concentrated in the south west of the licence area.			
Waste and bioenergy generation			
Biomass 56 MW	**Waste** 35 MW	**Renewable engines** 31 MW	
Waste-driven energy generation makes up only approximately 35 MW and takes several different forms. Of the three renewable engine sub-technologies, landfill gas makes up more than half of the installed capacity at 21 MW, followed by anaerobic digestion (8 MW) and sewage gas (3 MW).			
Fossil and gas generation			
Diesel 131 MW	**Gas** 45 MW	**Hydrogen generation** 0 MW	
Relative to renewable generation, the licence area has a much smaller deployment of fossil fuel generation, totalling 176 MW. All diesel capacity is made up of island backup generators.			
Sources of demand			**Energy storage**
EVs 10,000	**Heat pumps** 29,000	**Electrolysis** 0 MW	**Batteries** 183 MW
Electricity demand for heat is characterised by large areas of the licence area in the west that are rural and not connected to the gas grid, with a higher proportion of houses having electric heat. Many households still rely on fossil fuels for central heating in the east of the licence area[6]. Approximately 10,000 battery electric cars are currently registered, representing a 50% growth over the course of 2023. In addition, 29,000 households and businesses currently have a heat pump installed. The deployment of large-scale battery storage projects is beginning to ramp up, with 183 MW now deployed. All but 8 MW of this capacity has been commissioned over the past year (2023).			

Figure 5 2023 baseline capacities for electricity distribution connected sources of energy generation, demand and storage in the North of Scotland licence area

[6] https://www.nongasmap.org.uk/

The distribution network in the North of Scotland in 2030 under Consumer Transformation

Renewable generation			
Solar 1 GW	**Onshore wind** 5.2 GW	**Marine** 123 MW	**Hydropower** 940 MW
Distribution network connected renewable generation (solar, wind, marine and hydropower) capacity more than doubles from approximately 3 GW in 2022 to approximately 7 GW by 2030. Onshore wind deployment accounts for the majority of this projected increase in connected capacity, reflecting strong wind resources.			
Waste and bioenergy generation			
Biomass 43 MW	**Waste** 76 MW	**Renewable engines** 50 MW	
Waste and bioenergy generation capacity in the North of Scotland increases from 122 MW in 2022 to 169 MW in 2030. While biomass capacity decreases, growth is driven by advanced conversion technology, incineration and some small anaerobic digestion sites.			
Fossil and gas generation			
Diesel 137 MW	**Gas** 107 MW	**Hydrogen generation** 18 MW	
Diesel back-up generators on the Scottish Islands are projected to remain online in 2030. Fossil gas generation increases from approximately 45 MW in 2022 to 107 MW in 2030. This is driven by the connection of new gas reciprocating engines and CHPs with accepted connections. Some select fossil gas sites near existing hydrogen innovation zones or gas network infrastructure are projected to repower with hydrogen.			
Sources of demand			
EVs 271,000	**Heat pumps** 260,000	**Electrolysis** 83 MW	
The number of electric vehicles (EVs) registered increases significantly in all scenarios by 2030. 260,000 homes and businesses are also modelled to operate heat pumps by 2030. Hydrogen electrolysis projects are modelled to begin connecting to the distribution network, with 83 MW projected in the licence area by 2030.			
Energy storage		**New developments**	
Batteries 3.2 GW		**Domestic** 43k	**Non-domestic** 5.8m
Battery storage capacity significantly increases from 183 MW in 2022 to approximately 3.2 GW by 2030. This is a reflection of the significant pipeline of new sites.		Up to 43,000 new houses could be built and just under 5.8 million sqm of non-domestic floorspace developed by 2030, based on local authority data.	

Figure 6 The distribution network in the North of Scotland in 2030 (Consumer Transformation scenario)

The distribution network in the North of Scotland in 2050 under Consumer Transformation

Renewable generation			
Solar 3 GW	**Onshore wind** 7.3 GW	**Marine** 233 MW	**Hydropower** 1.0 GW
Solar, wind, marine and hydropower generation capacity in the licence area increases further to approximately 11.2 GW in 2050. Onshore wind continues to provide the bulk of capacity, with 7.3 GW projected to connect by 2050. Solar also sees strong growth, with 3 GW projected to connect by 2050.			
Waste and bioenergy generation			
Biomass 66 MW	**Waste** 66 MW	**Renewable engines** 35 MW	
Biomass deployment is projected to grow to 66 MW by 2050, while landfill and waste incineration begins to decommission from the network. In total, approximately 167 MW of waste-driven generation is operating in 2050.			
Fossil and gas generation			
Diesel 0 MW	**Gas** 0 MW	**Hydrogen generation** 71 MW	
No unabated diesel or fossil gas generation is operating on the system by 2050 under any net zero scenario, with all generators replaced with various alternative technologies, including biomass, biomethane, electricity storage or hydrogen-fuelled generation. Hydrogen generation is not projected to see significant deployment in the licence area under a Consumer Transformation scenario, with only 71 MW being deployed by 2050.			
Sources of demand			
EVs 810,000	**Heat pumps** 682,000	Electrolysis 203 MW	
While there is an overall reduction in vehicle numbers by 2050 under all net zero scenarios, by 2050, nearly 810,000 EVs are on the road in the licence area. In addition to this, 682,000 homes and businesses are heated by heat pump technology and the production of low-carbon hydrogen has seen continued development in the licence area, with just over 200 MW of hydrogen electrolysis capacity operating by 2050.			
Energy storage		**New developments**	
Batteries 3.7 GW		**Domestic** 84k	**Non-domestic** 9.7m
Growth in battery storage capacity slows post 2030 and 3.7 GW is deployed by 2050. 260 MW of this capacity is from domestic units.		Up to 84,000 new houses could be built, and just under 9.7 million sqm of non-domestic floorspace developed, by 2050.	

Figure 7 The distribution network in the North of Scotland in 2050 (Consumer Transformation scenario)

2050 spatial deployment of low-carbon technologies under Consumer Transformation

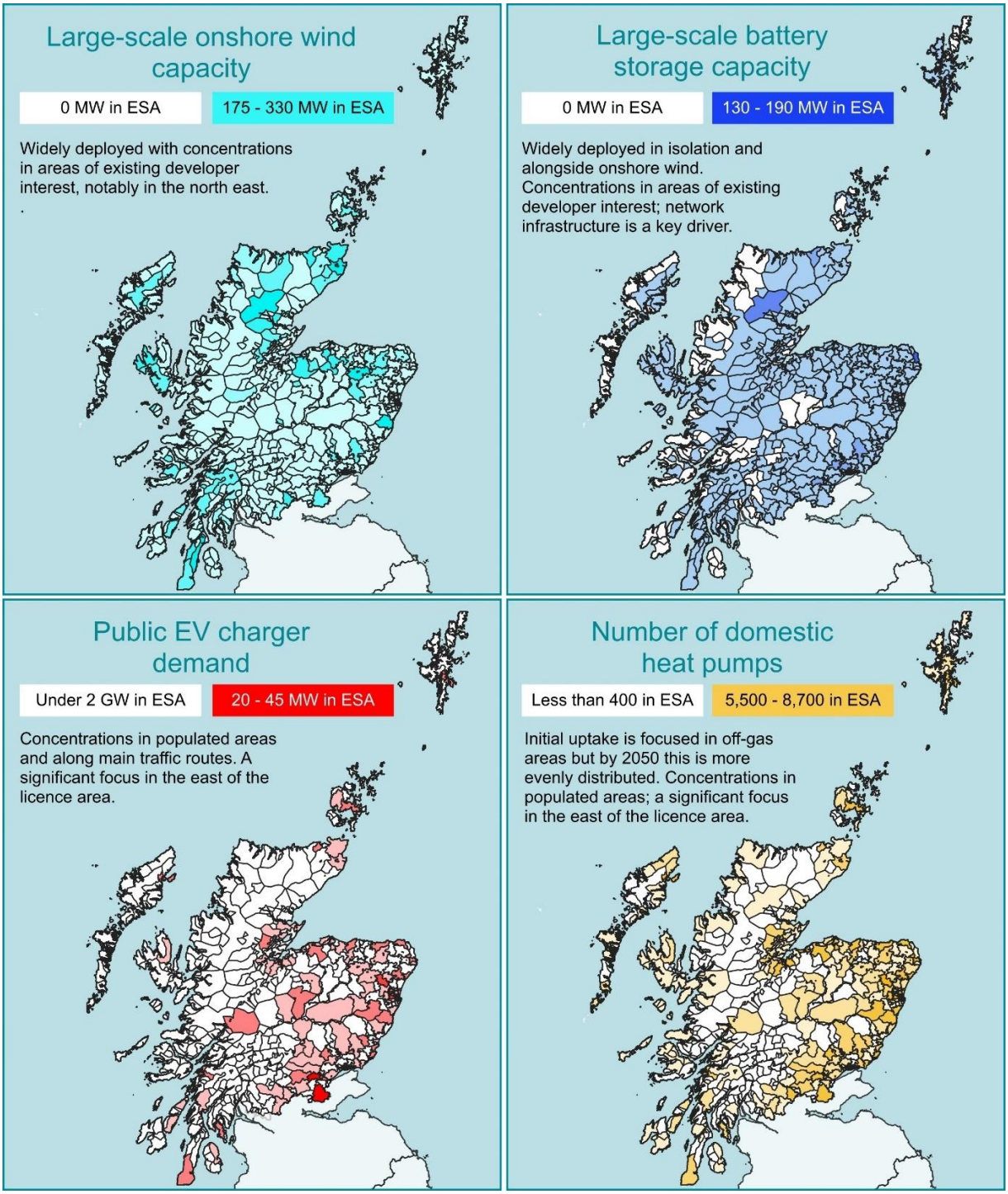


Figure 8 2050 deployment of key technologies in the licence area under a Consumer Transformation scenario

Key influential policy and targets for DFES 2023

Global events continued to impact the UK's energy market in 2023, including the ongoing Russian invasion of Ukraine, the conflict in Gaza and unprecedented extreme weather events. Despite this, the clean energy sector in the UK has continued to develop and build new projects over the last year.

2023 was the hottest year on record in human history[7] with extreme weather patterns seen all over the globe. COP28, in Dubai, resulted in significant commitments to a clean energy transition, with over 130 countries signing the 'Global Renewables and Energy Efficiency Pledge', agreeing to triple renewable energy capacity and double energy efficiency measures by 2030[8], as well as agreeing a roadmap to transition away from fossil fuels.

Steep rises in UK interest rates exacerbated the cost-of-living crisis and pressured consumers to reduce demand, whilst aggravating pre-existing fuel poverty issues. Although this has impacted the viability and choice of low-carbon technologies for some consumers, there has been a continued increase in the uptake of domestic solar PV and EVs across the country. This has driven increased demand on the UK's electricity distribution networks.

The UK government's 'Energy Security Day' in March 2023 brought in a total of almost 50 net zero and energy-related policy documents for the future of energy in the UK. New funding was announced for Carbon Capture and Storage (CCUS), nuclear and hydrogen as well as new oil and gas production in the North Sea. The government also opened applications for the £160m floating offshore wind (FLOW) manufacturing investment scheme to support FLOW to scale up to 5 GW by 2030. However, some previously launched policies were watered-down, including a delay to the ban on the sale of new internal combustion engine cars from 2030 to 2035.

[7] https://climate.copernicus.eu/2023-track-be-hottest-year-ever-whats-next

[8] https://www.cop28.com/en/news/2023/12/COP28-Presidency-launches-landmark-initiatives-accelerating-the-energy-transition

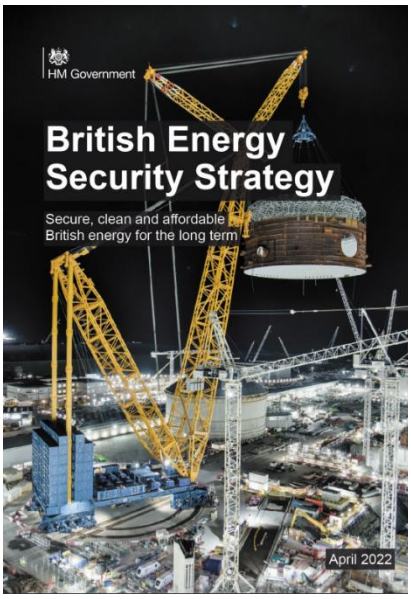
Towards the end of 2023, Ofgem also announced the creation of new regional energy planning organisations, Regional Energy Strategic Planners (RESPs), to support local-level energy planning, which will be overseen by the National Energy System Operator (NESO), formerly known as the Future System Operator (FSO). This new RESP body will have a significant role to play in local and regional energy network planning.

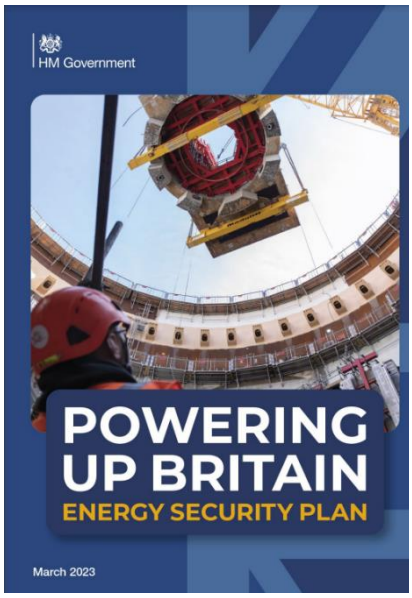
Government policy and its influence on DFES

There has been a continued political focus on energy in 2023, with the announcement of key policies, targets and regulatory reforms, as well as both regional and local government strategies that will impact the UK's energy system. These form key inputs into the DFES analysis and impact the technology projections on both a licence area level and a local level. Examples include:

- **National targets:** deployment targets in national policies are used as reference target figures for national deployment and uptake of specific technologies.
- **National policy:** broader energy policies and mechanisms have been used to justify scenario-specific assumptions for some technologies.
- **Devolved government policy and targets:** devolved government policy and targets have been used directly, alongside national policy, to influence the scenario projections for various technologies in the North of Scotland licence area. The DFES analysis also specifically reflects Scottish policy and ambition in the Consumer Transformation scenario, which provides a focal point for SSEN in the projections.
- **Local policy and targets:** local government strategies and targets have also been used to influence the spatial distribution of technologies.
- **Trade body recommendations and non-governmental plans:** for technologies where regulated government targets and ambitions were not available, policy recommendations on technology target setting from influential trade bodies have been reflected in net zero scenarios.

UK Government policy highlights





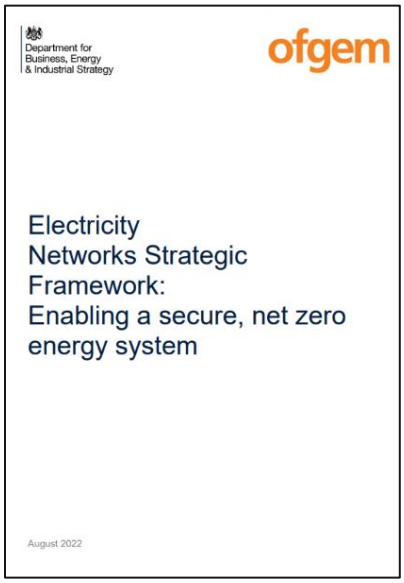
The technology-specific ambitions from the 2022 publication of the **British Energy Security Strategy**[9] and the closely related **Energy Security Plan**[10] and **Net Zero Growth Plan**[11] (both published in March 2023) have been reflected in the three DFES scenarios that are in line with net zero targets. These include targets of:

- 70 GW solar capacity by 2030.
- Up to 50 GW offshore wind by 2030, of which 5 GW is floating wind.
- 10 GW of low-carbon hydrogen, of which 5 GW is produced through electrolysis.
- Up to 1 GW electrolytic 'green' hydrogen operational or in construction by 2025.
- 600,000 heat pumps per year by 2028.
- As many fuel-poor homes as reasonably practicable achieve EPC C by 2030.

[9] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

[10] https://assets.publishing.service.gov.uk/media/642708eafbe620000f17daa2/powering-up-britain-energy-security-plan.pdf

[11] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147457/powering-up-britain-net-zero-growth-plan.pdf



Published in 2022, the **Electricity Network Strategic Framework**[12] outlined plans to develop the FSO and ensure adequate infrastructure is in place to meet the needs of an increasingly decentralised electricity system. The strategic framework included ambitions to remove barriers to grid flexibility via digitalisation and unlock infrastructure development through reformed planning and consenting.

The role of the system operator will be a crucial part of the transition to a net zero power system, and in November 2023, the UK government announced the decision to develop a **RESP** to sit within the FSO. The ambition for the RESP is to work with both the electricity and gas networks, local authorities and wider stakeholders to better enable strategic, whole-system planning of the energy system at a regional level to ensure the inclusion of local needs and ambitions.

The DFES analysis has been using net zero strategies and specific technology targets from local authorities to inform the scenario projection analysis for many years. The announcement of the RESP is a positive step, recognising the importance of local and regional energy planning and how it should work in-tandem with electricity network planning. The implementation of Ofgem's **Access and Significant Code Review**[13] has reduced overall connection charges and introduced non-firm contracts to unlock connections in congested areas of the networks. From April 2023, connection charges for network reinforcement were removed for demand customers and reduced for generation connections. It is likely that these reduced upfront connection costs will accelerate the deployment of some low-carbon technology projects. The implementation of the Access and Significant Code Review has been incorporated into the DFES analysis. More broadly, the allocation of distributed technologies has been modelled in congested ESAs under the three net zero scenarios, reflecting an assumption that this reform will mitigate grid congestion issues in the longer term.

[12] https://www.gov.uk/government/publications/electricity-networks-strategic-framework

[13] https://www.ofgem.gov.uk/publications/access-and-forward-looking-charges-significant-code-review-decision-and-direction

2023 was the first year of the five-year RIIO-ED2 price control period and sees SSEN continue to evolve its **Distribution System Operator (DSO)** capabilities. SSEN has published its 2022 DSO strategy and action plan and subsequently its **DSO acceleration strategy and action plan**[14] in October 2023.

Local Area Energy Plans (LAEPs), led by local authorities, set out the ambitions and resources required to facilitate net-zero energy at a local level. There is not currently a statutory duty for local authorities to produce LAEPs. Of those local authorities who responded to the local energy strategy survey (see page 30), four local authorities across SSEN's two licence areas have LAEPs already in place and a further nine local authorities are in the process of developing a LAEP[15]. DFES analysis seeks to make use of the disclosures in the LAEPs, including specific decarbonisation targets, technology deployment ambitions and regional zoning.

Over the past three years, SSEN has developed the **Local Energy Net Zero Accelerator**[16] (LENZA) tool to assist local authorities in developing LAEPs. LENZA is a geospatial software platform, based on Advanced Infrastructure Technology Ltd's LAEP+ tool. It provides network constraint data to inform local authority planning decisions for the development of new

[14] https://www.ssen.co.uk/globalassets/about-us/dso/dso-action-plan/ssen-dso-strategy-2023.pdf
[15] These figures refer only to the responses received by Regen from local authorities to the Local Energy Strategy Survey as part of the DFES 2023 analysis.
[16] https://www.ssen.co.uk/our-services/tools-and-maps/lenza/

energy assets, both generation and demand. In the future, LENZA may be able to help provide inputs to the DFES process, supporting improved forecasting capability.

A significant number of additional policies were reviewed, analysed and incorporated into the DFES analysis for each of the relevant technology models. Details of these technology-specific policies and targets can be found in each of the technology summary chapters (page 52 onwards in this report).

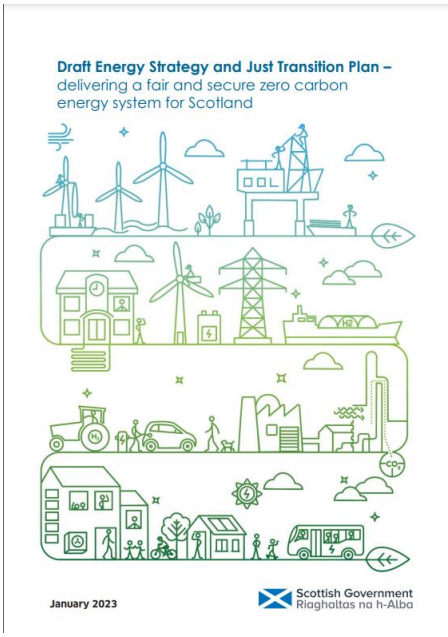
As can be seen in the technology analysis section of this report, the pipeline of contracted projects (mainly prospective solar and battery storage sites) in SSEN has significantly grown in recent years. This is common across the UK and has created a significant connection queue and a potentially detrimental delay on progress to net zero. Off the back of industry responses to this queue, **reforms to the electricity network connections process** have been outlined by the Energy Networks Association and National Grid ESO, and endorsed by Ofgem. These reforms have begun to be implemented, with Ofgem and National Grid ESO working with UK government and across industry to accelerate the process, with an emphasis on 'first ready, first connected' for sites with contracted connections. The Energy Networks Association has published a three-step plan to speed up connections to the grid[17] and National Grid ESO has also launched a five-point plan of "tactical initiatives to help improve the connections process in the short-term"[18]. One of the objectives within National Grid ESO's five-point plan is to accelerate the connections for energy storage projects, recognising the value that storage brings to the system in times of high demand, by issuing non-firm connection offers to battery sites. As these reforms are still very new, the impact on the connection queue in SSEN's licence area and across GB has not yet been realised. In DFES 2023, Regen and SSEN have opted to directly reflect current Statement of Works reinforcement timelines (where known) under the Falling Short scenario, but it is very likely that the connection pipeline will evolve when DFES 2024 analysis is undertaken, with a number of 'shovel ready' contracted projects moving up the queue and a number of more prospective or dormant sites falling away from the connection pipeline.

[17] https://www.energynetworks.org/newsroom/energy-networks-launch-action-plan-to-accelerate-grid-connections

[18] https://www.nationalgrideso.com/industry-information/connections/our-five-point-plan

Scottish Government policy highlights

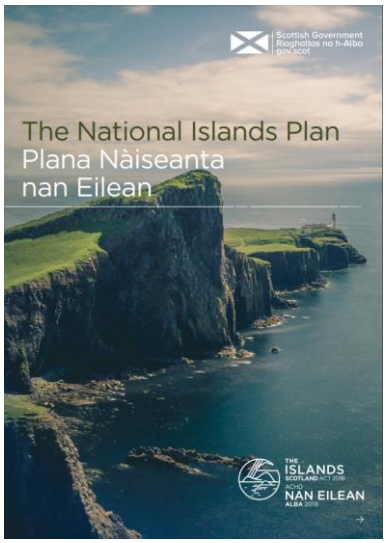
The Scottish Government's draft **Energy Strategy and Just Transition Plan**[19], published in January 2023, sets out specific ambitions and announcements for Scotland to achieve net zero by 2045. These targets have been integrated into the DFES analysis and include:

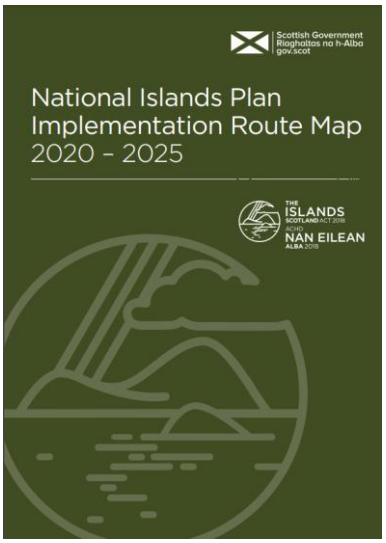


- 8-11 GW of offshore wind by 2030.
- Additional 12 GW of onshore wind by 2030 (20 GW total).
- An announcement for a Wave Energy Scotland 2021–2025 business plan, which includes £18.25 million of investment.
- Support to minimise barriers to deployment of solar PV with an increase in the number of solar installations offering community benefits.
- A £500m Just Transition fund to support Moray and the North East of Scotland to become centres of excellence for the net zero transition.
- A bioenergy action plan.
- Legislation requiring new homes and non-residential buildings to include EV charging points.

The DFES analysis has reflected Scotland's higher ambition towards net zero (at both national and local authority levels), particularly in the Leading the Way and Consumer Transformation scenarios, as well as including both statutory and non-statutory targets.

[19] https://www.gov.scot/publications/draft-energy-strategy-transition-plan/documents/





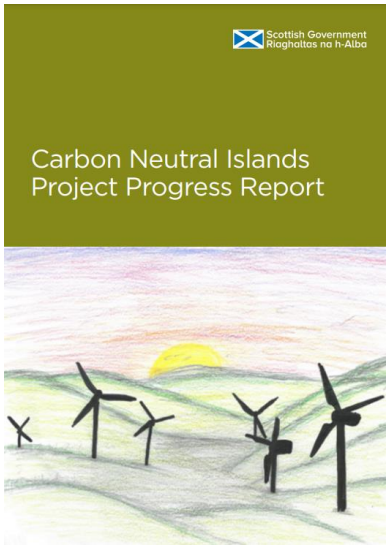
The **National Islands Plan**[20], first published in 2019, provides a framework to improve outcomes for Scottish island communities. In July 2023, the Scottish Government released the **Implementation Route Map**[21] detailing how they are delivering the priorities set out in the National Islands Plan.

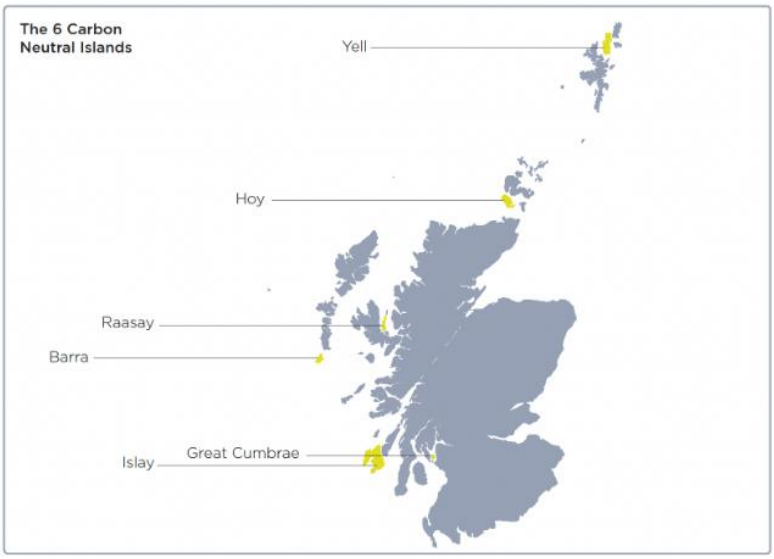
Climate change and energy is covered by Strategic Objective 9, which is "to contribute to climate change mitigation and adaptation and promote clean, affordable and secure energy". Community engagement is a strong thread running through the policy with a commitment to establish an island-specific Community Climate Action Hub. Other commitments relevant to the DFES analysis include:

- To increase the number of renewable assets on Scotland's islands.
- To reduce gas consumption.
- To deliver existing proposals for electricity transmission links to mainland Scotland.
- To focus on the resilience of islands' energy supply networks.
- To increase the number of low-carbon pilot projects across islands.

[20] https://www.gov.scot/publications/national-plan-scotlands-islands/

[21] https://www.gov.scot/publications/national-islands-plan-implementation-route-map-2023/





The Scottish Government published the **Carbon Neutral Islands project progress report**[22] in January 2023. Part of the wider renewable and low carbon energy policy, the Carbon Neutral Islands programme aims to support six islands to become carbon neutral by 2040. The DFES analysis reviewed the progress to date and incorporated this into the assessment of recent and historic uptake trends of low-carbon technologies.

Ofgem approved the need for a **subsea electricity transmission link to Orkney** in July 2023[23] which SSEN estimates will "enable the connection of up to 220 MW of new renewable electricity, from established onshore wind, to emerging marine technologies…"[24]. SSEN Transmission undertook significant stakeholder engagement over the course of 2023 as part of the **Western Isles Connection project**[25], approved by Ofgem in 2019, to consult with stakeholders about the overhead line route alignment and proposed substation connections.

Local Heat and Energy Efficiency Strategies (LHEES)[26] and delivery plans are the Scottish Government's primary mechanism for locally-led heat planning. Regional actions, decarbonisation targets and technology deployment ambitions set out in these have been

[22] https://www.gov.scot/publications/carbon-neutral-islands-project-progress-report/
[23] https://www.ofgem.gov.uk/publications/orkney-transmission-project-decision-final-needs-case
[24] https://www.ofgem.gov.uk/publications/orkney-transmission-project-decision-final-needs-case
[25] https://www.ssen-transmission.co.uk/projects/project-map/western-isles/
[26] https://www.gov.scot/publications/local-heat-energy-efficiency-strategies-delivery-plans-guidance/

reflected in the uptake of low-carbon heating technologies across the North of Scotland licence area.

Technology- and sector-specific targets, including those set out in the **Scottish National Transport Strategy (2nd Delivery Plan)**[27], the **Scottish Government Heat in Buildings strategy**[28], the **Scottish Onshore Wind Policy Statement**[29] and the **Hydrogen Action Plan**[30] have also been reviewed, analysed and incorporated into the DFES analysis for each of the relevant technology models. Details of the technology-specific policies and targets that influenced the DFES analysis can be found in each of the technology summary chapters (page 53 onwards in this report).

[27] https://www.transport.gov.scot/publication/national-transport-strategy-nts2-second-delivery-plan-2022-2023/

[28] https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/

[29] https://www.gov.scot/publications/onshore-wind-policy-statement-2022/

[30] https://www.gov.scot/publications/hydrogen-action-plan/

Stakeholder engagement

The DFES analysis incorporates a wide variety of evidence and data inputs. Although based on four national energy scenarios, the DFES is intended to assess future energy scenarios at a regional, sub-regional and local level. Therefore, the analysis is heavily influenced both by what is connected today, an assessment of known pipeline projects and by stakeholder consultation. To inform the SSEN DFES 2023 analysis, the project team has engaged with a wide range of stakeholders through several different approaches, which include:

Stakeholder engagement for DFES 2023	
	**Interactive online webinars for each licence area,** held in October 2023, where a broad range of regional and energy sector stakeholders were asked their views about the future of energy technologies in their area. In these sessions, SSEN summarised how the DFES outputs are used to inform longer-term network planning. Regen made use of online polling platform Menti to capture both qualitative feedback and quantitative data from stakeholders around specific technology sectors in the relevant licence area.
	A dedicated **Scottish Islands webinar,** also held in October 2023, brought together representatives and residents from the Scottish Islands, including relevant local authorities, local industry and island community representatives. Attendees shared their views on the development of island renewables, the uptake of low-carbon technologies across the Islands, the decommissioning of island diesel generators and other Island-specific topics, such as the Orkney transmission link needs case and the Carbon Neutral Islands programme.

	An **online data exchange for new developments** was established, liaising with the planning departments of the local authorities within SSEN's licence areas. This data exchange enabled Regen to directly engage with local authority planning and housing teams to gain up-to-date information on domestic property developments (of 100 houses or more in scale) and non-domestic developments (which includes plans for new supermarkets, offices, airports etc.).
	An updated **local energy strategy questionnaire** was prepared for 2023 and shared with the environmental and city planning teams for the local authorities across SSEN's two licence areas. The responses and accompanying documentation received from local authorities included individual council plans and ambitions for zero emissions targets, renewable energy development, low-carbon transport, low-carbon heat, waste collection, hydrogen and LAEPs. These responses and documents were used to inform the spatial distribution factors for scenario projections for relevant technologies.
	**Technology and sector-specific interviews** were conducted with project developers, technology companies and other sector representatives to inform the modelling of pipeline projects and test assumptions made about specific sectors or technologies.

Engagement webinars

North of Scotland licence area webinar

Regen worked with members of the SSEN team to host interactive stakeholder engagement webinars in October 2023 to collect views and feedback to inform the DFES analysis. These collaborative sessions sought to:

- Provide a summary of the background, method and purpose of the DFES.
- Road-test assumptions around technology capacity growth and locational distribution factors that determine the scenario projections.

- Tap into local and sector knowledge, insights and ambitions relevant to the licence area.
- Discuss views and insights on new or disruptive future technologies and how they may impact the electricity network in the licence area.

The **North of Scotland regional webinar** brought together representatives from local authorities, community energy groups, project and technology developers and other sector-specific representatives. The webinar had 48 on-the-day attendees and over 80 people registered to attend, who all received copies of the presentation material from the event. This year, the largest proportion of stakeholders was from the 'local authority and government' sector.

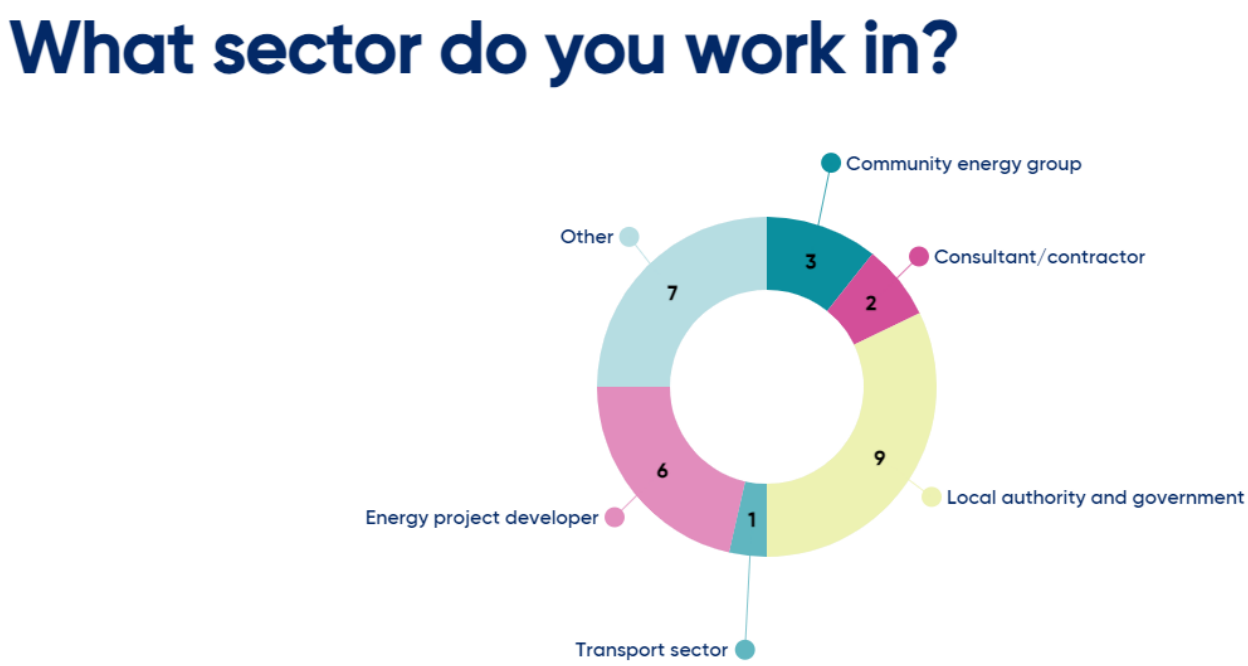


Figure 9 Extract from the North of Scotland regional webinar showing the industry sector of the stakeholders

In addition to an overview of the DFES methodology, an introduction to each of the key technology areas was given. This included low-carbon demand sources (i.e. heat and transport), renewable generation and energy flexibility (i.e. battery storage and hydrogen). For each technology area, Regen presented:

- An overview of the technology.

- Relevant policy updates.
- Deployment projections of each technology in the licence area.
- A series of technology-specific interactive polling sessions using the online voting and live visualisation platform Menti [31] to gather both quantitative and qualitative stakeholder feedback that was subsequently used to inform and modify the DFES analysis.

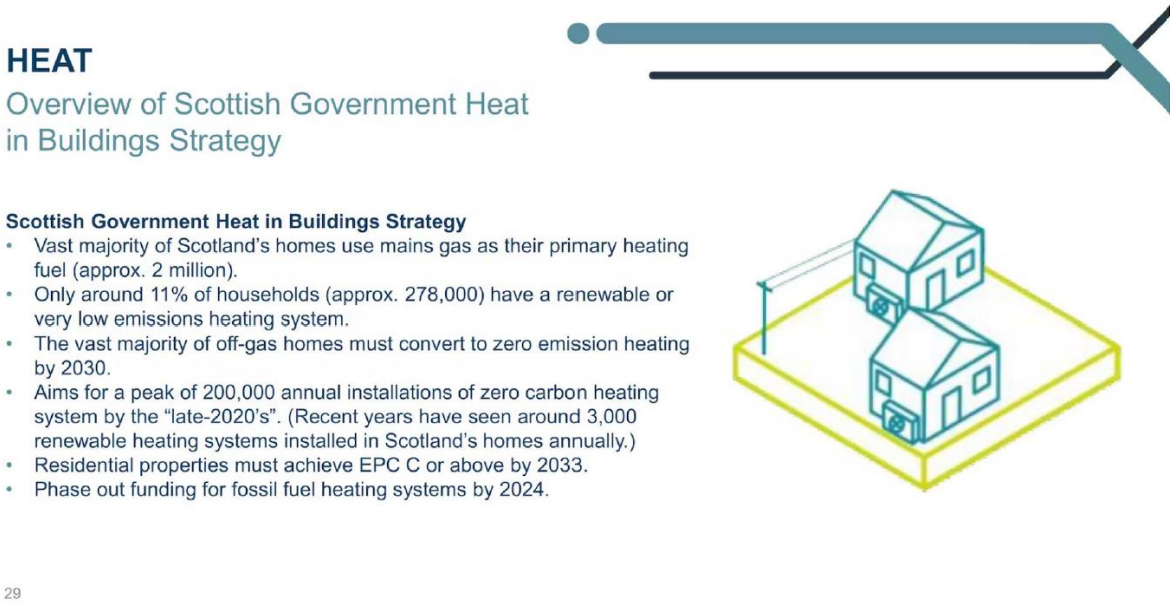


Figure 10 Extract from the North of Scotland regional webinar showing an overview of the Scottish Government's Heat in Buildings strategy

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

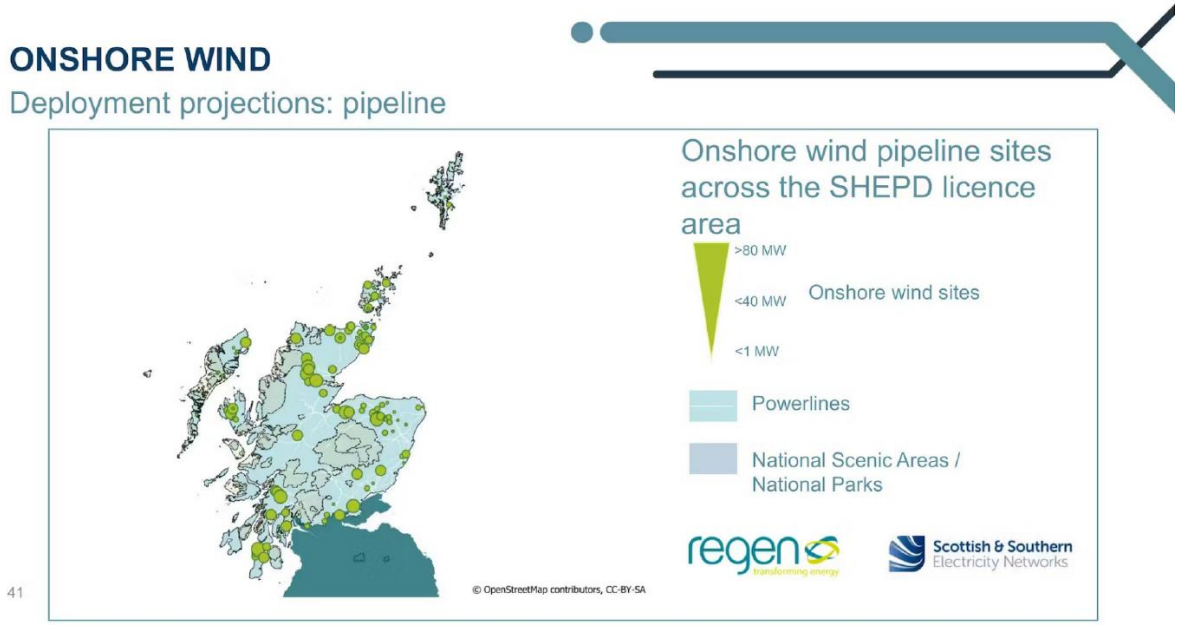


Figure 11 Extract from the North of Scotland regional webinar showing the projected deployment of onshore wind across the licence area

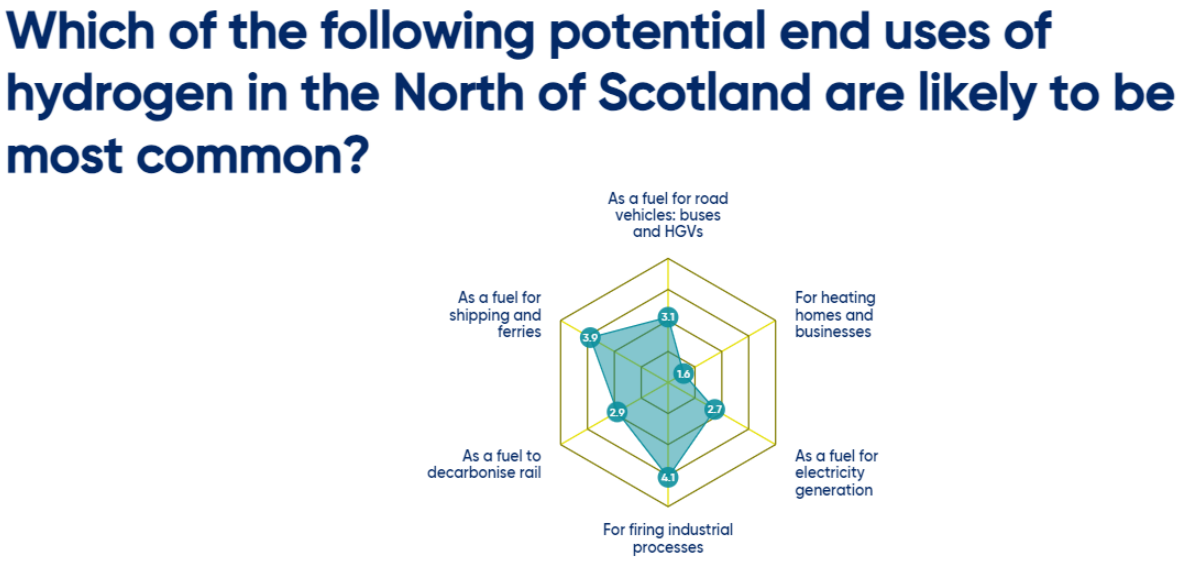


Figure 12 Extract from the North of Scotland regional webinar showing the quantitative feedback stakeholders gave in answer to a question about the future use of hydrogen

Scottish Islands roundtable

Regen and SSEN also held a roundtable event specifically for Scottish Island stakeholders. This was an opportunity for a deep-dive discussion into the energy challenges and opportunities facing the Scottish Islands, as well as seeking feedback from these stakeholders to inform the DFES analysis. The Scottish Islands roundtable hosted 43 stakeholders from across a range of Scottish island communities, as seen in Figure 13.

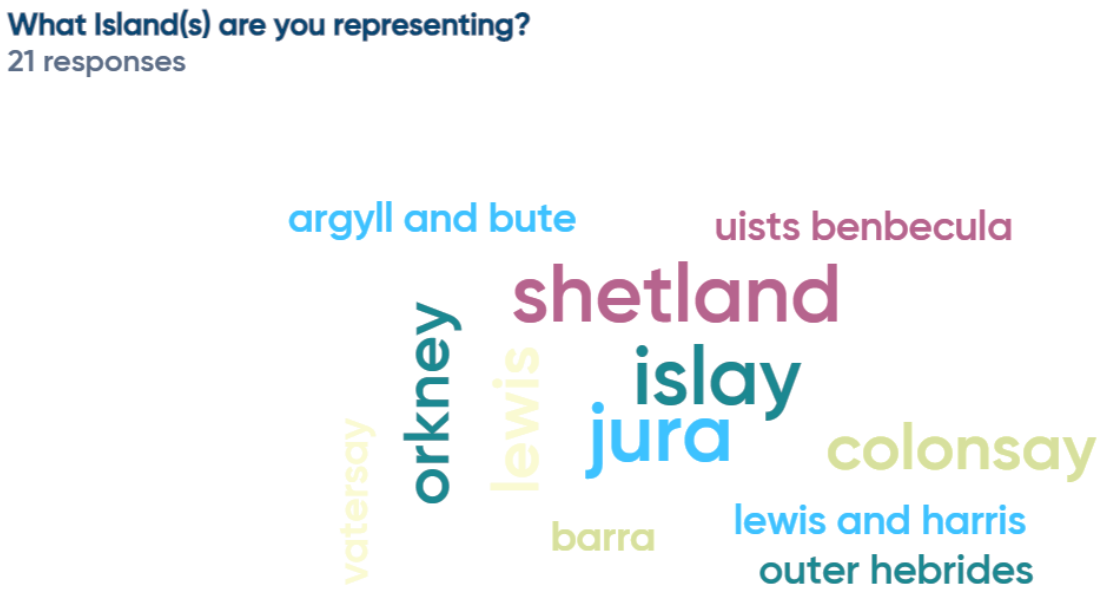


Figure 13 Extract from the Scottish Islands roundtable showing a 'word cloud' of the Scottish islands represented at the event

Feedback from the island stakeholders was sought for each of the key technology areas (low-carbon demand, renewable generation and energy flexibility) and the points raised in the discussion, as well as the qualitative and quantitative feedback gathered, was used to inform the DFES analysis.

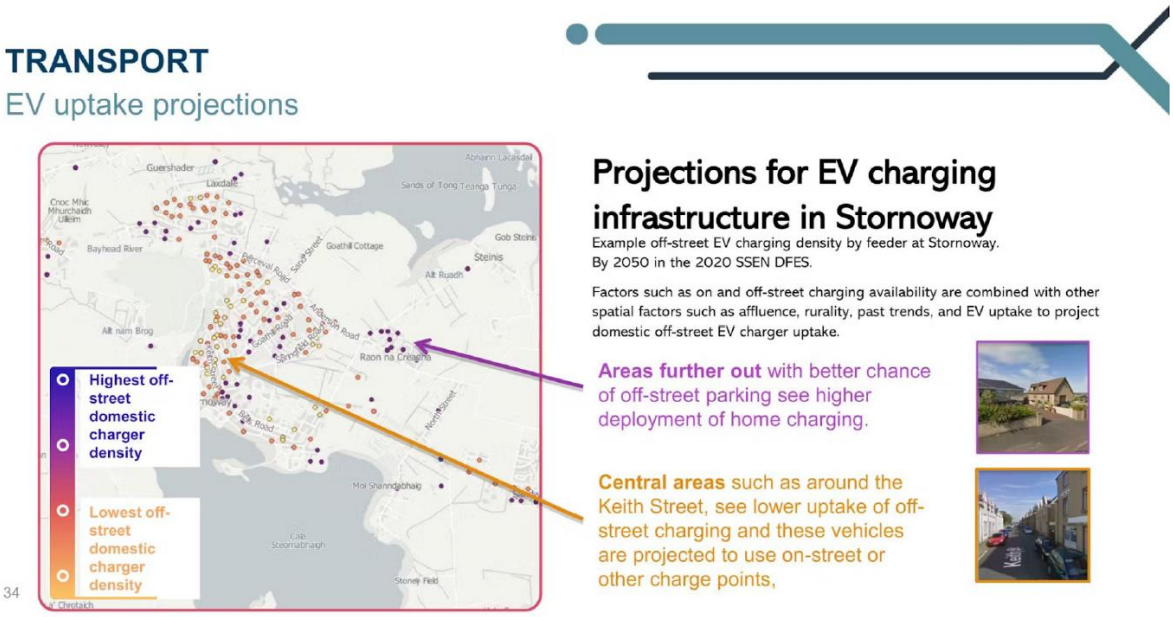


Figure 14 Extract from the Scottish Islands roundtable showing projections for EV charging infrastructure in Stornoway

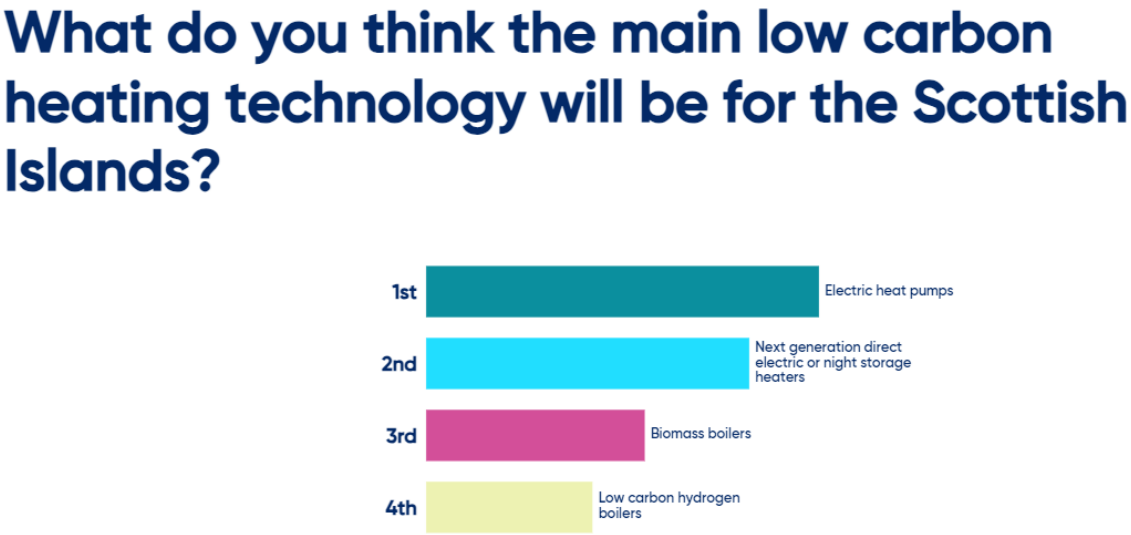


Figure 15 Extract from the Scottish Islands roundtable showing the quantitative feedback stakeholders gave in answer to a question about the future of heating on the Scottish Islands

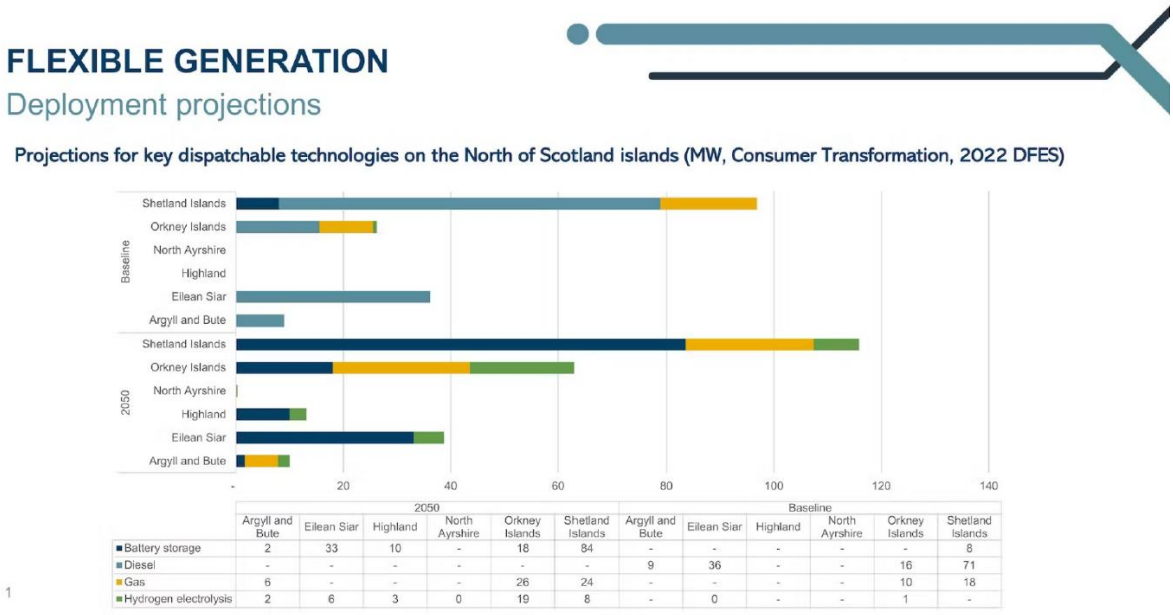


Figure 16 Extract from the Scottish Islands roundtable showing the projections for key dispatchable technologies on the Scottish Islands

Local authority engagement

To further inform DFES 2023, the analysis team collected data from local authority planning departments in SSEN's North of Scotland licence area via an online data exchange. This focused on two elements: details of planned domestic and non-domestic new developments and a local energy strategy survey.

New developments

Regen liaised with the planning departments of local authorities within the North of Scotland licence area and specifically sought to update the registers of:

- **Planned new houses:** limited to strategic housing developments of 100 houses or more.
- **New non-domestic developments (measured in sqm):** categorised by eight commercial and industrial development archetypes which are: office, retail, factory and warehouse, hospital, hotel, medical, restaurant, school and college, university, sport and leisure and other.

Local energy strategy survey

As with previous years, Regen issued a local energy strategy survey to the environmental and climate change project teams within each of the local authorities. For DFES 2023, three new questions were added to this survey, seeking information on whether local authorities had used DFES modelling before and what elements of the data they found useful, as well as a question about the support that is available for low-income households to adopt low-carbon technologies. All responses and document links received were used to influence and evidence the spatial distribution of individual technology projections in this year's DFES.

A summary of the 2023 responses to the local energy strategy survey questions can be seen in Figure 18. A total of eight local authorities responded to the survey in the North of Scotland licence area. This information was used as a key input for the DFES analysis and spatial distribution.

Your local authority's energy strategies - 2023

Questionnaire

SSEN prepares for changing demands by regularly constructing energy scenarios. The questions below on transport, heat, renewable energy, waste collection, hydrogen and emissions ambitions, helps feed local plans and ambitions into these energy scenarios so the networks can be ready for the new demands.
Click here for an example of last year's DFES report

Instructions: 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. You may not have planning jurisdiction over all of the below factors so please just answer the questions where you do have planning powers.

Any questions? Please contact:

ssennewdevs@regen.co.uk

1a	Do you have a **transport** strategy or a low-carbon transport strategy in your area?	Yes/No	--Select transport strategy priority--
b	Do you have plans for the installation of public electric vehicle charge points?	Yes/No	--Select EV charger priority--
c	Do you have any requirements for EV charge points in planning for new developments?	Yes/No	please provide details -->
2a	Do you have a **heat** strategy or low-carbon heat strategy in your area?	Yes/No	--Select priorities for decentralised heat--
b	Do you have plans to expand or build new district heat networks?	Yes/No	--Select heat source technology--
3a	Do you have a **renewable energy** strategy in your area?	Yes/No	--Select technology type--
b	Have you set a renewable energy capacity or other target?	Yes/No	please provide details -->
c	Have you allocated areas in your local plans for renewables?	Yes/No	please provide details -->
4	Do you have a **waste collection** strategy in your area?	Yes/No	--Select food waste collection status--
5	Do you have a **hydrogen** strategy in your area?	Yes/No	--Select technology type--
6	Do you have **zero emissions** ambitions or plans for your area?	Yes/No	--Select best description of publication--
7	Do you have a Local Area Energy Plan **(LEAP)**?	Yes/No	please provide details -->
8	Have you used SSEN's annual DFES modelling in your local net zero planning processe	Yes/No	If you have, please share details about how it has informed your planning processes -->
9	What do you find to be the most useful data that the DFES captures (eg projected EV numbers, heat pumps, large scale energy storage, projected large and small scale renewable capacity etc)		answer here-->
10	Do you have any retrofit or low carbon technology rollout programmes in your area that consider or target low income households or vulnerable areas?	Yes/No	If so – could you provide details of where, and for which technology(ies) -->

Figure 17 Survey extract from the 2023 local energy strategy survey

Y = Yes, a strategy **is** in place

N = No, a strategy **is not** in place

ID = A strategy is **in development**

* Blank entries indicate **no response** from the Local Authority to the question.

Local Authority	Transport strategy	Public EV charger plans	EV charging in new developments	Heat strategy	Heat networks	RE strategy	RE targets	Development areas
Aberdeen City	Y	Y	Y	Y	Y	Y		Y
Aberdeenshire	Y	Y	Y	ID	ID	Y	N	N
Angus				ID	ID			
Argyll and Bute		Y	Y	ID	ID	Y	N	N
Dundee City	Y	Y		ID	ID	N	N	N
Moray	Y	Y	Y	ID	ID	Y	N	Y
Na h-Eileanan Siar	Y	ID	Y	Y	N	Y	Y	Y
Perth and Kinross	ID	Y	ID	ID	ID	Y	N	Y
Shetland Islands	Y	Y	N	ID	N	ID	N	N
Stirling	Y	Y		Y	Y	Y	N	Y

Local Authority	Waste collection	Hydrogen strategy	Emissions target	Local Area Energy Plan	DFES used in planning	Vulnerable households scheme
Aberdeen City	Y	Y	Y	Y		
Aberdeenshire	Y	N	Y	N		Y
Angus			Y	N		
Argyll and Bute		N	Y	N	N	Y
Dundee City	Y	N	Y	ID		ID
Moray	Y	Y	Y	N		Y
Na h-Eileanan Siar		Y				
Perth and Kinross	Y	ID	Y	ID	Y	Y
Shetland Islands	Y	ID	Y	N	Y	Y
Stirling		N	Y	Y	N	

Figure 18 Summary of the 2023 local energy strategy survey responses

(Note: This is not a complete list of the local authorities in the North of Scotland licence area. This table only shows the local authorities who responded to the survey as part of the 2023 DFES stakeholder engagement.)

Targeted sector and development engagement

The Regen project team also engaged directly with individual energy project developers and sector representatives to better understand their plans and ambitions for each of the technology sectors included in the DFES analysis. This engagement included:

- Email exchanges with project developers holding contracted connection offers with SSEN for individual generation or storage projects. Developers were asked about their development progress and timelines. Responses received were used to inform future connection timelines for individual sites, under each of the scenarios.
- Interviews with technology companies, including emerging and innovative technology sectors.

Direct stakeholder feedback			
Engagement	**Technology sector**	**Organisation engaged**	**Summary of input/feedback**
Engagement in DFES 2023	**Solar PV**	Dundee City Council, Solar Investment Company Ltd., Wessex Solar Energy and Low Carbon UK, NEScol, Whirlwind Renewables, ESB, Orkney Community Wind, Bluestone energy, Gridserve, Cambridge Power and Voltis.	Engagement on project-specific status and planned construction and energisation dates. A total of 25 sites have had deployment assumptions informed by developer engagement in DFES 2023. This included information about delays or cancellations, as well as projects that are currently in construction.
	Battery storage		
	Onshore wind		
	Offshore / marine generation	Isle of Wight representatives and EMEC (project partner of Perpetuus Tidal Energy Centre - PTEC).	Feedback provided was used to inform the scenario projections for marine energy generation support and build-out timelines.

	Hydrogen electrolysis	Storegga, ZeroAvia, Protium, IAAPS and Hyppo.	Regen gathered input from organisations that had published plans for hydrogen projects to request an update on progress. Protium and IAAPS have successfully completed electrolyser projects. The other organisations were at the planning phase with their projects.
	Fossil gas and hydrogen-fuelled generation	Mercia Power Response, Conrad Energy, DESNZ	Developers provided insights into their long-term approach for decarbonising their fossil sites (including switching to battery storage, hydrogen or CCUS). DESNZ provided an update on policy thinking, in particular that its focus is on sites in industrial cluster zones.
Previous engagement that has applied to DFES 2023	**Solar PV**	Innova/Novus, BNRG, Wessex Solar Energy, Aura Power, Solar2, Roadnight Taylor, Grey Associates, Constantine Wind Energy and Boralex	Engagement on project status and planned deployment dates from previous years' DFES was also carried forward. A total of 27 sites have had deployment assumptions informed by engagement with developers in DFES 2022.
	Battery storage		
	Onshore wind		
	Hydropower	British Hydropower Association	The British Hydropower Association was engaged to confirm resource assessment and high projection numbers from FES 2022. The engagement confirmed that

			hydropower highly depends on funding mechanisms and developments in micro-/pico-scale schemes. Feedback influenced the assumption of growth to micro-/pico-scale projects contributing to growth under the Consumer Transformation scenario.
	Hydrogen electrolysis	Storegga	A discussion of hydrogen business models in 2022 revealed that the long-term direction of electrolysis may be prioritised towards large-scale transmission-connected projects and small-scale distribution-connected projects may be more prominent in the near-term.
	Liquid Air Energy Storage (LAES)	Highview Power	Previous engagement with Highview Power highlighted that the location of LAES plants in the North of Scotland licence area could be based on a potential to co-locate with large-scale renewable energy generation sites or large-scale data centres, due to cooling demand.

Table 1 Summary of sector specific engagement undertaken to inform DFES 2023

Further detail of the sector- and technology-specific engagement undertaken, the feedback received and how it was applied to the DFES modelling can be found in each of the technology

summary chapters included in this report. In addition, the Regen project team have continued to engage with the National Grid ESO FES team both as part of the launch of FES 2023 and throughout the ongoing analysis, to discuss and share modelling assumptions and market intelligence.

DFES methodology

The DFES analysis projects the capacity of distribution network connected sources of energy generation, demand and storage across the licence area. The DFES methodology comprises five key areas:

Stage	Description	
1		The **technologies** that are in the scope of the future scenario analysis.
2		The **scenario framework** that defines the overarching societal, technological and economic 'worlds' that the DFES scenario projections sit within.
3		The **stakeholder engagement evidence and input** that is used as direct inputs into the scenario modelling.
4		The **analysis stages** undertaken for each technology when developing and modelling scenario projections.
5		The **geographical distribution** of the projections to sub-regional (11 kV substation) or LV levels.

Table 2 Summary of DFES methodology

Technologies in scope

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

Technology class	Description
Electricity generation technology classes	• **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.
Electricity storage technology classes	• **Battery storage:** Grid-scale, commercial and domestic battery storage asset classes. • **Liquid Air Energy Storage (LAES), a**lso referred to as cryogenic energy storage: demonstrator-scale LAES plants connecting to the distribution network.
Future disruptive sources of electricity demand	• **Electric vehicles (EVs)**: cars, vans, motorbikes, LGVs, HGVs and buses. • **EV chargers**: on-street for domestic properties, off-street domestic, car parks, destination, workplace, fleet/depot, en-route local and en-route national. • **Electricity-fuelled heating and cooling technologies:** air source and ground source heat pumps, hybrid heating, direct electric heaters and domestic air conditioners. • **Hydrogen electrolysers.** • **Data centres.** • **New properties:** strategic housing developments as well as new commercial and industrial developments.

Table 3 Summary of technologies in scope of DFES 2023

The National Grid ESO Future Energy Scenarios 2023 framework

The 2023 DFES analysis has continued to use and reconcile to the National Grid ESO Future Energy Scenarios 2023[32] (FES 2023) as the assessment's overarching scenario framework. This framework also provides:

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

The FES 2023 scenario framework is based on two key axes: speed of decarbonisation and level of societal change, as seen in Figure 19.

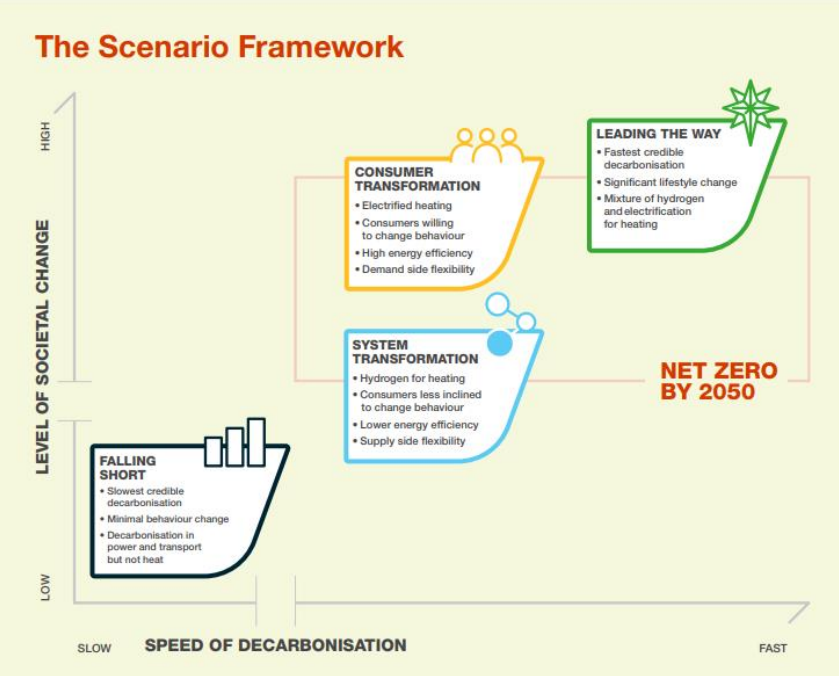


Figure 19 FES 2023 scenario framework (source: National Grid ESO)

[32] National Grid 2023, Future Energy Scenarios 2023 https://www.nationalgrideso.com/future-energy/future-energy-scenarios-fes

For some technologies, the DFES and FES projections are well aligned in the near, medium, or even long term. However, other aspects of the energy system have very different outcomes between the DFES and FES analyses. A description of each of the scenarios can be found in Table 4. The technology summary chapters within this report also outline specific scenario variances seen under each technology and how the DFES applies to them. Where available, FES 2023 Grid Supply Point (GSP) projection data has been used to complete an SSEN DFES 2023 to FES 2023 reconciliation. Regional building blocks were sometimes unavailable or not directly comparable due to sub-technology classifications. In these cases, national FES 2023 projections have been used to undertake a higher-level reconciliation.

Consumer Transformation The net zero target is met in 2050 with measures that have a greater impact on consumers and is driven by higher levels of consumer engagement. 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. A typical homeowner will use an electric heat pump with a low temperature heating system and EV. The system will have higher peak electricity demands managed with flexible technologies including energy storage, Demand Side Response (DSR) and smart energy management.	**Leading the Way** The net zero target is met by 2046. We assume that GB decarbonises rapidly with high levels of investment in world-leading decarbonisation technologies. Our 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 measures 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 mostly from electrolysis powered by renewable energy.
System Transformation The net zero target is met in 2050. The typical domestic consumer will experience less change than in Consumer Transformation as more of the significant changes in the energy system happen on the supply side. 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	**Falling Short** This scenario does not meet the net zero by 2050 target. There is still progress on decarbonisation compared to today, 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. EV take-up grows more slowly, displacing petrol and diesel vehicles for domestic use. Decarbonisation of other vehicles is slower still with continued reliance on diesel for HGVs. In 2050 this scenario

high, mostly produced from natural gas with CCUS.	still has significant annual carbon emissions, short of the 2050 net zero target.

Table 4 National Grid ESO FES 2023 scenario descriptions (source: National Grid ESO)

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. This assessment defines the baseline year as the end of the 2022 calendar year.
2. The **near-term development pipeline** is then assessed by reviewing projects with network connection offers with SSEN or planning applications with the relevant local authority. 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 variation can be seen across the four scenarios over the 2030s and 2040s.
4. Annual licence area projections of either MW of capacity (e.g. of onshore wind) or the number of units (e.g. of heat pumps) are then **geographically distributed** across the licence areas. More detail on the nature and granularity of this spatial distribution is outlined below.

Some scenario variations 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, see Figure 20.

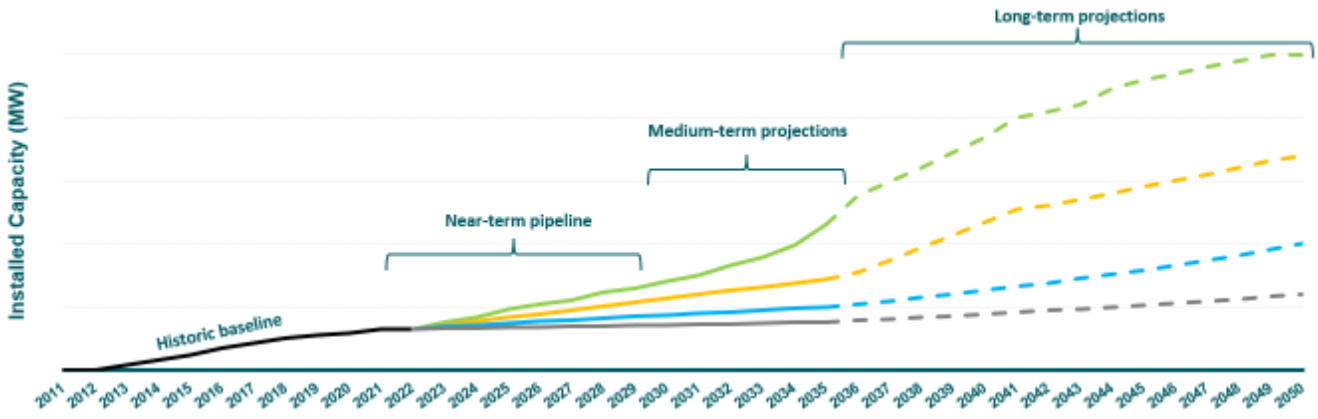


Figure 20 Illustrative stages of DFES scenario analysis

Technology and scenario uncertainty

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

Over the medium and longer term, projections reflect the underlying systemic, technological and societal scenario assumptions defined for each technology within the FES framework. This is also augmented by levels of certainty provided by, for example, regional and national policies. Adopting legally binding net-zero emissions targets and government energy and net-zero strategies clarifies future energy pathways.

The key assumptions made in this analysis include:

- Distributed renewable energy generation capacity will continue to significantly increase.
- Unabated fossil fuel electricity generation will decline, more rapidly in some areas than others.
- The shift to decentralised energy generation assets will continue (to some degree).
- The electrification of transport is already in progress and will continue to accelerate.
- Low-carbon hydrogen will begin to be produced and could play a key role in decarbonising industrial processes and some forms of transport. The scale and location of hydrogen production and use is unclear.

- Further energy efficiency deployment will take place 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, especially in hydrogen innovation zones.

There are, however, a number of uncertainties when undertaking scenario projections for a broad range of technologies and sources of demand. The key uncertainties in the DFES analysis include:

- The range of different outcomes assumed across the FES 2023 scenario framework.
- National, and devolved, government regional and local policy.
- Commercial and financial.
- Technology development and capability.
- Consumer adoption and behaviour.
- Local spatial distribution factors.
- Transmission vs distribution network connection decision.
- Uncertainties related to international markets and impacts of global conflicts.

At an individual technology level, uncertainty is considered a key part of the analysis and is reflected in the range of scenario outcomes presented. The technology-specific assumptions that have been made are summarised in each technology summary chapter.

DFES geographical distribution

The final stage of the DFES modelling is to estimate the geographic spread of the scenario projections across the licence area. This provides granular, locationally distributed data that the SSEN Network Planning teams can use to inform long-term network investment at specific locations or for individual substation assets. The DFES geographically distributes licence area projections to **Electricity Supply Areas** (ESAs). An ESA is a geographical zone representing a block of demand or generation sharing upstream network infrastructure.

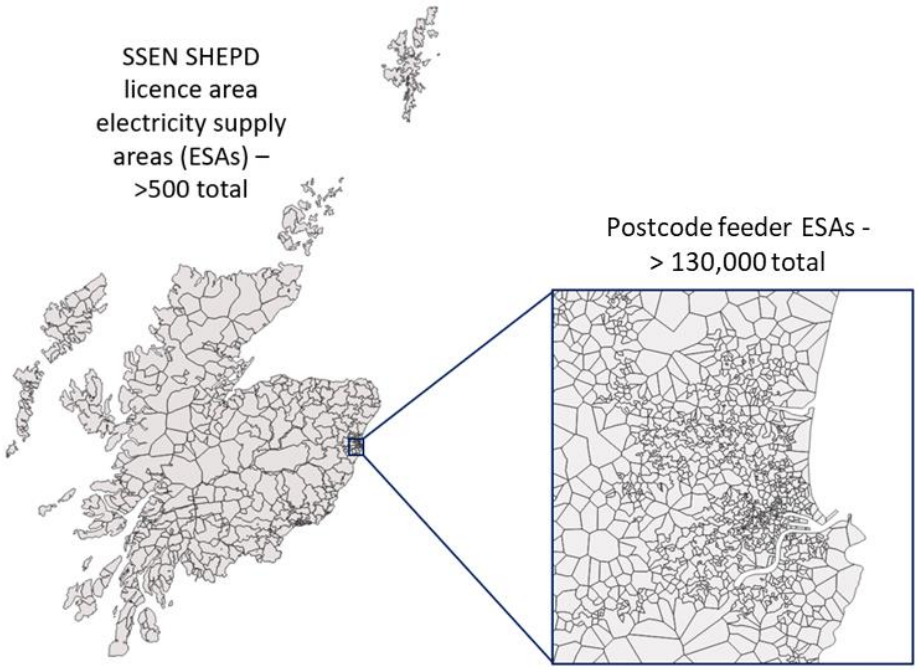


Figure 21 Map of 11 kV and feeder ESAs in the North of Scotland licence area

In the North of Scotland licence area, for large generation and storage technologies, projections are distributed to approximately 500 individual 11 kV primary ESAs. ESAs are smaller in size in areas of high population density. Therefore, ESAs falling within urban areas might equate the size of a small urban borough, whereas ESAs situated in rural areas will cover a larger geography. DFES projections have been designed to be aggregated to support network analysis at higher voltage levels or to local authorities or other regional boundaries for local energy planning purposes.

DFES 2023 scenario projections for EVs, EV charger capacity, domestic heat pumps, rooftop PV and domestic battery storage are distributed to either secondary distribution substations or individual LV feeder lines serving small groups of customers. This level of granularity corresponds to roughly a postcode or street-level analysis.

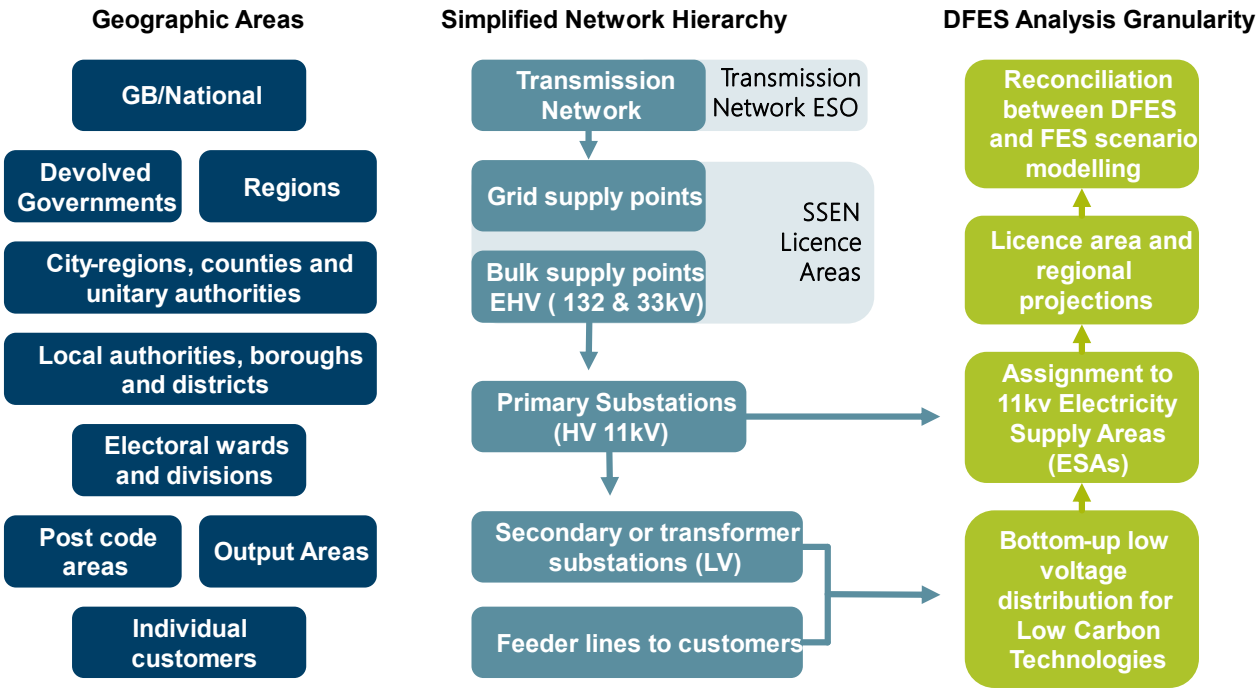


Figure 22 Network hierarchy (and associated geographic area) that determines the DFES analysis granularity for the spatial distribution to ESA

Multi-voltage tier distribution

For DFES 2023, Regen has completed a multi-voltage tier distribution for all known baseline and pipeline projects that hold a connection agreement (or connection offer) with SSEN. These sites are assessed not just for their geographical location, but also for the voltage tier of the distribution network they connect to. The main connection point for lower capacity assets is 11 kV primary substations. Higher capacity assets may connect at higher voltage tiers, such as 33 kV or 66 kV bulk supply points. This multi-voltage tier distribution complements the existing spatial distribution to 11kV and LV ESAs.

Spatial distribution factors

The DFES analysis incorporates key relevant spatial distribution factors for each technology building block. These factors are based on 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 their targets and strategies for specific

technology sectors, has also specifically influenced the spatial distribution factors for the SSEN DFES 2023.

For example, the DFES analysis integrates several spatial distribution factors for domestic EVs, which include:

- The number of vehicles per household (sourced from Census data).
- Affluence levels (sourced from Census data).
- Type of vehicles (sourced from Department for Transport).

The DFES projections currently indicate that households with high affluence, a high number of vehicles per household and pre-existing ownership of a petrol and/or diesel car in an urban area are most likely to have a high uptake of EVs in the future. These factors affect the near-term projections most strongly before moving to a more equitable projection in the medium and long term.

Another example of the spatial distribution factors used in the DFES analysis for 2023 is the EPC and Census data used in Regen's heat model. This models domestic buildings in each feeder area into around 30 archetypes, based on the combination of existing heating technology, building type, tenure, construction age (used as a proxy for energy efficiency) and potential for district heating. The final stage of analysis is to then develop scenario projections for each of the building archetypes, in terms of converting from the current heating technology to a heat pump, district heat connection or resistive electric heating, between now and 2050.

A full list of each of the spatial distribution factors underpinning and included in the modelling are described in more detail within each technology summary chapter (page 53 onwards in this report).

Large-scale battery 'Storage Planning' scenario

The pipeline of battery storage projects with connection offers in the UK has continued to significantly increase over the past 2-3 years[33]. This is reflected in in both SSEN licence areas, currently totalling 16 GW, as shown in Table 5.

The scale of this growth is unprecedented when viewed against other technologies assessed in the DFES. The proportion of this significant development pipeline that will move through to build-out and commissioning is also highly uncertain. As a result, the DFES 2023 analysis continues to include a fifth scenario, in addition to the four defined under the FES National Grid framework, for battery technologies: the '**Storage Planning'** scenario. This scenario provides a view to 2050 that assumes almost all of the known battery storage pipeline projects will connect. In reality, not all projects will come to fruition, as financial and planning challenges will cause setbacks, delays or projects to be abandoned altogether, and this likelihood is reflected in the four main FES scenarios. The Storage Planning scenario enables a view of what the electricity system would look like if all battery storage sites currently holding a connection agreement were to connect to the network.

Licence area	Pipeline			
	DFES 2020	DFES 2021	DFES 2022 *Incl. quote issued*	DFES 2023 *Incl. quote issued*
Southern England	0.8 GW	1.6 GW	5.3 GW	8.2 GW
North of Scotland	0.3 GW	0.4 GW	4.2 GW	7.8 GW
SSEN total	**1.1 GW**	**2 GW**	**9.5 GW**	**16 GW**

Table 5 Summary of prospective battery storage projects in SSEN's licence areas

[33] Electricity Storage Network Conference 2023, *Grid connections – is a revolution or evolution on the horizon for electricity storage?* https://youtu.be/zS73b1X2bdo

	Granted/Under construction	Application submitted	Pre-planning	No information
Storage Planning	100%	100%	100%	91%
Leading the Way	100%	100%	100%	14%
Consumer Transformation	97%	100%	15%	20%
System Transformation	97%	100%	5%	11%
Falling Short	95%	7%	5%	5%

Table 6 Proportion of SHEPD battery storage projects modelled to connect in the licence area, by scenario

(Note: other variables such as scale of site, business model, co-located project details and capacity market records also determine if sites are modelled to build out.)

Supporting studies

DFES reports for Local Authorities

The DFES analysis and engagement has become a key part of SSEN's long-term network planning and investment processes. Both SSEN and Regen recognise the importance that this annual study for both SSEN licence areas must provide context, evidence and trajectories for the evolution of regional and local energy systems. As well as moving to make the DFES data more accessible, two new guidance documents have been produced as part of DFES 2023, specifically for the local authorities in SSEN's two licence areas. These reports provide a summary of how DFES data and analysis can be used by local authorities to inform local planning processes, such as LAEPs and LHEES. They also include signposts and guidance on how to interact with and make use of DFES data that SSEN is making available on its data portal.

These guides are published here.

Consumer vulnerability and just transition study

Capturing consumer vulnerability within the DFES allows for a more accurate modelling of scenarios and technology uptake, while supporting more effective targeting of vulnerability overall. Accounting for vulnerability also allows questions of fairness to be built into the scenario modelling.

As part of DFES 2023, an additional study has been completed to design a specific vulnerability and just transition distribution within the wider DFES analysis. This builds on the evolution of SSEN's Vulnerability Future Energy Scenarios (VFES) project, which has developed a new tool for predicting vulnerability dynamically over time using machine learning.

Heat has been identified as one of the most pressing issues from a citizen and vulnerability perspective and this study overlaid additional vulnerability metrics and factors to the heat model, within the Consumer Transformation scenario, to understand where changes are likely to impact vulnerable consumers. This analysis was informed by additional direct engagement with fuel poverty charities and social and equalities organisations to get a more in-depth view

of the specific needs and barriers that different vulnerable groups face to more accurately model technology uptake and distribution overall.

The output of this analysis can be found here.

Outer Hebrides Net Zero Load Growth evidence summary

SSEN's RIIO-ED2 business plan included proposed investments in 15 subsea cables to enable the transition to net zero and maintain security of supply for specific Scottish Islands. Through SSEN's final business plan dialogue with Ofgem, the funding for some of these cables was determined to be assessed under an investment re-opener, the Hebrides and Orkney Whole System Uncertainty Mechanism (HOWSUM).

Figure 23: SSEN HOWSUM whole system optioneering assessment methodology

SSEN commissioned Regen to support the HOWSUM assessment by collating a body of evidence around future electricity load growth on the island groups, building on relevant scenario projections from DFES 2022 and an updated view of current connection baselines and pipelines from DFES 2023. Additional desktop research and industry engagement was undertaken to gain further insight into future electricity loads across industries that are not currently included in the DFES technology scope, such as maritime decarbonisation, aviation, distillery electrification and aquaculture.

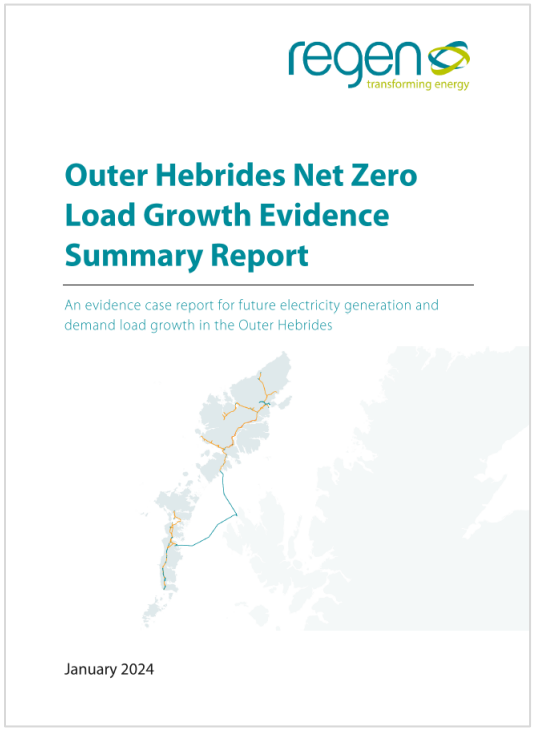


Figure 24 Regen load growth summary report for the Outer Hebrides island group

This study identified future electricity needs across these Scottish Island groups to inform the network investment requirements to enable future uptake of renewable generation and low-carbon technologies, allowing for both net zero and security of supply. The analysis and evidence resulting from this study were combined with SSEN's wider evidence base, as well as a companion cost-benefit analysis (completed by engineering consultants Jacobs) and fed into the HOWSUM dialogue and application process with Ofgem in January 2024.

SSEN has recently published documentation related to its **HOWSUM** application on its website, as well as the Outer Hebrides Net Zero Load Growth Evidence Summary that Regen provided[34]. The Inner Hebrides and Orkney Net Zero Evidence Summary is also published on Regen's website[35].

SSEN's Data Visualisation Platform and Open Data Portal

SSEN's data portal[36] is a single point of access to all the data SSEN publishes. This catalogue of data will bring visibility to SSEN's network assets, their location, their usage, and their performance.

[34] https://www.ssen.co.uk/globalassets/about-us/projects-and-live-works/howsum/outer-hebrides-net-zero-network-investment-study---regen.pdf

[35] https://www.regen.co.uk/project/hebrides-and-orkney-future-load-growth-investigation/

[36] https://data.ssen.co.uk/

The aim of the portal is to engage with all data consumers from local authorities, SSEN's supply chain, flexibility providers, energy suppliers as well as anyone with an interest in achieving net zero.

The current open data portal contains a load summary view of SSEN's transformers, starting with baseline loadings and includes low carbon technology growth across the network for all four FES scenarios. The next iteration of the data portal is currently in development and will include the 2023 DFES datasets along with several functionality improvements.

Net Zero Strategic Plans

The aim of SSEN's Net Zero Strategic Planning process is to "provide the capacity on the network to deliver net zero by 2050 while retaining a clear focus on safety and reliability"[37]. These documents aim to communicate long-term network plans at a regional level to local authorities and other stakeholders involved in local area energy planning.

The results of the DFES analysis feed into this process. All four scenarios are considered and Consumer Transformation is currently taken as the most credible 'best view' for future network requirements. SSEN engages with local stakeholders to develop these plans and analyses future investment requirements at all voltage levels, to ensure network development meets customer needs and addresses capacity and load constraints.

[37] https://www.ssen.co.uk/globalassets/about-us/dso/consultation-library/dnoa-methodology.pdf

Technology summaries

The DFES 2023 projections comprise 20 separate technology sector analyses. The following technology summaries detail the specific modelling, assumptions and evidence used to produce the scenario projections for each technology sector as well as the key differences when compared to DFES 2022. Table 7 (below) categorises the technologies included in the DFES analysis 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

Table 7 Categorisation of DFES 2023 technologies

Onshore wind

Summary of modelling assumptions and results

Technology specification

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

Technology building blocks: **Gen_BB015 - Large-scale (≥1 MW) onshore wind; Gen_BB016 - Small-scale (<1 MW) onshore wind**

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

Technology	Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Large-Scale (≥1 MW)	**Falling Short**	2,012	2145	2879	3263	3878	4158	4247
	System Transformation		2394	3176	3706	4799	5050	5229
	Consumer Transformation		3400	4987	5695	6505	6948	7050
	Leading the Way		2951	3983	4769	5669	6181	6312
Small Scale (<1 MW)	**Falling Short**	167	169	172	175	178	181	183
	System Transformation		169	174	179	183	188	193
	Consumer Transformation		180	195	211	229	251	275
	Leading the Way		172	178	188	200	215	233

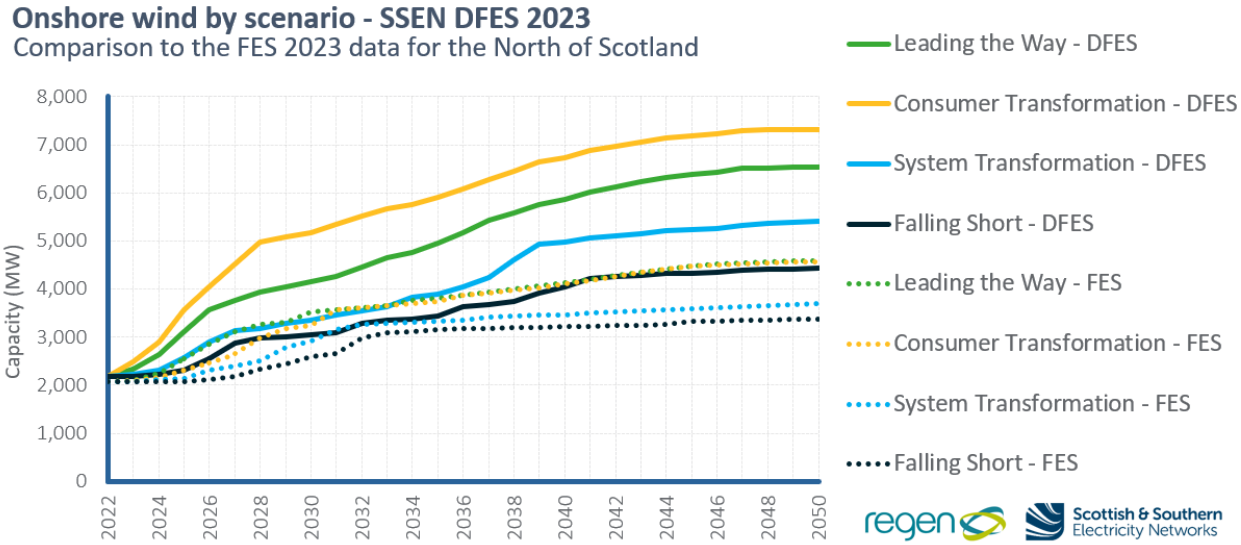


Figure 25 Onshore wind projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- There are currently 482 onshore wind sites, totalling 2,148 MW, deployed in the North of Scotland licence area. These are concentrated in the east of the licence area, with a significant number of larger-scale projects (>10 MW) deployed around the Moray Firth.
- There are 112 sites with connection agreements with SSEN totalling 2,814 MW. This pipeline also mainly comprises larger sites (>10 MW) around the Moray Firth and in the north region of the licence area. There are also some additional developments planned on Orkney, Shetland, the Outer and Inner Hebrides and in the south west of the licence area.
- Future projections for onshore wind capacity in the North of Scotland licence significantly increases in the mid-to-late 2020s, reflecting the large, growing pipeline and a supportive policy environment:
    - In December 2022, the Scottish Government adopted a target of 20 GW of onshore wind capacity by 2030[i] and committed to establishing an Onshore Wind Strategic Leadership Group to oversee the delivery of this target.
    - The Contract for Difference Allocation Round 5 (AR5) was favourable for onshore wind, allocating nearly 1.5 GW of capacity across 24 sites. All sites except one are in Scotland.

- Ofgem's recent Access SCR[ii] has reduced overall connection charges and introduced non-firm contracts, enabling projects to connect in congested areas of the network.

- A wind resource assessment and feedback from engaging wind developers and sector representatives has informed long-term projections in the DFES. As a result, large-scale capacity could reach 7 GW by 2050 under the **Consumer Transformation** scenario. The lowest scenario, **Falling Short**, sees 4.4 GW by 2050.
- Onshore wind projections in DFES 2023 are broadly similar to DFES 2022, despite projections reducing for onshore wind between FES 2022 and FES 2023. DFES 2023 onshore wind projections are largely unchanged due to the existing Scottish Government onshore wind ambition and similar scale pipeline. Although FES 2023 projections for onshore wind have reduced across the UK, the projections for onshore wind in FES 2023 in the North of Scotland licence area have increased.

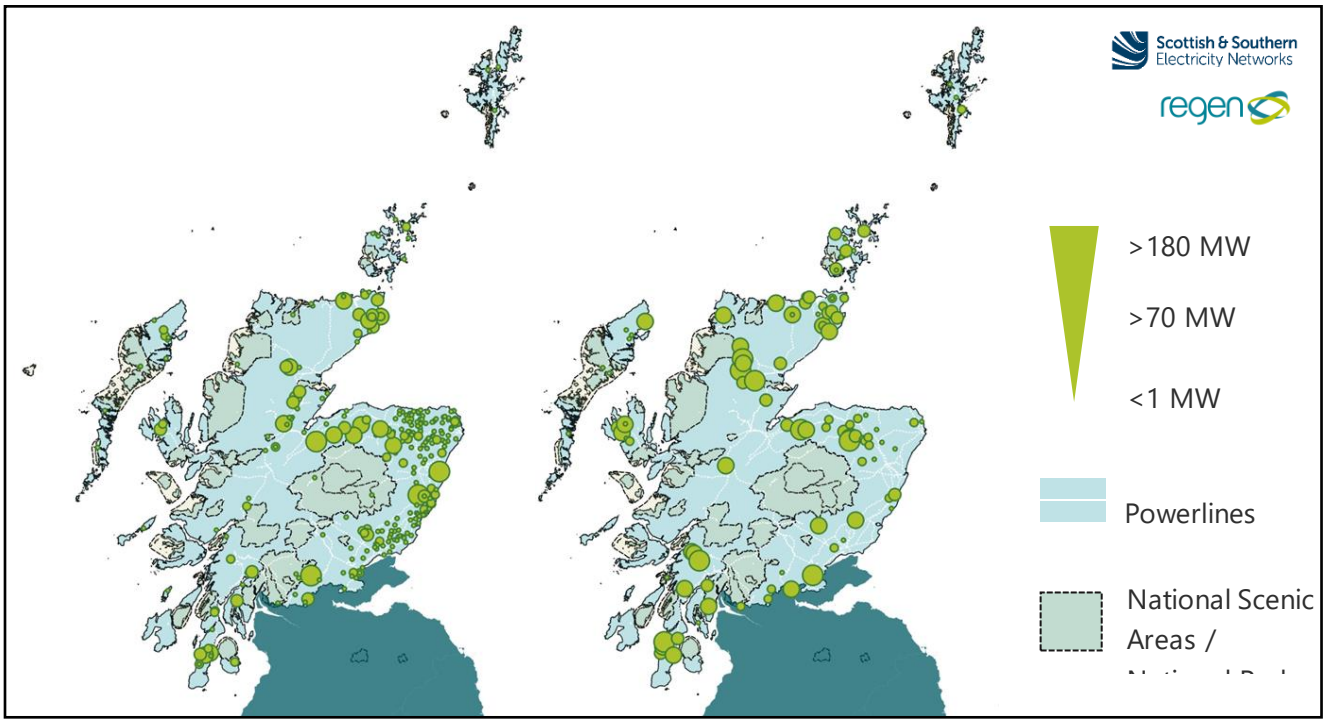


Figure 26 Baseline and pipeline onshore wind deployment in the North of Scotland licence area, August 2023.

Modelling stages

Baseline (2022)			
Scale	**Number of sites**	**Total capacity (MW)**	**Description**
Total	482	2,179	There has been a 47 MW increase in the baseline since DFES 2022, largely the result of Fairburn Wind in Orin commissioning in 2022.
Above 1 MW	157	2,012	The average site capacity is 12.4 MW, with only seven sites individually over 50 MW. The largest site currently connected is the 75 MW Mid Hill wind farm, located southwest of Aberdeen
Below 1 MW	323	167	Most small-scale onshore wind sites were funded through the Feed-in Tariff, with over 100 MW of capacity connecting between 2011 and 2016 in the licence area. Since 2017, only 15 small-scale sites, totalling c.37 MW, have been connected.

Pipeline (2023-2033)	
Number of pipeline sites	**Total capacity (MW)**
111	2,814

Pipeline analysis			
Status	**Description**	**Sites**	**Capacity (MW)**
Under Construction	A 2.3 MW site in the Highlands and an 8 MW site in Perth & Kinross are both under construction. This constitutes 0.3% of the total pipeline capacity.	2	10.3
Planning Permission Granted	Nearly 860 MW has been found to have planning approval in the licence area, equating to c.30% of the total pipeline. This includes 17 sites that are over 30 MW, the majority of which are in the Highland local authority area.	33	862
Planning Application Submitted	A little under 500 MW of capacity has been found to have submitted planning applications, equating to c.17% of the pipeline. Six of these sites are 45-80 MW in size.	12	474

Pre-planning	Sites in pre-planning make up 18% of the pipeline capacity. This includes the 68 MW Strathcarron (Braelangwell) site in the Highlands.[iii]	20	517
No information/ other	27% of the pipeline capacity could not be found in planning. Relative to solar and battery storage, this is a much smaller percentage of capacity with no planning information. These sites are only modelled to build out under **Consumer Transformation**.	35	751
Planning refused, withdrawn or expired	7% of the pipeline (just under 200 MW) has seen planning applications rejected, withdrawn or expired. These nine sites are not modelled to build out under any scenario.	9	199

Planning logic and assumptions (percentage of capacity modelled to come online)

The scenario assumptions around the proportion of pipeline sites and capacity that make it through planning at each stage are derived from a statistical analysis of the REPD.

Scenario	Planning Granted or Under Construction	Planning Application Submitted	Pre-planning	No information	Years from Planning Submitted to completion
Falling Short	100%	100%	No capacity taken forward	No capacity taken forward	5-16 years
System Transformation	100%	100%	100%	No capacity taken forward	4-14 years
Consumer Transformation	100%	100%	100%	100%	2-10 years
Leading the Way	100%	100%	100%	No capacity taken forward	2-10 years

Repowering logic

The repowering of baseline sites reaching the end of their operational life with more efficient and larger turbines is supported in the Scottish Government Onshore Wind Policy Statement.[i] In the projections, repowering drives a proportion of the capacity growth from the early 2030s to the mid-2040s. The four scenarios vary by how soon a site could be repowered after commissioning and to what additional capacity percentage. Sites below and above a 5 MW threshold are treated differently, with higher repowering potential for sub-5 MW sites.

	Falling Short	System Transformation	Consumer Transformation	Leading the Way
Repowering year delay	25	25	25	25
Large-scale repowering	+25%	+25%	+50%	+40%
Small-scale repowering	--	+50%	+100%	+100%
Repowering capacity by 2050 (MW)	439	525	1,075	900

Scenario projections

The medium and long-term projections for onshore wind are subject to scenario assumptions around levels of societal change, the impact of renewable energy targets and the viability of different business models.

In the medium term, higher levels of deployment continue in all net zero scenarios. This is driven by pipeline sites already in development and new projects being developed in areas of high wind resource and fewer planning constraints. One key factor that is applied to varying degrees in this period, is the impact of the Scottish Government's onshore wind policy on driving distribution scale sites in the licence area.

Developers are expected to continue to bid into future CfD auctions, with ambitious scenarios assuming that the CfD scheme enables an accelerated development of onshore renewable energy. However, given the increasing competitiveness of the auctions, and the growing maturity of subsidy-free business models, the continuing support of the CfD is not assumed to be a prerequisite for continued deployment under all scenarios.

Regen's longer-term analysis is driven by our in-house onshore wind resource assessment, expressed through planning applications and the pipeline analysis and augmented by onshore wind developer interest. The resource assessment accounts for protected areas, proximity to homes, and availability of suitable wind speeds and network. With some of the best wind resource in the country, the North of Scotland licence area will continue to be a prime location for distributed onshore wind in all scenarios.

Scenario	Description	Capacity by 2035 (GW)	Capacity by 2050 (GW)
Falling Short	Under **Falling Short**, future capacity uptake broadly aligns with the growth rate over the past ten years. Few projects are projected to build out beyond the known pipeline.	3.4	4.4

	Under this scenario, projects on GSPs, subject to a Transmission Statement of Works (SoW) were modelled to build out only after the SoW completion year. This results in an accelerated projection in the late 2020s. **Falling Short** assumes low impact towards renewables targets, local ambition, and poor planning friendliness, so overall capacity by 2050 is significantly lower than the three net zero scenarios.		
System Transformation	More of the known development pipeline builds out under **System Transformation** than in **Falling Short**, resulting in a growth rate of onshore wind capacity being slightly higher than that of the past decade. In the late 2030s, assumptions about ambition, planning friendliness and repowering result in accelerated deployment. However, **System Transformation** assumes a greater proportion of future wind capacity is delivered by larger projects connecting to the transmission network (132kV and above in the licence area), so the resultant growth of onshore wind capacity on the distribution network out to 2050, is not significantly higher than historic deployment rates.	3.9	5.4
Consumer Transformation	Under **Consumer Transformation**, a large proportion of the pipeline builds out, resulting in a near-term acceleration of connected capacity. It is assumed that 4.3 GW of the 20 GW 2030 Scottish Government onshore wind target is provided by projects connecting to the distribution network in the North of Scotland. Repowering of older sites also adds an additional 1.1 GW of capacity from 2030-2045. The long-term projection assumes favourable conditions for further development in the licence area, resulting in 7.3 GW of distributed onshore wind deployed by 2050.	5.9	7.3
Leading the Way	Under **Leading the Way**, similar assumptions around the near-term delivery of pipeline projects are applied under **Consumer Transformation**. This results in an accelerated	5.0	6.5

	deployment of pipeline onshore wind projects. However, under **Leading the Way**, distribution scale sites are not as critical in meeting The Scottish onshore wind target, with a greater reliance on transmission scale sites. The longer-term projection to 2050 assumes favourable conditions for development in the licence area, and growth continues to 2050, with the repowering of older sites adding an additional 0.9 GW of capacity. By 2050, 6.6 GW is deployed under this scenario.		

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation
Baseline	The FES 2023 baseline for onshore wind in the North of Scotland licence area is 2.1 GW, which is slightly lower than the 2.15 GW identified in the 2023 DFES analysis. The reason for this small variance is unknown.
Pipeline	In the near term, the analysis of known pipeline projects has resulted in a higher and faster rate of capacity growth in the DFES, than occurs in the same period in the FES 2023 regional data. Alongside the visibility of a large pipeline, this variance may stem from projects being built and targeting commissioning in the next few years. Projected commissioning years have been modelled in the DFES based on direct feedback from individual project developers.
Projections	The FES 2023 projections under **System Transformation** and **Falling Short** see deployment from 2032 onwards. The DFES 2023 sees moderate, continued capacity growth in the same timeframe, due to baseline projects being modelled to repower in these years. The FES 2023 projections under the **Leading the Way** and **Consumer Transformation** scenarios show sustained capacity growth to 2050, with approximately 1 GW added in 2030-2050. However, in the DFES 2023, these scenarios are modelled to reflect a more ambitious and supportive environment for wind power in Scotland. As a result, 2 to 2.3 GW (respectively) of new capacity is modelled to connect to the distribution network in the same period.
Overarching Trend	The higher rate of annual deployment and resultant cumulative capacity by 2050 seen in the DFES 2023 is notably higher than the FES 2023. This reflects current data on sites coming forward, current policy direction and very favourable wind resource in the licence area.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Onshore wind resource assessment	New projected onshore wind capacity, not including the repowering of existing sites, is based on Regen's onshore wind resource assessment. This assessment considers relevant factors such as wind speed, landscape designations, dwelling proximity and peat land.
Island interconnectors	Several islands in the North of Scotland rely on new interconnectors to facilitate new renewable generation projects such as onshore wind. Based on research and discussion with developers on these islands, the following assumptions have been made: • SSEN is assessing the long term requirements and security of supply considerations for a number of subsea cables supplying the Scottish Islands. This is being assessed through the Hebrides and Orkney Whole System Uncertainty Mechanism (HOWSUM) project, that Regen is supporting SSEN with. • The Needs Case for the Orkey to Caithness subsea cable has now been met and approved by Ofgem. Developers are aiming to connect in 2025/26.[iv] • The Western Isles transmission reinforcement commissions in 2027.[v] Except for **Falling Short**, this is not assumed to delay current pipeline sites with positive planning evidence. However, much of this additional capacity will be allocated to an individual onshore wind project: the 300 MW Stornoway Wind Farm that has secured a CfD. • Several use cases for green hydrogen are tethered to onshore wind development using surplus generation. This is prevalent around the Scottish Islands. • An EU energy transition pilot has identified the Outer Hebrides as a strong area for the development of onshore wind.[vi] The Shetland transmission reinforcement commissions in late 2024.[vii] No pipeline sites are currently impacted.
Planning friendliness and local ambition	Analysis of the REPD identified local authorities which have historically approved a higher percentage of onshore wind planning applications. This was used to inform the near-term scenario projections on which pipeline projects may be successfully built-out. However, this is a snapshot that may not fully reflect local authority ambition in the longer term and so it was not used as a major factor in the projections in the medium and long term. Council Climate Action Scores [viii] were used in the medium and short-term

	projection years with an understanding that current local government initiatives may not reflect long-term local authority ambition.

Relevant assumptions from National Grid FES 2023

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

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
At the North of Scotland stakeholder engagement webinar, local stakeholders responded to three polls on the future of onshore wind development in the licence area.	On the future balance of distribution and transmission connected onshore wind in the licence area: 24 attendees responded, with half responding that a greater capacity of onshore wind could connect at transmission level in future. This outcome is reflected in the DFES in **Falling Short** and **System Transformation**. On the proportion of the current project pipeline that will eventually be developed and in what timeframe: 21 responded with a range of views on connection capacity and timeframes. This aligns well with the range of pipeline logic applied under the four DFES scenarios. On the likelihood of 6-7 GW of distribution connected onshore wind in the licence area by 2050: 23 attendees responded (including seven wind developers), with a majority believing this was an unlikely prospect, and land/resource availability was the most cited reason for this. Whilst an ambitious 2050 projection remains under **Consumer Transformation** and **Leading the Way**, a lower long-term projection for distributed onshore wind is reflected under the **Falling Short** and **System Transformation** scenarios, where 2050 capacity does not exceed 5.4 GW.

[i]Scottish Government 2022, *Onshore wind policy statement*. https://www.gov.scot/publications/onshore-wind-policy-statement-2022/#:~:text=Sets%20out%20our%20ambition%20to,an%20onshore%20wind%20sector%20deal

[ii] Ofgem 2022, *Access SCR decision and direction*. https://www.ofgem.gov.uk/publications/access-and-forward-looking-charges-significant-code-review-decision-and-direction

[iii] The Highland Council 2022, *Braelangwell wind farm planning application*. https://wam.highland.gov.uk/wam/applicationDetails.do?keyVal=PUH8K9IH0AI00&activeTab=summary

[iv] Renewables.biz 2022, *Orkney 28MW wind farm*. https://renews.biz/82710/orkney-gets-nod-for-28mw-wind-farm/

[v]SSEN 2022, *Western Isles Connection Project*. https://www.ssen-transmission.co.uk/globalassets/projects/projects/western-isles-downloads/arnish-booklet-artwork-digi-single-pages.pdf

[vi] Project RIPEET. https://ripeet.eu/our-regions/scotland

[vii]Ofgem 2021, *Shetland HVDC link – Project Assessment*. https://www.ofgem.gov.uk/sites/default/files/2021-09/Shetland%20HVDC%20Link%20Project%20Assessment_0.pdf

[viii] Climate Emergency UK 2023, *Council Climate Plan Scorecards*. https://councilclimatescorecards.uk/

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.

Very few large-scale offshore wind projects are expected to connect to the distribution network. Therefore, the SSEN DFES analysis has focused on small-scale demonstration and trial projects that could be distribution network-connected.

Technology building block: **Gen_BB014 – Offshore Wind**

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

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	80	80	80	80	80	80	80
System Transformation		80	80	80	80	80	80
Consumer Transformation		80	80	80	80	80	80
Leading the Way		80	80	80	80	80	80

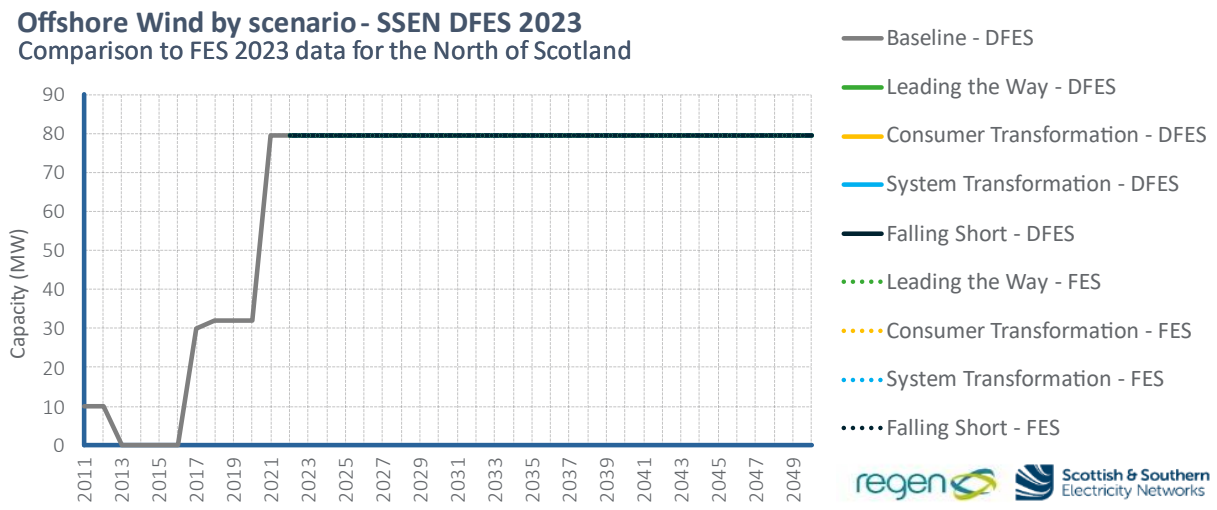


Figure 27 Offshore wind projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- The current baseline consists of the Kincardine[ix] (50 MW) and Hywind[x] (30 MW) floating offshore wind farms.
- The only pipeline project, the EMEC Floating Wind Test and Demonstration Site (60 MW) has not been modelled since the site only connects to the distribution network as a temporary measure due to the expectation of a significant transmission network upgrade.
- A previous 10 MW pilot project was connected from 2008 to 2013, the Dunbeath Beatrice Wind project.[xi]
- The Scottish Offshore Wind Policy Statement sets out an ambition to install 8-11 GW of offshore wind capacity by 2030. Respondents to the Scottish Government's consultation on the draft Energy Strategy and Just Transition Plan[xii] generally agreed that the Scottish Government should set an increased ambition for offshore wind deployment in Scotland by 2030. Respondents also generally agreed that there should be an additional ambition for 2045.
- The Offshore Transmission Network Review (OTNR) concluded in May 2023.[xiii] Its core outputs included:
    - Delivering a holistic approach to network planning – including the Holistic Network Design (HND), the first iteration of which recommended network design to enable the connection of 18 new offshore wind farms with a combined capacity of 23 GW.

- Setting the direction through policy change and action, including:
  - How best to facilitate Multi-Purpose Interconnectors, which combine interconnection with direct connections to, and transmission of electricity generated by, offshore wind farms.
  - Recommendations for a Future Framework that will take a more strategic approach to how offshore wind and associated transmission infrastructure is developed and delivered.
  - A decision to introduce a new Accelerated Strategic Transmission Investment (ASTI) framework to accelerate the delivery of strategic electricity transmission network upgrades needed to meet the government's 2030 renewable electricity generation ambitions. SSEN Transmission's 'Pathway to 2030' programme, which will invest over £10bn to increase transmission network capacity in northern Scotland, is being taken forward under Ofgem's Accelerated Strategic Transmission Investment (ASTI) framework.
- Regulatory change to enable coordination, including a decision on Anticipatory Investment, which will develop infrastructure that will support later connections of other offshore developments.

- The resultant expansion of offshore wind will be almost entirely transmission network-connected due to the location and capacity of the projects being considered. This is especially true in Scotland, where the transmission network is at a voltage tier lower than the rest of GB. Therefore, no additional offshore wind capacity is expected to connect to the distribution network in the licence area out to 2050.

Modelling and assumptions

Baseline (2022)		
Number of sites	**Total capacity (MW)**	**Description**
2	80	The baseline capacity of offshore wind in the licence area comprises two sites: Kincardine (50 MW, fully commissioned in 2021) and Hywind (30 MW, commissioned in 2017) floating offshore wind farms.
Pipeline and scenario projections (2023-2050)		
Projections for offshore wind would be based entirely on the modelling of pipeline and known sites for future development. However, only one pipeline site has been identified as being in development, which		

is the EMEC Floating Wind Test and Demonstration site (60MW) that is expected to connect in 2028. This site has a distribution network connection agreement. Theoretically, this could connect to the distribution network if commissioning occurs before transmission network reinforcement is fulfilled. However, most distribution network capacity headroom at this location has already been allocated, so the DFES has opted not to model the connection of the EMEC floating wind demonstrator to the distribution network, even temporarily, under any scenario. DFES 2022 included a 10 MW connection for Pentland Floating Offshore Wind project but this no longer has a connection agreement with SSEN.			
Scenario	**Description**	**Capacity by 2035 (MW)**	**Capacity by 2050 (MW)**
Falling Short	No additional distribution-connected capacity is added to the baseline before 2050.	80	80
System Transformation	No additional distribution-connected capacity is added to the baseline before 2050.	80	80
Consumer Transformation	No additional distribution-connected capacity is added to the baseline before 2050.	80	80
Leading the Way	No additional distribution-connected capacity is added to the baseline before 2050.	80	80

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation
Baseline	The DFES 2023 baseline and pipeline for offshore wind is directly aligned with the National Grid FES 2023 for the licence area.
Pipeline	
Projections	Neither FES 2023 nor DFES 2023 assume any further post-pipeline distribution network connections for offshore wind.
Overarching Trend	The DFES and FES match directly.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Location of known baseline and pipeline projects	The DFES analysis for offshore wind is based solely on the location of known projects, sites and developer activity. As there are no sites projected to connect, there is no future offshore wind capacity to distribute.

Relevant assumptions from National Grid FES 2023

Scenario		4.1.4 - Wind generation (offshore)
Falling Short	Low	Slower pace of decarbonisation.
System Transformation	Medium	Strong growth in offshore wind as has lower societal impact (land use and visibility) than onshore wind. Build-out is limited versus other scenarios as less demand (e.g. less hydrogen production from electrolysis).
Consumer Transformation	Medium	Strong growth in offshore wind as higher societal impact (land use and visibility) than onshore wind is countered by the need for more generation to support higher demands (e.g. hydrogen production from electrolysis).
Leading the Way	High	High growth driven by the decarbonisation agenda and high demands from hydrogen production from electrolysis.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
The project team engaged representatives from the European Marine Energy Centre (EMEC). This provided information about the state of the sector and feedback on likely site-specific project timelines.	Engagement with EMEC resulted in an up-to-date view on the EMEC Floating Wind Demonstrator project.

[ix] Principle Power n.d., *Kincardine Offshore Wind Farm*. https://www.principlepower.com/projects/kincardine-offshore-wind-farm

[x] Equinor n.d., *Hywind Scotland*. https://www.equinor.com/energy/hywind-scotland

[xi] Talisman Energy (UK) Limited 2005, *Beatrice Wind Farm Demonstrator Project: Environmental Statement*. https://www.biofund.org.mz/wp-content/uploads/2018/11/1543325522-F1898.Environmental%20Statement_Beatrice_Environmental%20Statement.Pdf

[xii] Scottish Government 2023, *Draft energy strategy and Just Transition Plan: consultation analysis*. https://www.gov.scot/publications/analysis-consultation-responses-draft-energy-strategy-transition-plan/pages/5/

[xiii] BEIS & DESNZ, *Offshore Transmission Network Review: summary of outputs*. https://www.gov.uk/government/publications/offshore-transmission-network-review/offshore-transmission-network-review-summary-of-outputs

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
Falling Short	46	131	540	791	917	1,131	1,357
System Transformation		271	710	1,023	1,280	1,691	2,024
Consumer Transformation		271	713	1,075	1,356	1,827	2,227
Leading the Way		472	1,256	2,071	2,234	2,443	2,471

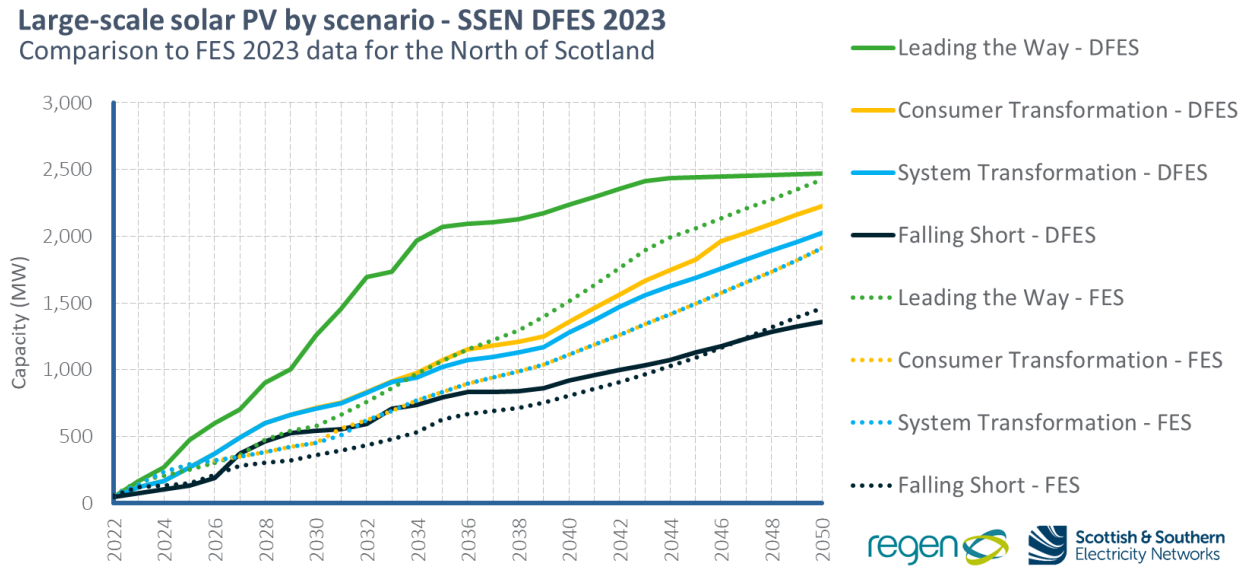


Figure 28 Large scale solar PV projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- The North of Scotland licence area has seen historically low levels of large-scale solar deployment, with only 46 MW of installed capacity currently connected.
- Despite this small baseline, there is current a pipeline of 432 MW new solar projects with connection agreements and planning approval. This accounts for 23% of a wider 1.9 GW pipeline of contracted or quote issued sites in the licence area.

There are a number of indicators, specific to Scotland and Scottish energy policy, that suggest this pipeline could be built out in the near to mid-term:

- In October 2023, the Scottish Government committed to a target of 4-6 GW of solar PV capacity, at all scales, by 2030.[xiv] This has been well received by the Scottish Solar Trade Association (STA) who had called for such action, having set their own target for 3.5 GW of ground-mount solar PV by 2030.[xv]
- Currently in draft, the Scottish Government's Energy Strategy and Just Transition Plan [xvi] may deliver more detail on how this 4-6 GW is to be delivered, including how much emphasis will be placed on supporting domestic and commercial rooftop solar arrays.
- The DFES has sought to reflect the impact of achieving these Scottish Government policies and targets in more optimistic scenarios, with **Leading the Way** reflecting the 6 GW upper ambition; **Consumer Transformation** a credible route to the 4 GW minimum target. Irradiance levels and developable land space in the North of Scotland licence area relative to Southern Scotland have also been considered, as well as the

likely balance of deployment between transmission and distribution networks in Scotland.

- Historic planning friendliness towards solar installations is very high in the licence area, with c. 96% of projects being accepted by relevant local authorities. Recent planning reform has also removed barriers to future projects gaining consent, with the final version of the Scottish Government's National Planning Framework 4 (NPF4) published in February 2023, with one aim being to "encourage, promote and facilitate all forms of renewable energy development".[xvii]
- DFES 2023 has also evidenced the Scottish Government's Planning and Environmental Appeals division already being active in overturning local authority rejections to solar projects.[xviii] With NPG4 now in place, this may become a more regular occurrence.

There are also national and international drivers which could support additional uptake of solar PV in general:

- Solar PV remains one of the cheapest forms of renewable energy. Ongoing reductions in capital costs,[xix] improvements in solar panel efficiency[xx] and the development of more dynamic and lucrative power purchase agreements,[xxi] are driving new interest to deploy more capacity of large-scale solar PV nationally and internationally. By growing economies of scale further, costs will decrease further.
- Current business models are based around large-scale standalone solar farms and some co-location with battery storage. However, in the future, as some projects are already exploring, solar PV could be co-located with hydrogen electrolysis to mitigate generation constraints or export limitations.
- In 2022, the British Energy Security Strategy[xxii] set an ambitious goal of 70 GW of solar capacity by 2030, a five-fold increase from the 14 GW of domestic and large-scale solar connected at the time it was published.
- Across the UK, the main barrier for new solar sites connecting to the network is the large connections queue at both transmission and distribution level voltages. Many developers have been given connection dates in the late 2020s and, in some cases, into the 2030s due to upstream transmission network constraints. These delays, reflected in a 'Statement of Works' delivery year, have been reflected solely in the **Falling Short** scenario. There are, however, reforms being pursued nationally through Ofgem and National Grid ESO's November 2023 'Joint Connections Action Plan'.[xxiii]
- In net zero compliant scenarios it is assumed that these connection policy reforms are successful in tackling the queue, fast-tracking viable projects and reducing overall connection timeframes.

- Considering the current project pipeline and these contributing factors, DFES 2023 makes a range of projections across the scenarios. Under the most ambitious scenario, **Leading the Way**, large scale solar reaches 1.3 GW of deployed capacity in the North of Scotland by 2030, and continues to 2.5 GW by 2050. The least ambitious scenario, **Falling Short**, sees 0.5 GW deployed by 2030 and 1.4 GW by 2050.

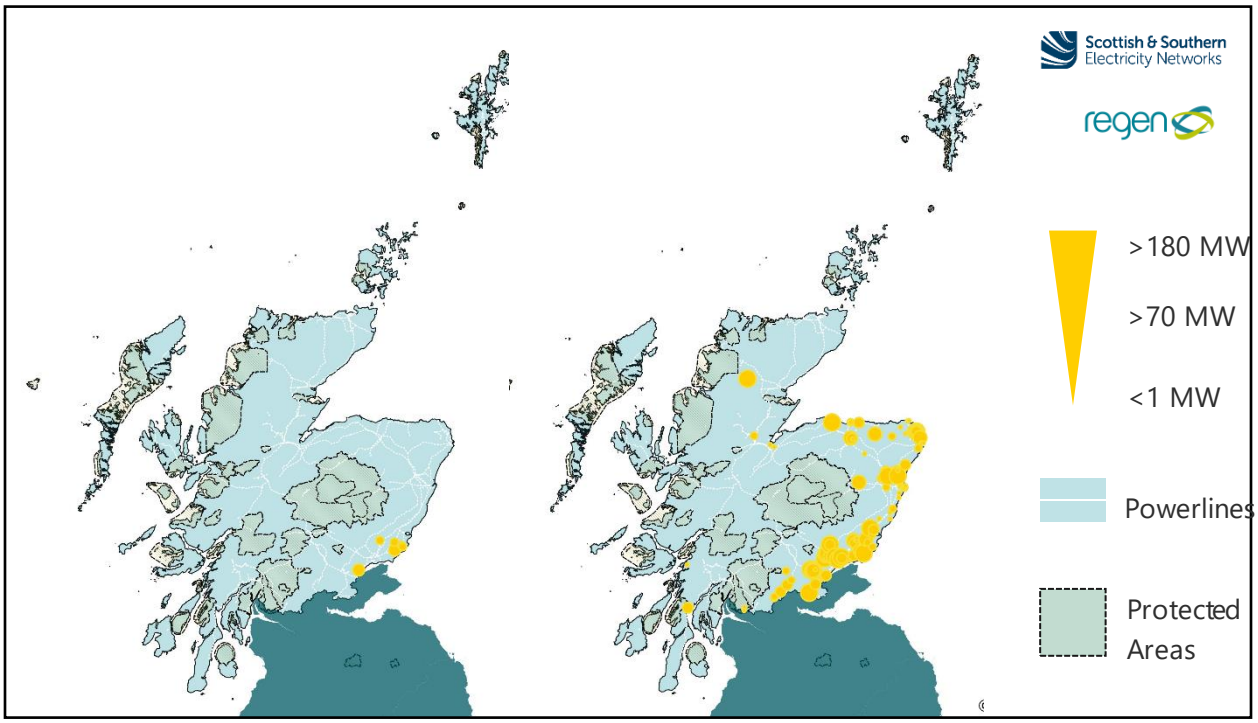


Figure 29: Baseline and pipeline large scale solar PV sites in the North of Scotland licence area, August 2023

Modelling Stages

Baseline (2022)		
Number of sites	**Total capacity (MW)**	**Description**
9	46	The only change since DFES 2022 is the 5 MW Dragonhill Farm solar site, which came online in mid-2023. These baseline projects are all in the South East of the licence area, with the largest being the 9.9 MW 'Errol PV' site in Perth.

Pipeline (2023-2035)			
	Total	**Contracted**	**Grid connection offered**
Number of sites	79	58	21
Capacity (MW)	1,870	1,380	490

For each annual DFES analysis, the pipeline of large scale solar projects has grown. This year is no exception; the pipeline of contracted/offered sites has increased from 1.2 GW (53 sites) in DFES 2022, to 1.9 GW (79 sites). This represents a 50% increase in pipeline capacity over the year. 73% of the sites in the current connections pipeline are contracted; accounting for 1.4 GW (73%) of the total pipeline capacity.

Notable additions to this project pipeline include the 57 MW 'Ladyatt Farm PV/BESS' site near Dundee, alongside three similarly sized projects co-located with battery storage around Aberdeen and Perth. The majority of the development pipeline is focused on the east coast, specifically the south east, the area with the highest solar irradiance levels in the licence area.

630 MW, 34% of the total pipeline capacity, is co-located with battery storage; 20 sites are currently subject to a Statement of Works connection date, due to upstream constraints on the transmission network. These connection delays have been directly reflected in the **Falling Short** scenario.

Pipeline analysis			
Status	**Description**	**Sites**	**Capacity (MW)**
Under Construction	One site was found to be under construction, Bilbo Farm[xxiv] and was due to be commissioned in 2022, but there has been no public announcement of its commissioning as of Q4 2023. It is modelled to build out in 2024.	1	25
Planning Permission	407 MW, 21% of the project pipeline capacity, has received planning permission. All sites have accepted connection offers with SSEN.	19	407

Granted	The 49.9 MW 'Milltown' solar site in Moray is the largest of the sites with planning approval in the licence area. Included here is the 45 MW 'Berryhill Solar Farm' site, which saw planning refusal overturned by the Scottish Government's planning and environmental appeals division in late 2022.[xviii] Six of these approved 19 sites are co-located with battery storage.		
Planning Application Submitted	Six sites totalling 157 MW have submitted for full planning permission. These sites all have connection agreements with SSEN. Three of these are proposed to be co-located with battery storage.	6	157
Pre-planning	A further five sites are in earlier stages of planning; yet to submit a full application. With an average capacity of 30 MW, these sites are typically larger than those with planning permission (21 MW average) or with a submitted application (26 MW average). This trend indicates that developers are looking to deploy larger sites in the licence area, though site sizes decreasing as a byproduct of the planning process could equally be a factor.	5	155
No information	For 42 sites, no planning information was able to be found. This indicates very early stage or speculative projects. This less well evidenced portion of the pipeline is significantly larger than was seen in DFES 2022 (22 sites). This increase in sites with no development evidence potentially illustrates that the project pipeline has become less progressed, and more speculative over 2022-2023. This could relate to challenges with the connection queue and long lead times for network reinforcement. New sites entering the connections data in 2023 account for the 31 of the 42 sites. Approximately half of these sites do not yet have a connection agreement.	42	986
Abandoned, Refused, Withdrawn & Other	Two small sites have not seen development evidence since 2018 or earlier and are assumed abandoned. A 45 MW site, 'Coupar Solar', also had planning permission refused in the past year. The developer may appeal this decision through the Scottish Government. Two projects are deemed to have been superseded with new connection applications in SSEN's connections data.	6	140

Planning logic and assumptions (percentage of capacity modelled to come online)

An analysis of solar PV sites within the REPD is used to estimate the time from a project's current stage of development to buildout. These timeframe estimates are specific to the capacity of the project, with larger projects having longer development timeframes, and to the scenario, with less ambition scenarios assuming longer development timeframes.

Less ambitions scenarios also assume that less well evidenced sites do not build out. For example, those which have submitted only pre-planning documents, or those with no submitted planning documents at all.

A secondary stage of scenario-based logic considers the success rates of the remaining projects; given their current development stage. In **Falling Short** and **System Transformation**, it is assumed that sites which have submitted a planning application do not see deployment in their existing development cycle. Similarly, in **System Transformation** and **Consumer Transformation** and **Leading the Way**, sites in pre-planning are subject to an additional delay. The length of this additional delay ranges from 2-8 years and is impacted by the historic planning friendliness of the local authority, again a metric derived from REPD analysis.

This approach allows a moderation in the near-term buildout rate of the large project pipeline, while reflecting the possibility that, in ambitious net zero scenarios, locations of interest to developers now will eventually host a project.

Repowering

From the mid-2030s onwards, existing baseline sites could begin to repower. The modelling accounts for the possibility that uprated/higher yield solar panels or extensions to panel numbers will increase site capacities.

With a small baseline, only 20 MW of capacity is added through repowering under **Leading the Way**, and

10 MW is added through repowering in **System Transformation** and **Consumer Transformation**. Sites remain at their original capacity under **Falling Short** and are not modelled to decommission. Future repowering of pipeline sites could play a role in later projection years but has not been modelled in the DFES 2023 due to significant uncertainty of repowering rates for future sites.

	Falling Short	**System Transformation**	**Consumer Transformation**	**Leading the Way**
Year Delay	--	25 years		
Repowering	--	+25%		+50%
Added Capacity	--	10 MW		20 MW

Scenario projections			
Scenario	**Description**	**Capacity by 2035 (MW)**	**Capacity by 2050 (MW)**
Falling Short	Under **Falling Short**, only those solar projects with strong evidence of imminent development are modelled to build out in the near term. In the late 2020's projects with current planning permission begin to connect, resulting in some capacity increase. 786 MW of large scale solar PV is deployed by 2035 under this scenario. Beyond 2035, this growth in new solar capacity is maintained and 1.4 GW is modelled to operate by 2050. Despite being the least ambitious scenario, this is still a significant increase from the current baseline. This projection has higher post-2035 growth than was forecast in DFES 2022, with an additional 300 MW by 2050. This is driven by an uprated FES projection for the licence area under this scenario.	791	1,357
System Transformation & Consumer Transformation	**Consumer Transformation** and **System Transformation** have equal FES projections for large scale solar in the North of Scotland licence area. Because of this the DFES has applied the same treatment to the near-term pipeline of projects in each scenario. All sites with some planning evidence, even pre-planning documents, are modelled to build out. The DFES has also considered the Scottish Government's target of 4-6 GW of solar by 2030 in these scenarios: • There is a very small baseline of solar capacity in Scotland. • As of November 2023, the Transmission Entry Capacity register lists 2.3 GW of Scottish solar projects which are expected to connect before 2030. • Current DFES projections for *domestic and commercial rooftop solar* from the SSEN and SPEN licence areas suggest they could contribute at most	1,023 & 1,075	2,024 & 2,227

	1 GW to this 2030 target, under **Consumer Transformation.** • SPEN's 2022 DFES [xxv] projects that *large scale distribution connected* solar in the South of Scotland could contribute 1 GW by 2030, under **Consumer Transformation.** With the 4-6 GW target largely dependent on deployment on the transmission network, in the South of Scotland (where solar irradiance is higher), or at smaller scales, an accelerated buildout of SSEN's pipeline in the North of Scotland has not been modelled. The projected deployed capacity of 700 MW by 2030 is consistent with meeting the Scottish Government's credible 4 GW minimum target. The buildout of the current pipeline sees solar capacity growing to 1 GW by 2035. To reflect Scottish Government net zero target year of 2045, **Consumer Transformation** has been modelled to have slightly higher levels of solar deployment between 2035 and 2050. By 2050, 2 GW and 2.2 GW are deployed under **System Transformation** & **Consumer Transformation** respectively. This projection does not differ significantly to the equivalent scenario projections in DFES 2022.		
Leading the Way	Under **Leading the Way**, the current project pipeline is built out with minimal delay. This results in 1.25 GW being deployed by 2030. This contributes to meeting the Scottish Government upper target for 6 GW of deployed solar capacity by 2030. Further deployment is modelled to 2035, as the final sites in the existing pipeline connect and 2 GW overall is modelled to be deployed. Post-2035, development is modelled to slow down, with 2.5 GW modelled to connect by 2050. This 2050 projection does not differ significantly from that made for DFES 2022. A c.400 MW increase in deployed capacity by 2035 is justified by the increased project pipeline.	2,071	2,471

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation
Baseline	The DFES baseline of 46 MW is slightly lower than the 58 MW FES 2023 baseline. The FES baseline has decreased from 108 MW in 2022, now aligning more closely with the DFES baseline.
Pipeline	The DFES projection diverges from the FES projection from 2024 onwards under **Leading the Way** and from 2026 onwards in **System Transformation**, **Consumer Transformation** and **Falling Short**. This is justified by the significant connection pipeline seen in the DFES data and the detailed research and analysis applied to identify sites that will likely be commissioned in the near term out to the late 2020s. A sustained high growth rate in **Leading the Way** results in a large variance with the FES projections by 2035. A lower growth rate under the other three scenarios means projections are relatively similar to FES, with sub-500 MW differences by 2035.
Projections	**Leading the Way** and **System Transformation** and **Falling Short** see reduced annual growth rates in new solar capacity post 2035, which causes them to align with the FES projection and results in similar 2050 projections for total deployed capacity. **Consumer Transformation** maintains higher growth rates relative to the FES, the result is a larger projection for total capacity deployed by 2050.
Overarching Trend	**Falling Short** sees a comparable projection for solar PV to the FES across the analysis period. DFES projections for **Leading the Way** and **System Transformation** see higher near term, but lower long term, growth rates, when compared to the FES projections. **Consumer Transformation** sees consistently higher growth rates than the FES.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Unconstrained solar resource	Regen's in-house solar resource assessment considers solar irradiance/resource, land availability and planning constraints in the licence area.
Climate score cards[xxvi]	Local ambition, reflecting the local authority policy landscape and proclivity to renewable energy deployment and net zero goals.

Renewable Energy Planning Database	The proportion of solar sites that are/have been successful with a planning application in the local planning authority.

Relevant assumptions from National Grid FES 2023

Scenario		4.1.15 – Solar generation (plant greater than 1MW)
Falling Short	Low	Slower pace of decarbonisation.
System Transformation	Medium	Transition to net zero results in strong growth in large solar.
Consumer Transformation		
Leading the Way	High	Very high ambition to decarbonise drives a focus on low-carbon technologies. Supports the production of hydrogen by electrolysis.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
During the SHEPD webinar event, stakeholders were asked how much of the current large scale solar pipeline would connect and in what timeframe. They responded with a large range of answers, with an average suggesting more than half of the current 1.4 GW contracted pipeline would connect by the early 2030s.	The four scenarios modelled reflect this spread in opinion. The average view is most closely reflected in **System Transformation.**
Solar Developers were contacted by email and phone to supplement desk-based research on progress with planning applications and the expected commissioning years of individual projects.	Feedback from developers was incorporated into the pipeline analysis. Direct feedback was prioritised over online publicised information when assigning pipeline commissioning years in each scenario while preserving the commercial confidentiality of projects that have not publicly released information.

[xiv] Solar Energy UK 2023, *Scottish Solar industry welcomes commitment to boost solar energy generation in Scotland*. https://solarenergyuk.org/news/scottish-solar-industry-welcomes-commitment-to-boost-solar-energy-generation-in-scotland/

[xv] Solar Energy Scotland 2021, *Scotland's Fair Share: solar's role in achieving net zero in Scotland*. https://solarenergyuk.org/wp-content/uploads/2021/10/1SES-Scotlands-fair-share-FINAL-PDF-Version.pdf

[xvi] Scottish Government 2023, *Draft Energy Strategy and Just Transition Plan*. https://www.gov.scot/publications/draft-energy-strategy-transition-plan/pages/5/

[xvii] Scottish Government, 2023, *National Planning Framework 4*. https://www.gov.scot/publications/national-planning-framework-4/documents/

[xviii] Scottish Government, 2023, *Berryhill Solar Farm Planning permission appeal*. https://www.dpea.scotland.gov.uk/CaseDetails.aspx?id=122223&T=0

[xix] Power Engineering International 2021, *IRENA: Wind and solar costs will continue to fall*. https://www.powerengineeringint.com/renewables/irena-wind-and-solar-costs-will-continue-to-fall/

[xx] NREL n.d., *Best Research-Cell Efficiency Chart* https://www.nrel.gov/pv/cell-efficiency.html

[xxi] Solar Power Portal 2023, *Vodafone, Mytilineos and Centrica sign second solar PPA for 232MW*. https://www.solarpowerportal.co.uk/news/vodafone_mytilineos_and_centrica_sign_second_solar_ppa_for_232mw

[xxii] UK Government 2022, *British Energy Security Strategy*. https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy#renewables

[xxiii] Ofgem & DESNES, 2023, *"Joint connections action plan"*. https://www.ofgem.gov.uk/publications/ofgem-and-desnz-announce-joint-connections-action-plan

[xxiv] Power Technology 2022, https://www.power-technology.com/marketdata/bilbo-farm-solar-pv-park-uk/

[xxv] SPEN, 2022, *"Distribution Future Energy Scenarios "* www.spenergynetworks.co.uk/userfiles/file/DFES_SP_Distribution_December_2022.pdf

[xxvi] Council Climate Plan Scorecards, 2022, https://councilclimatescorecards.uk/

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.

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

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

Installed domestic capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	81	97	136	196	251	296	339
System Transformation		100	164	238	301	354	404
Consumer Transformation		129	252	360	451	532	611
Leading the Way		152	331	483	609	724	837
Installed commercial capacity (MW)	**Baseline**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Falling Short	46	73	79	92	104	117	129
System Transformation		73	87	104	121	138	155
Consumer Transformation		78	99	125	150	176	201
Leading the Way		79	110	147	183	219	256

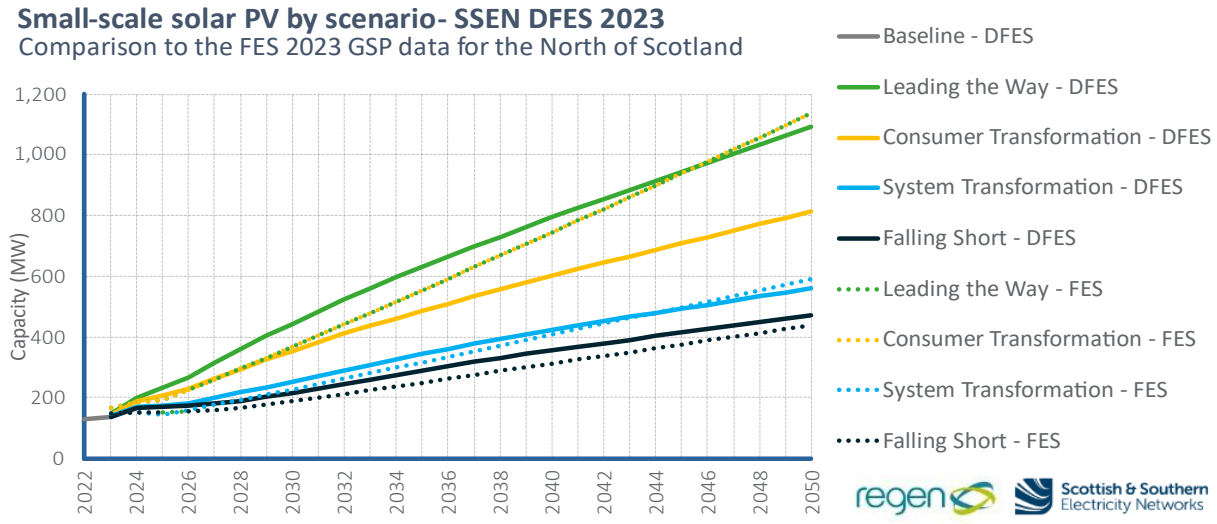


Figure 30 Small scale solar PV projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- Growth in the deployment of domestic rooftop solar capacity in the UK has reached its highest level since the early Feed-in-Tariff era (2010s). According to the Department for Energy Security & Net Zero (DESNZ), the whole UK added just under 630 MW of small scale solar (< 50 kW)[xxvii] in 2023.
- The current North of Scotland licence area baseline for small scale solar stands at 127 MW, up from 116 MW in DFES 2022, a 9.5% increase in the baseline installed capacity.
- The DFES 2023 pipeline of 25 MW is more than double the 11 MW pipeline present in DFES 2022, this difference influences the projections out to 2050. The largest influence on projects however is the modelling of new build homes. Evidence suggests that a higher percentage of new build homes are installing **domestic scale PV** in Scotland compared to the rest of the UK[xxviii]. This evidence supported the increase of new builds modelled to have **domestic scale PV** in all four scenarios, with the largest change in **Falling Short**.
- Future deployment of small scale solar varies strongly by scenario. Under **Consumer Transformation** and **Leading the Way**, as the scenarios reflecting the highest decarbonisation ambition, high electrified transport and heating levels drive small scale solar uptake. In **Leading the Way**, 838 MW of domestic and 256 MW of commercial solar PV is installed by 2050 – over eight times today's connected capacity.

This level of deployment reflects the high ambition for solar across Scotland, as highlighted through engagement with the Scottish Solar Trade Association (STA).

- Despite being a scenario with lower levels of electrification, **System Transformation** still sees high deployment levels, reaching 3.5 times today's level by 2050. Reducing costs and uptake of electric vehicles drives solar PV uptake under every scenario.
- **Falling Short** sees relatively low deployment, with annual growth remaining at the levels seen in the post FiT era-2021 and 2050 deployment reaching 450 MW.

Modelling and assumptions

Baseline (2022)		
Scale	**Total capacity (MW)**	**Description**
Domestic (<10 kW) (<10 kW)	81	There are 81 MW of domestic-scale solar PV in the North of Scotland licence area, equivalent to rooftop arrays on 3.7% of domestic buildings, slightly below the GB-wide average figure of 4.1%. 2022 has seen a significant increase in domestic solar installations, the rate of which has not been seen since the FiT period. This period now accounts for 8% of total baseline installed capacity. This is just under the total capacity installed in the 4-year period between 2017-2021 (12%).
Commercial (10 kW – 1 MW)	46	There are 46 MW of commercial rooftop solar PV baseline capacity in the North of Scotland licence area. This is an 8.5% yearly increase in the commercial baseline, the largest yearly increase since the ending of the FiT scheme in 2016.

Pipeline (2023-2030)	
There are 132 sites totalling 25 MW with accepted or quoted connection offers in the licence area. These are **all commercial scale (10 kW – 1 MW) solar arrays**. This is more than double the 11 MW pipeline, made up of 69 sites, from the DFES 2022 analysis.	
Already connected	10 MW of small scale solar PV sites have already connected in 2023. Since these sites connected after 2022, they are not considered in the DFES 2023 baseline or pipeline, but rather modelled to connect in all four scenarios to reflect their current status.
Contracted	109 sites, totalling 21 MW of capacity, have accepted connection agreements in the North of Scotland licence area. Sites with accepted connection offers older than 3 years (65 sites, 10.7 MW) were removed from analysis if no planning evidence could be found. Unless planning

	evidence was found for a refused or expired planning application all sites were modelled to connect in **2024** under all four scenarios.
Quote Issued	23 sites, totalling 4.2 MW, have a connection quote issued, which have not yet been accepted. These sites were modelled in the same manner as Contracted sites to connect in **2024** under all four scenarios, where planning evidence such as planning permission, was available to support connection.

Rooftop solar PV on new homes

Rooftop solar PV on new build homes is modelled using the outputs of the DFES projections for new housing developments. It is estimated that around 10% of recently built homes in the UK have been built with rooftop solar PV installed, however EPC data suggests that 60% of new builds in Scotland have rooftop solar installed.[ii] To account for this wide range a baseline percentage for the North of Scotland licence area was set at 20% for **Falling Short** and **System Transformation**, 50% for **Consumer Transformation** and 75% for **Leading the Way** (to account for evidence suggesting that this could be significantly higher[xxix] at 70%).

With Scotland's New Build Heat Standard in development, a potentially highly impactful policy change is imminent. The requirement for all new build homes post-2024 to include solar PV has notably been *removed* from draft legislation.[xxx] Scotland's recently approved National Planning Framework 4[xxxi] has removed planning barriers for warehouse solar PV installations, which will affect commercial rooftop solar uptake. Under **Consumer Transformation** and **Leading the Way**, deployment of rooftop solar on new-build homes increases to 80% and 95% respectively of all new homes by 2050 from their baseline percentage. Reflecting the evidence suggesting that 70% of new homes have installed roof-top solar currently, **System Transformation** and **Falling Short** will increase to this benchmark by 2050.

Scenario	The proportion of new-build homes with rooftop solar PV		
	2025	2030	2050
Falling Short	20%	25%	70%
System Transformation	20%	30%	70%
Consumer Transformation	50%	55%	80%
Leading the Way	75%	80%	95%

Scenario projections

Beyond the near term, small scale solar PV uptake depends strongly on national trajectories and less on licence area-specific factors.

The North of Scotland licence area has lower solar irradiance levels than the rest of the UK. However, the historic uptake is around 13% higher than the overall GB trajectory per home basis. This could be due to many 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 factors such as solar irradiance, social housing, affluence and available roof space, the uptake of rooftop solar PV in the North of Scotland licence area is expected to be in line with national trajectories.

Beyond the 2020s, the volume of new housing developments is expected to reduce, especially in more rural areas of the Highlands and Islands, where population levels are steady or expected to decline. As a result, the impact of solar PV on new build housing resultantly decreases over time.

Scenario	Description	Capacity by 2035 (MW)	Capacity by 2050 (MW)
Falling Short	**Falling Short** reflects a lower uptake of low carbon technologies and smart tariffs, and consumers are less engaged. This results in a much lower demand for small scale solar on homes and businesses. This scenario sees the largest change from 2050 projections compared to DFES 2022 due to the increase in percentage of new build homes projected to have small scale solar PV.	288	468
System Transformation	Due to the need to decarbonise electricity demand quickly to meet carbon reduction targets, solar PV uptake is also high under **System Transformation**. However, greater use of larger scale solutions and a reliance on low carbon hydrogen for space heating (rather than electrification) results in an overall lower uptake in small scale solar than in the other two net zero scenarios. The DFES 2023 projection is marginally higher in 2050 than in DFES 2022.	342	559
Consumer Transformation	Under **Consumer Transformation** and **Leading the Way**, high consumer ambition and engagement,	485	812

Leading the Way	coupled with high levels of electrification in the transport and heat sectors, all drive a large increase in new small scale solar PV capacity. Peaking at 1 GW MW under **Leading the Way**. These projections are approximately 60 MW higher than the DFES 2022 analysis.	629	1,093

Reconciliation with National Grid FES 2023

Modelling Stage	Reconciliation
Baseline	The updated DFES 2023 baseline aligns closely with the FES 2023 baseline.
Projections	As small scale solar PV is more strongly driven by national considerations, support, policy, and public adoption, the DFES 2023 aligns with the FES 2023 regional data regarding the spread between scenario projections. However, the **System Transformation** and **Leading the Way** DFES 2023 scenario projections are consistently lower that the FES 2023 projections due to a less ambitious near-term growth rate, which has a lasting impact to moderately dampen future ambition and rollout. The exception is the **Consumer Transformation** scenario, where the DFES uptake is significantly lower than the FES 2023 regional figures. The DFES modelling for this scenario has increased its ambition to reflect stakeholder feedback (including insight from the Scottish Solar Trade Association gained from previous DFES assessments). However, the projections under this scenario remain lower than FES 2023 due to the evidence of historic deployment trends and the limited pipeline of new sites.
Overarching Trend	Whilst there is close alignment in the baseline and spread between scenarios, smaller near-term growth rates in the DFES result in lower 2050 projections than FES 2023.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Domestic uptake	Domestic uptake is mainly influenced by 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 rooftop solar PV deployment becomes increasingly ubiquitous.
New developments	Over 65,000 new homes are projected to be built in the licence area between now and 2050. In **Leading the Way** (the highest deployment scenario), 95% of these new build homes could have a total of 212 MW of rooftop solar capacity installed by 2050. The location of existing new build sites influences the distribution of this capacity.

Relevant assumptions from National Grid FES 2023

Scenario		4.1.5 – Solar generation (plant smaller than 1MW)
Falling Short	Low	Slower pace of decarbonisation.
System Transformation	Medium	Transition to net zero results in strong growth in small solar. Supports production of hydrogen by electrolysis.
Consumer Transformation	Medium	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	High	Very high growth in small solar as it supports the transition to net zero and is highly aligned to the high societal change.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
DFES 2023 engaged with solar developers Eden Sustainable on their commercial scale developments.	The DFES team engaged with solar developers Eden Sustainable on their commercial scale sites, to identify any constraints or allowances from the industry that can be reflected in scenario projections. Skill shortages and connection applications were among the largest barriers to growth. This has been considered a broader influencing factor for delayed uptake of commercial scale solar under **Falling Short**. They also indicated the current obligations of the Minimum Energy Efficiency Standards (MEES) in the domestic sector were aiding growth. This, along with the potential changes to non-domestic MEES in the coming years, are reflected under **Leading the Way** and **Consumer Transformation**.
DFES 2023 continued to assume a high level of future ambition for	The Scottish STA highlighted a high-ambition target for solar in Scotland that surpasses historic trends. The STA considered 6 GW

solar PV in the licence area based on engagement with the Scottish STA in a previous DFES rounds.	for all solar across all of Scotland (North and South) by 2030, of which: • 3.5 GW of large ground-mounted arrays • 1.5 GW of commercial rooftop arrays • 1 GW of domestic rooftop arrays

[xxvii] Solar photovoltaics deployment, 2023 See: https://www.gov.uk/government/statistics/solar-photovoltaics-deployment

[xxviii] Solar Energy UK 2021, *Future homes are solar homes.* https://solarenergyuk.org/future-homes-are-solar-homes/

[xxix] Solar Energy UK 2021, Scottish Building Regulations. https://solarenergyuk.org/wp-content/uploads/2021/11/SEUK-response-Scottish_Building-Regulation.pdf

[xxx] Solar Power Portal 2022, *Scottish Government warned on plan to remove new building solar PV mandate.* https://www.solarpowerportal.co.uk/news/scottish_government_warned_on_plans_to_remove_solar_pv_from_new_buildings#:~:text=Under%20plans%20detailed%20in%20the,and%20other%20buildings%20from%202024.

[xxxi] Scottish Government 2022, *Approved NPF4.* https://www.transformingplanning.scot/national-planning-framework/approved-npf4/

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 – Hydro**

Data summary for hydropower in the North of Scotland licence area

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	895	905	906	907	908	909	909
System Transformation		909	919	928	938	947	957
Consumer Transformation		913	940	961	980	997	1,015
Leading the Way		908	920	929	939	948	958

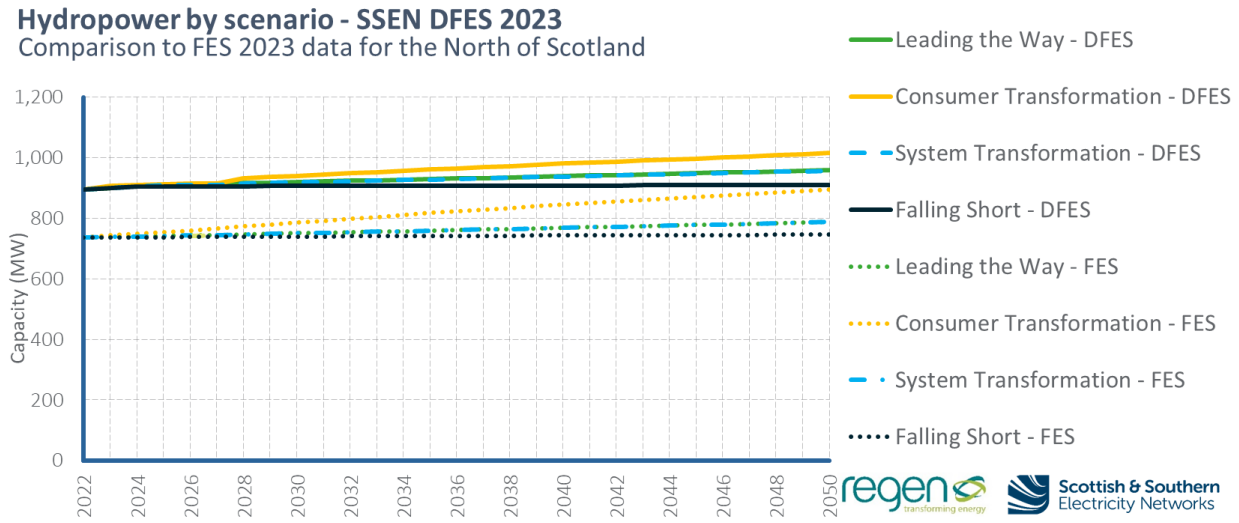


Figure 31 Hydropower projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- Due to the strong topology and water resources, hydropower is a well-established technology in the North of Scotland licence area.
- The total capacity connected to the distribution network in the licence area is 895 MW, across 619 sites. This is an increase in capacity of 60 MW from 2022 and 11 more sites. The largest addition in 2022 is a 52 MW added capacity to the existing Lochaber Aluminium Smelter, which was originally 28 MW, bringing the site to a total grid-connected capacity of 80 MW.[xxxii]
- The pipeline for the North of Scotland comprises 26 sites. The largest single site in the pipeline is an additional capacity to the Tummel Bridge existing scheme due to renovation works. The average size of new sites, excluding Tummel Bridge, is c.500 kW.
- An estimate of the hydropower resource potential in the North of Scotland licence area was based on a comprehensive study commissioned by the Scottish Government in 2008.[xxxiii] Geospatial mapping of catchment area resources in the licence area suggests an untapped potential of 657 MW, with the vast majority (90%) located in the Highlands.
- The potential for future hydropower project development depends on several factors, including revenue uncertainty and abstraction licence costs.
- The UK Hydropower Resource Assessment 2022[xxxiv] report confirms that hydropower deployment is highly dependent on the economic viability of the specific site and market forces within the Scottish Government and the UK government's control.

- Small scale sites see continued improvements as technology increases efficiency, and the possibility of co-located batteries can increase their economic viability.[xxxiv]
- The analysis has reflected a more ambitious uptake of new hydropower projects in the **Consumer Transformation** and **Leading the Way** scenarios, while limited growth is seen in **Falling Short**. An increase in the range of between 90 and 280 MW by 2050 is shown across the four scenarios.

Modelling and assumptions

Baseline (2022)			
Scale	**Number of sites**	**Total capacity (MW)**	**Description**
Total	619	895	Hydropower in SSEN's licence areas has already been developed in most of the high resource yielding areas and is considered a mature technology. Only around 276 MW of the total 895 MW of installed capacity were installed after 2010.
1 MW and above	113	761	The vast majority of large scale sites were developed pre-2002. Since 2002, less than 70 projects with a capacity of greater than 1 MW have been developed. The largest site in some time to be commissioned was an additional capacity extension to the Lochaber Smelter, which was increased by 52 MW in 2022.
Below 1 MW	506	134	The majority of sites below 1 MW were commissioned as a result of the Feed-in Tariff, with over 50% of installed capacity coming online between 2011 and 2016. A total capacity of 19 MW (67 sites) has been connected since 2017.

Pipeline (2023-2030)	
Number of pipeline sites	**Total capacity (MW)**
26	19.4

Pipeline analysis			
Status	**Description**	**Sites**	**Capacity (MW)**
Operational	Two sites of 100 kW and 50 kW respectively were classified as pipeline sites but have since been found to have commissioned. They have been modelled to connect in 2023 under all scenarios.	2	0.15
Under Construction	Three medium-scale hydropower sites totalling c. 9 MW are currently under construction at the time of writing in December 2023. Two of the	3	8.97

	three were added capacity to existing operational sites; the 6.5 MW increase due to refurbishment to Tummel Bridge in Perth[38] and Kinross and the 2 MW added capacity to Allt Na Moine in the Highlands, near Shieldaig.		
Planning Permission Granted	The majority of sites with planning permission granted are small-scale (<1 MW), except for the Three Lochs project (2 MW), located in the Highlands. There are two entries in the connections data for Garvie Burn hydro at 450 kw, introducing uncertainty as to whether or not one of these sites is a requote or an added capacity site.	4	3.89
Planning Submitted	One site was found to be submitted in planning at Ardgour in the Highlands with 1.5 MW of capacity.	1	1.5
Planning Application withdrawn	An application for a small 100 kW project located in Argyll and Bute was withdrawn.	1	0.1
No information	No information could be found for thirteen pipeline sites. These are generally small-scale, with an average capacity of 0.33 MW.	13	4.27
Other notes	A single site at Russel Burn has been labelled as added capacity, but with a capacity value of 0 MW. It is unclear how much additional capacity will be required for this site.	1	*(added capacity)*

Planning logic and assumptions

The assumptions around the years for pipeline sites to progress through each planning stage are derived from a statistical analysis of the Renewable Energy Planning Database[xxxv].

Assumed number of years between connection offer and commissioning by planning stage

Scenario	Planning Granted (PG) or Under Construction (UC)	Planning Application Submitted	Pre-planning	No information
Falling Short	(UC) – four years (PG) – not modelled to come online	Not modelled to come online	Not modelled to come online	Not modelled to come online
System Transformation	Three years	Three years	Four years	Not modelled to come online
Consumer Transformation	Three years	Three years	Four years	Not modelled to come online
Leading the Way	Three years	Four years	Five years	Five years

[38] See https://www.sserenewables.com/hydro/tummel-valley/

Scenario projections (2030 to 2050)			
Scenario	**Description**	**Capacity by 2035 (MW)**	**Capacity by 2050 (MW)**
Falling Short	Under this scenario, only pipeline projects currently under construction are modelled to come online, plus very minimal projected capacities.	907	909
System Transformation	Projects under the **System Transformation** scenario see more pipeline sites built in the near-term, and then a steady growth out to 2050.	928	957
Consumer Transformation	The **Consumer Transformation** scenario has the highest hydropower development overall. It follows the same accelerated near-term projection as **System Transformation**, but with continued growth out to 2050. This reflects the Scottish Government's renewable energy targets [xxxvi] and assumptions that economic policies will be developed to support small scale renewable technologies such as hydropower.	961	1,015
Leading the Way	This scenario sees all but sites with withdrawn applications connecting and coming online, but at a slower rate than seen in **Consumer Transformation** and **System Transformation**. This scenario also assumes favourable government policies and support for small scale renewable energy projects.	929	958

Reconciliation with National Grid FES 2023

Modelling Stage	Reconciliation
Baseline	The FES 2023 baseline for distributed hydropower in the North of Scotland is 726 MW compared to 856 MW in FES 2022. The reason for this decrease in baseline capacity under the FES is unclear. The DFES has sight of internal SSEN connections data, which is much more closely aligned to FES 2022 baseline figures.
Pipeline	The DFES 2023 models a similar near-term growth in hydropower to the FES 2023 in all scenarios except for **Consumer Transformation**, which shows a slightly lower near-term growth rates than in the FES. The DFES reflects a site-specific analysis of planning data.
Projections	The FES 2023 **Falling Short** scenario shows similarly limited growth to 2050, as reflected in the DFES. The FES 2023 scenario with the most sustained growth is **Consumer**

	Transformation reaching just under 900 MW by 2050 – a significant decrease compared to 1.2 GW in this scenario in FES 2022. The DFES assumes a much higher uptake of sites above 1 GW by 2050 under the most ambitious scenario.
Overarching Trend	DFES 2022 scenarios reflect real site build out, showing a linear trend that reflects similar levels of growth to the FES.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Resource assessment	Hydropower potential is limited to regions with rivers or watercourses with high flow rates or significant elevation change. The North of Scotland licence area is home to the region with the highest potential for hydropower in the UK, the Scottish Highlands. This region is both mountainous and sees large amounts of rainfall annually.
Resource distribution	The distribution of capacity beyond the known pipeline is based on the location of known projects and resource availability.

Relevant assumptions from National Grid FES 2023

Scenario		4.1.2 - Other renewables including marine and hydro generation[xxxvii]
Falling Short	Low	Low support and therefore other renewables cannot compete with low-cost solar and wind generation.
System Transformation	High	Support for large scale renewable technologies (i.e., tidal marine).
Consumer Transformation	High	Potential for a lot of small scale projects that will have a larger societal impact coupled with support for marine technologies across all scales.
Leading the Way	Medium	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.

Incorporating stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
Engagement with small-scale hydropower developers in the North of Scotland.	As part of DFES 2021, several developers were asked about constraints and limitations in the industry. Economic viability was highlighted as a key limiting factor for new hydropower projects.

	Under **Consumer Transformation** and **Leading the Way**, future policy support and alternative methods of project financing have been assumed to encourage future project development beyond the known pipeline.
Engagement with British Hydropower Association	The British Hydropower Association were engaged in 2023 to understand the degree of resource potential in the UK as a whole. This engagement revealed that the state of the sector has remained similar to previous years of analysis. However, several new studies on specific sites have since been conducted, although the area of focus for these studies was outside of the SSEN licence areas.

[xxxii] The Gazetteer for Scotland (2022). *Lochaber Aluminium Smelter* https://www.scottish-places.info/features/featurefirst10539.html

[xxxiii] Nich Forest Associates, SISTech & Black & Veatch 2008, *Scottish Hydropower Resource Study*. https://archive.uea.ac.uk/~e680/energy/energy_links/other_renewables/Scottish_hydropower_2008_0064958.pdf

[xxxiv] British Hydro Association 2022, *UK Hydropower Resource Assessment*. https://zenodo.org/record/7229023/files/BHA%20report%20draft%20v1.0.2.pdf?download=1

[xxxv] UK Government 2022, *Renewable Energy Planning Database (REPD)*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1114586/repd-october-2022.csv/preview

[xxxvi] Scottish Government Renewable 2021, *Scottish Government and low carbon energy policy*. https://www.gov.scot/policies/renewable-and-low-carbon-energy/

[xxxvii] Refers to FES 2023 assumptions workbook

Marine generation

Summary of modelling assumptions and results

Technology specification

The analysis includes marine generation projects (tidal stream, wave power, tidal lagoon) 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 European Marine Energy Centre and the Marine Energy Council to identify potential pipeline projects that will likely connect to the distribution network out to 2050.

The technologies included in the DFES marine energy analysis are:

- Wave energy – smaller pre-commercial arrays that typically connect to the distribution network.
- Tidal stream energy – this technology harnesses kinetic tidal flows around headlands and in channels. Most projects are now at commercial scale with some connecting to the distribution network and some connecting to the transmission network.

Note: there are no tidal lagoon projects in the licence area, but these may connect at transmission network 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 capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	17	17	25	25	25	25	25
System Transformation		17	78	138	153	153	163
Consumer Transformation		17	123	170	178	193	233
Leading the Way		17	32	63	64	64	64

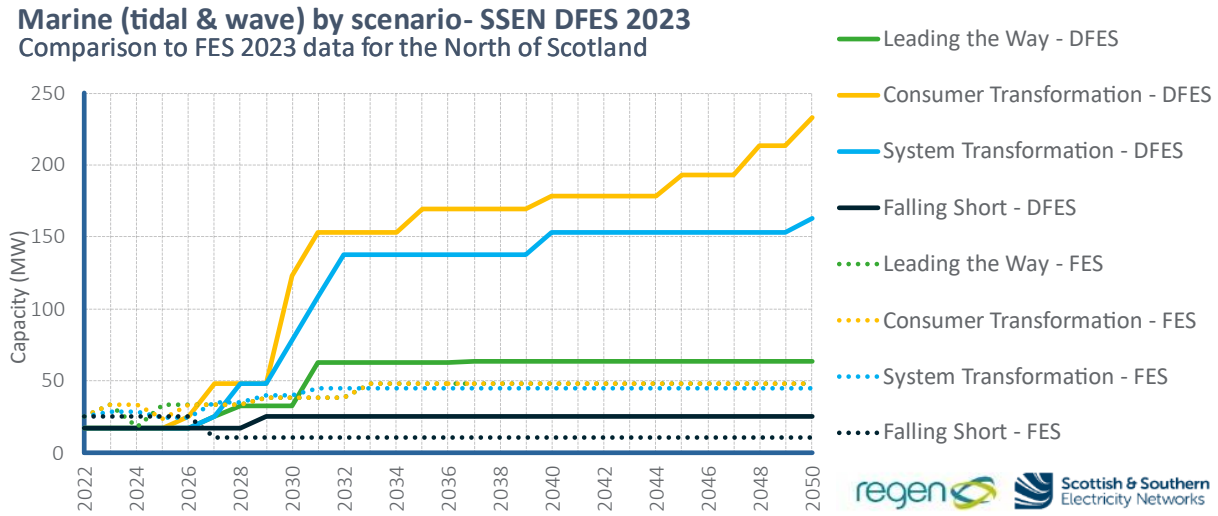


Figure 32 Marine generation projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- There are five connected marine generation projects in the North of Scotland licence area, totalling 17 MW. This is a reduction compared to the DFES 2022 baseline, which corresponds to a reduced connection capacity at Ness of Quoys in Pentland Firth. The updated connection capacity reflects what is in use, with future additional site capacity likely to be via a transmission network connection.[xxxviii] In addition, four tidal stream projects, totalling 107 MW, have secured connection agreements with SSEN. This is a significant increase of almost 100 MW compared to the DFES 2022 pipeline, reflecting development at sites including Orbital Marine Power's Westray Firth[xxxix], Òran na Mara on Islay[xl] and Nova Innovation's Yell Sound project.[xli]
- In September 2023, the results of the Contracts for Difference (CfD) Allocation Round 5 (AR5) were announced, which included a minimum budget of £10m for tidal stream.[xlii] 53 MW of projects succeeded in winning a CfD at a strike price of £198/MWh (2% lower than the administrative strike price of £202/MWh).
- Over 30 MW of CfDs were awarded to projects in the licence area (on top of 35 MW from AR4), including:
    - SAE Renewables' MeyGen (22 MW, transmission-connected)[xliii]
    - Orbital Marine Power's Eday 3 & 4 (7.2 MW, distribution-connected)[xliii]
    - Magallanes' berth at EMEC (1.5 MW, distribution-connected)

- These results have strengthened the renaissance of the UK marine generation industry. However, further development will depend on the industry's ability to reduce technology costs and receive continued policy support – particularly as tidal stream's CfD success in AR5 was predicated upon an absence of bids from offshore wind projects. With a significantly increased Administrative Strike Price for AR6, offshore wind projects are very likely to bid into the auction, but at prices that are significantly lower than the previous tidal stream strike price. This means that the success of tidal stream energy in AR6 will very likely be limited to the minimum budget allocated specifically for the technology. A £10m tidal stream minimum budget and strike price of £198/MWh in AR6 would equate to around 19 MW of capacity, for example – just over a third of the tidal stream capacity won in AR5.
- Beyond the known pipeline in the licence area, additional marine generation capacity has been modelled at both commercial and test facility scales. This projected future capacity is modelled at the most viable locations, reflecting further development of mature and viable tidal stream technologies at suitable sites.
- As the tidal stream sector expands, larger-scale projects are expected to connect to the transmission network, especially in the North of Scotland, where the transmission network is a voltage tier lower.
- Distribution network-connected projects will likely be limited to smaller-scale commercial projects, demonstration projects, trial sites and testing facilities.
- The wave energy industry is yet to demonstrate a commercially viable technology, but it could see significant scaling once it does.

Modelling and assumptions

Baseline (2022)			
Technology	**Number of sites**	**Total capacity (MW)**	**Description**
Total	5	17	Almost two-thirds of the existing marine generation capacity stems from EMEC's tidal stream and wave test sites.
Wave	1	7	A 7 MW installation is located at EMEC's wave energy test site at Billia Croo on Orkney.
Tidal Stream	4	10	There are three small pre-commercial tidal arrays: SAE's MeyGen site (5.7 MW), Nova Innovation's Cullivoe Tidal berth (45 kW) and Shetland Tidal Array (0.5 MW), and the EMEC Eday test site (4 MW).

Pipeline (2023-2030)

Number of pipeline sites	Total capacity (MW)
4[xliv]	107

Pipeline analysis

Status	Description	Sites	Capacity (MW)
Planning permission granted	One site has planning permission in the licence area: the first expansion phase of the EMEC Eday[xlv] tidal test facility (3.2 MW).	1	3.2
Pre-planning	EMEC is also in the process of developing a new EIA and S.36 consent application to expand to 50MW at their Eday tidal test site[xlv]. Orbital is developing a consent application for a new tidal energy project in the Westray Firth, having been awarded an Option Agreement from Crown Estate Scotland in March 2023.[xxxix]	2	87.6
No information	No development or planning information could be found for the two Nova Innovation projects – Òran na Mara on Islay and 15 MW Yell Sound tidal array.	2	16.5

Scenario projections (2030 to 2050)

Scenario	Description	Capacity by 2035 (MW)	Capacity by 2050 (MW)
Falling Short	Low support for tidal stream means that future ring-fenced budgets for tidal stream in future CfD Allocation Rounds are dropped under this scenario. Only AR4 CfD-winning, distribution network-connected projects are completed, while others struggle to get off the ground without further subsidy support. As a result, capacity grows slightly to 25 MW by 2050. The capacity projection is less than DFES 2022 due to a reduced baseline connection capacity at Ness of Quoys.	25	25
System Transformation	Under this scenario, support for larger-scale technologies and projects, likely via future CfD	138	163

	rounds, leads to further expansion in the 2030s at several prospective sites around the Scottish coast, ranging from 10 MW to 60 MW: • EMEC – Fall of Warness, • Westray South/Duncansby Head • EMEC – Billia Croo wave test facility • Lashy Sound Projections differ to DFES 2022 with greater expansion at known operational or in-development sites, and less projected capacity at sites that have not progressed for several years (which were projected to continue development work in DFES 2022).		
Consumer Transformation	Marine generation technologies receive good support across all scales in this scenario, and there is consistent industry development out to 2050. This results in earlier development for sites, further expansion at Lashy Sound and development of projects at Òran na Mara, Yell Sound and Churchill Barriers. Total capacity reaches 233 MW by 2050, which equates to 68% of the FES GB projection for distributed marine generation in 2050. After the spike in capacity by 2030, marine projects are expected to be at commercial scale and connect to the transmission network.	170	233
Leading the Way	In this scenario, the prioritisation of solar and wind generation results in a lesser need for tidal energy. Nevertheless, some development occurs at EMEC's Fall of Warness site (expanded only to support Orbital Marine Power's CfD AR4 and AR5 contracts), Orbital Marine Power's Westray South and Nova Innovation's Òran na Mara site.	62	64

Reconciliation with National Grid FES 2023

Modelling Stage	Reconciliation
Baseline	The FES 2023 baseline (25 MW) is 8 MW higher than the DFES 2023 baseline (17 MW), with all the FES baseline capacity connected to the Thurso GSP. This is likely due to the FES not yet accounting for the reduced connection capacity at Ness of Quoys in Pentland Firth.
Pipeline	Based on the most recent connection data and developer engagement, we have

	identified and modelled several specific pipeline projects that are not reflected in national FES 2023 projections. As a result, marine generation capacity in the DFES 2023 starts at a lower baseline than the FES 2023 but reaches 32-123 MW by 2030 (scenario dependent, excluding **Falling Short**) in the DFES 2023, compared to 38-40 MW in the FES 2023.
Projections	Looking further ahead to 2050, the DFES has projected a significantly higher level of distribution connected marine generation in the North of Scotland licence area compared to the FES 2023. Under **Consumer Transformation**, the FES 2023 remains at 48 MW by 2050, accounting for only 14% of all GB distribution network-connected marine energy capacity in 2050 (according to FES 2023 GB projections). In contrast, the DFES has considered that the North of Scotland is likely to be one of the more prominent regions for hosting distributed marine generation projects in GB in the longer term and as such projects a much higher capacity out to 2050.
Overarching Trend	The DFES models marine generation capacity based on knowledge of site and company-specific development activity and where increased capacity is most likely to occur. Whereas the FES 2023 projects a more constant distribution-connected capacity, the DFES 2023 considers the potential for marine energy to expand through CfD support in the North of Scotland as an area of strong marine generation resource, initially building capacity at existing operational sites with potential future phased expansions. More optimistic scenarios, such as **Consumer Transformation**, reflect a more ambitious long-term outcome where successful developers branch out to develop several new sites.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Location of known pipeline projects and industry knowledge	The DFES analysis for marine generation uses stakeholder engagement to focus on the location of known projects, sites and developer activity, most of which are located in the waters off the north coast, west coast and the major Scottish islands.

Relevant assumptions from National Grid FES 2023

Scenario	4.1.2 - Other renewables including marine and hydro generation	
Falling Short	Low	Low support and therefore other renewables cannot compete with low-cost solar and wind generation.

System Transformation	High	Support for large-scale renewable technologies (i.e. tidal marine).
Consumer Transformation	High	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	Medium	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.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
Representatives from EMEC and MEC were engaged to identify site-specific insights for future opportunities and timelines for potential projects at some specific site locations. Wider sector knowledge around project development timelines and how projects are likely to develop relative to government support was also provided, including development timing relative to future CfD Allocation Rounds.	We have used this information to directly influence the scenario projections across the licence area.

[xxxviii] https://cfd.lowcarboncontracts.uk/cfd-register/register/AR4-MEY-510/

[xxxix] https://www.orbitalmarine.com/westray-tidal-energy-project/

[xl] https://marine.gov.scot/node/24310

[xli] https://novainnovation.com/news/net-zero-ambitions-boosted

[xlii] UK Government 2023, *Contracts for Difference (CfD) Allocation Round 5: results*. https://www.gov.uk/government/publications/contracts-for-difference-cfd-allocation-round-5-results

[xliii] Low Carbon Contracts n.d., *CfD Register*. https://www.lowcarboncontracts.uk/cfd-register/

[xliv] The Eday tidal test site has multiple connections at different planning stages. In this analysis, we have counted multiple connection offers at the same site and same planning phase as a single site. Connections at different planning stages at the same site are counted separately in the 'Pipeline Analysis' table above.

[xlv] European Marine Energy Centre Ltd. (EMEC) n.d., *Grid-Connected Tidal Test Site*. https://www.emec.org.uk/facilities/tidal-test-site/

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 Combined Heat and Power (CHP). However, the analysis does not include biomass used solely for heat or bioenergy generation with carbon capture and storage (BECCS).

Technology building block: **Gen_BB010 – Biomass & Energy Crops (including CHP)**

Data summary for biomass in the North of Scotland licence area

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	56	56	55	55	55	55	43
System Transformation		56	43	43	31	15	0
Consumer Transformation		56	43	98	82	67	66
Leading the Way		56	43	43	31	15	0

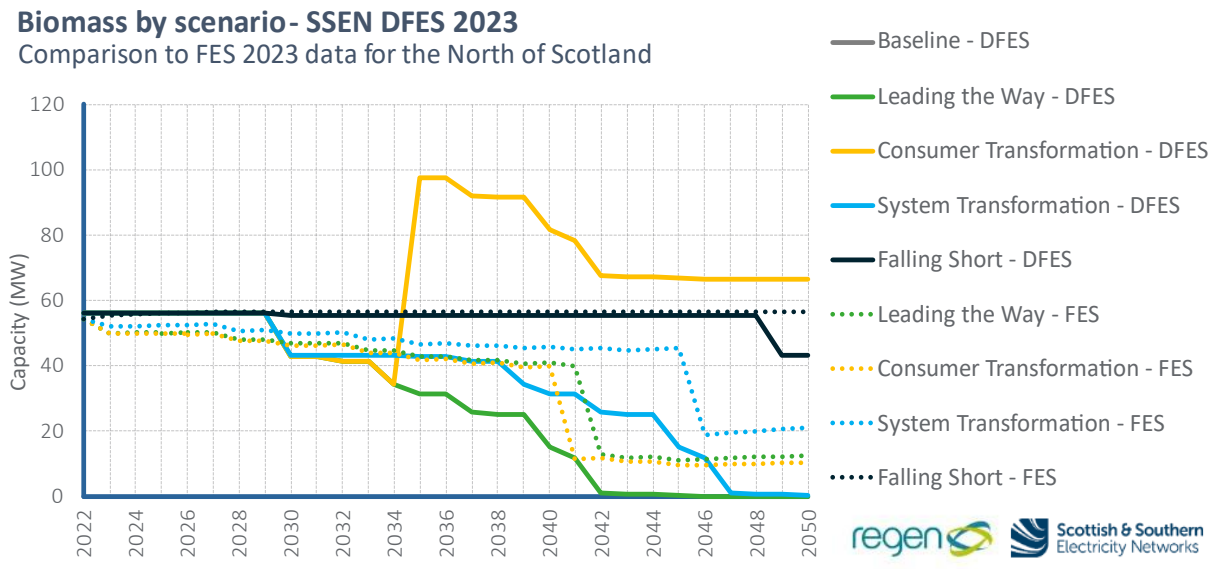


Figure 33 Biomass generation projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- The North of Scotland licence area has significant local biomass resource as a by-product of the forestry industry. As a result, the licence area has a decent baseline of distribution network-connected biomass generation and CHP plants totalling 56 MW. Existing business models range from small, farm-scale plants, large or medium-sized CHP plants, to larger-scale commercial plants developed for power generation.
- The DFES 2023 projections differ to DFES 2022, primarily due to the change in assumptions around the repowering of unabated diesel generation. Previously, Scottish island diesel backups sites were modelled to transition to biomass under **Consumer Transformation** and **Falling Short** with staggered years. In DFES 2023 these have been modelled to transition to biomass only under **Consumer Transformation** in 2035. Fewer diesel sites in the licence area are modelled to transition to biomass overall.
- Due to economies of scale, most BECCS-enabled sites are likely to connect to the transmission network where the significant investments required for carbon capture technologies are more feasible.
- The development of smaller-scale biomass sites that could connect to the distribution network under the three net zero scenarios could leverage short-rotation crops and sustainable biomass business models, as supported under the Scottish Bioenergy Policy.[xlvi] However, the development of locally sourced biomass would be better used to displace biomass currently being supplied from unsustainable sources overseas.

- Under the UK Biomass Policy Statement,[xlvii] most off-gas grid small-scale biomass sites are to be reserved for heating purposes. The DFES reflects this in its approach to decommissioning existing baseline sites.
- In 2021, the UK Government issued a call for evidence on the proposed removal of the 300 MW threshold for Decarbonisation Readiness (DR) requirements for combustion power plants, which went to consultation in 2023 and will come into force for new and refurbished plants by July 2024 in England alone.[xlviii] The DR will require sites to set aside space for carbon capture technology. If this removal goes through the business model will become increasingly challenging without further subsidy support, unless in rare cases it is exempt from the environmental permitting regime.[xlix]
- Under **Consumer Transformation** Scottish Island diesel backup generators are modelled to be replaced with biomass engines in 2035, making up the sole post-pipeline growth in capacity. These remain online to 2050.
- **Leading the Way** and **System Transformation** see no new additional biomass generation capacity connecting to the distribution network out to 2050, with all unabated sites being decommissioned under **Leading the Way** by 2045 and by 2050 under **System Transformation**. **Falling Short** sees a continuation of current trends, with no new sites being built and no decommissioning within the modelling timeframe.

Modelling and assumptions

Baseline (2022)

Number of sites	Total capacity (MW)	Description
20	56	The most recently commissioned site was in 2021 at Ardblair Sports Importers in Perthshire. The baseline of biomass sites has otherwise not changed since DFES 2021.

Pipeline (2023-2030)

Number of pipeline sites	Total capacity (MW)
2	0.2

There are two pipeline sites included in the analysis totalling 0.2 MW, sites have been issued a quote but have not yet secured connection agreements with SSEN. They have been modelled to connect in **Falling Short**.

DFES 2022 also captured a connection offer to extend the capacity of the existing Stoneywood mill site by 9.4 MW at the Arjowiggins New Energy Centre in Aberdeen.[l] However, it is no longer in SSEN's

connections data, potentially refusing its previous grid connection offer after going into administration in September 2022.[li]

Decommissioning logic

Because most small-scale biomass plants will not find it economically viable to retrofit CCUS technologies, existing sites are modelled to decommission and not be replaced with new assets in the three net zero scenarios. Under **Falling Short**, existing sites stay online past the 2050 net zero target. All pipeline sites modelled to connect are assumed to continue operating out to and/or beyond 2050.

Falling Short	System Transformation	Consumer Transformation	Leading the Way
Does not decommission before 2050	30 years	25 years	25 years

Scenario projections (2030 to 2050)

Scenario	Description	Capacity by 2035 (MW)	Capacity by 2050 (MW)
Falling Short	Biomass capacity remains relatively stable out to 2050, assuming that existing plants are replaced or refurbished as frequently as they are decommissioned.	56	43
System Transformation	Baseline biomass sites decommission in line with net zero targets out to 2025. The decision to decommission existing biomass sites in net zero scenarios echoes the UK's Biomass Policy Statement, which stipulates that most off-gas biomass sites should be reserved for heating. Under **Leading the Way** and **System Transformation** there is no operational biomass electricity fuelled generation in the licence area by 2050. Under **Consumer Transformation**, 61 MW of biomass generation is installed on Scottish Islands to replace existing unabated diesel engine assets.	43	0
Consumer Transformation		98	66
Leading the Way		31	0

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation
Baseline	The DFES 2023 baseline aligns directly with FES 2023 at 56 MW.
Pipeline	The pipeline projections are closely aligned between FES and DFES 2023, although decommissioning of smaller sites occurs earlier under FES 2023, whereas DFES 2023 decommissions sites at a faster rate from 2030 onwards.
Projections	Under DFES 2023, **Leading the Way** and **System Transformation** fully decommissions all biomass capacity by 2045 and 2050 respectively, whereas FES models at least 10 MW of capacity remaining online by 2050 under all scenarios. The largest variance in long-term projections is seen under **Consumer Transformation** which is due to the DFES approach to modelling the transition of some Scottish Island diesel engines to biomass. DFES 2023 **Falling Short** projections are directly aligned to the FES 2023.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Baseline and pipeline sites	The geographical location of future capacity is based entirely on known baseline and pipeline locations.

Relevant assumptions from National Grid FES 2023

Assumption number	4.1.11 - Unabated Biomass and Energy from Waste (EfW) generation	
Falling Short	High	Unabated biomass generation does not convert as rapidly to BECCS. No significant change in waste management from society; leaving waste available as a fuel source for unabated generation.
System Transformation	Medium	Unabated biomass is supported for longer than in **Leading the Way** as slower to adopt CCS. Less waste to burn in general due to a highly conscious society adapting to low waste living.
Consumer Transformation	Medium	
Leading the Way	Low	Unabated biomass drops away rapidly as BECCS and other uses for biomass increases. Less waste to burn in general due to a highly conscious society adapting to low waste living.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
No stakeholder feedback was captured for this technology in DFES 2023.	

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

[xlvii] Department for 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

[xlviii] https://assets.publishing.service.gov.uk/media/640efb5ad3bf7f02f4c7682c/decarbonisation_readiness_consultation.pdf

[xlix] See page 27 of the consultation: https://assets.publishing.service.gov.uk/media/640efb5ad3bf7f02f4c7682c/decarbonisation_readiness_consultation.pdf

[l] Aberdeen Live 2022, *'Rapid' work needed to secure future of 'crucial' Aberdeen paper mill*. https://www.aberdeenlive.news/news/aberdeen-news/rapid-work-needed-secure-future-7763200

[li] Press and Journal 2022, *EXCLUSIVE: Bid to save Aberdeen's Stoneywood paper mill rejected*. https://www.pressandjournal.co.uk/fp/politics/scottish-politics/4990828/stoneywood-paper-mill-bid-rejected/

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.

Technology 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 capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Renewable Engines	**Falling Short**	31	33	32	16	14	13	12
	System Transformation		34	38	23	21	20	19
	Consumer Transformation		36	50	37	36	35	35
	Leading the Way		36	52	40	39	39	38

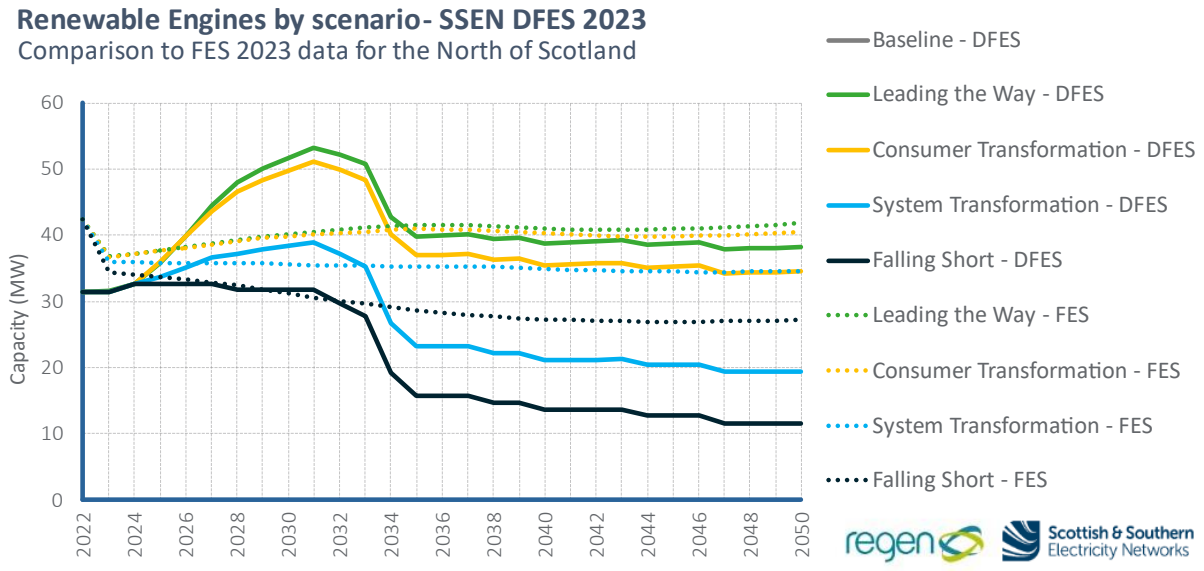


Figure 34 Renewable engines projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- As of the end of 2022, there was 31.4 MW of installed renewable engine capacity in the licence area, of which 7.7 MW was anaerobic digestion (AD), 21.1 MW was landfill gas, and 2.6 MW was sewage gas.
- Compared to DFES 2022, the baseline and projections are largely similar, with the largest deviation being a more ambitious level of installed capacity under **Consumer Transformation** by 2050. The reason for this deviation from DFES 2022 is a modelling decision to align more closely with FES 2023 regional projections.
- The future of AD in the North of Scotland depends heavily on feedstock availability. As most councils already collect food waste, food industry and agricultural and animal husbandry by-products are most likely to serve as future feedstocks.
- Agricultural land grade in the North of Scotland licence area is relatively low, representing just 3.9% of all viable land in GB.
- Landfill gas is expected to decrease over time due to Scotland's ban on sending biodegradable municipal waste to landfill by 2025 (pushed back from the original date of 2021) in Scotland,[lii] leading to a gradual decommissioning by 2048 of all landfill sites under all scenarios.
- Sewage gas remains at similar levels under all scenarios with a notable amount of the sewage gas resource already being captured and used for electricity and CHP generation by Scottish Water.[liii]

- Increased demand for green gas is expected in the medium and long term for transport, heat networks, and gas grid injection. However, electrolytic hydrogen and electrification are also expected to play a role in decarbonising these end-use sectors.
- The injection of green gas into the gas network is currently incentivised via the Green Gas Support Scheme,[liv] funded through payments made by licenced gas suppliers under the Green Gas Levy. This may limit the amount of future electricity distribution connected sites.
- Projected increase in anaerobic digestion from redistributed FES projections across all DNO licence areas results in a net increase in total capacity out to 2032 under the three net zero scenarios. After 2032, decommissioning logic leads to a decrease in capacity as legacy landfill gas sites begin coming offline rapidly.
- Under **Leading the Way**, overall renewable engine capacity out to 2050 increases compared to the baseline, reaching 38 MW by 2050. Only a slight increase is seen under **Consumer Transformation**, with 35 MW by 2050.
- The other two scenarios see a small net decrease due to decommissioning of landfill gas, decreasing to 19 and 12 MW by 2050 under **System Transformation** and **Falling Short** respectively.

Modelling and assumptions

Baseline (2022)		
Number of sites	**Total capacity (MW)**	**Description**
40	31	The baseline consists of 31 MW from 40 sites, of which 7.7 MW was AD, 21.1 MW was landfill gas, and 2.6 MW was sewage gas. The majority of AD capacity has been added since 2013 (10 MW), whereas only 2 MW of landfill gas, c. 10% of the landfill gas baseline, has been commissioned since 2013.

Pipeline (2023-2030)	
Number of pipeline sites	**Total capacity (MW)**
2	1.2
There are two renewable engine sites in planning, one AD site in Beyside with a planning application submitted and one sewage gas site in Perth. Several sites were identified in the REPD and included in the pipeline for DFES 2022. This year, they have been removed from the analysis, following an assumption	

that their absence from SSEN connections data means they are either gas grid connected or not network-connected at all.

Pipeline sites

Status	Description	Sites	Capacity (MW)
Planning application submitted	One site in Moray called Beyside Anaerobic Digestor (application reference 23/00894/APP) is modelled to connect by 2024 under all scenarios.	1	1
No information	A 180 Kw sewage gas site in the SSEN connections data was not found in desk research but has been modelled to connect in all scenarios. However, due to its small size it will have limited impact on the network.	1	0.180

Decommissioning logic

Landfill gas sites are modelled to disconnect after 30 years in all scenarios. This is because landfill gas is considered a legacy technology since waste management is expected to shift to incineration and Advanced Combustion Technologies (ACT) moving forward. There is also the assumption that a more waste conscious society under **Leading the Way** and **Consumer Transformation** will lead to less volumes of waste being treated overall. AD and sewage gas sites are modelled to stay online in all scenarios.

Scenario projections (2030 to 2050)

AD sites are the only renewable engine sub-technology modelled to see any long-term projected capacity growth in the licence area after the known pipeline. Projections are based on locations close to agricultural land that could produce biogenic waste products as feedstocks. Since all Scottish councils already collect food waste, it is assumed that most food waste is already being utilised and thus does not largely influence the projections, limiting AD capacity by 2050 to 35 MW under **Leading the Way**. Sewage gas sites are expected to remain at current levels in all scenarios, while landfill gas decommissions in all scenarios to be in line with a ban on new landfill sites in Scotland.

Scenario	Anaerobic digestion capacity (MW) by		Landfill gas capacity (MW) by		Sewage gas capacity (MW) by	
	2035	2050	2035	2050	2035	2050
Falling Short	9	9	4	0	3	3
System Transformation	16	17	4	0	3	3
Consumer Transformation	30	32	4	0	3	3
Leading the Way	33	35	4	0	3	3

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation
Baseline	The FES 2023 baseline (42 MW) is higher than the SSEN baseline of 31 MW, followed by a swift decrease to 34 MW in **Falling Short** in 2023. The reason for this variance is unclear.
Pipeline	Not including the significant baseline variance, projections across the 2020s are nominally aligned. However, some variance is seen in part due to the individual site commissioning and decommissioning modelled under the DFES. For instance, legacy landfill sites are modelled to come offline under all scenarios in the early 2020s. Another reason for deviation from the FES is due to the Regen methodology of redistributing projections across all DNOs based on geographical factors, which accounts for the higher estimates out to 2032 in **Consumer Transformation** and **Leading the Way**. In contrast, FES projections reflect a smoother decommissioning trend, except under **Falling Short** and **System Transformation**, in the 2030s.
Projections	By 2050, DFES projections align more closely with the FES in **Leading the Way** and **Falling Short**. The DFES models a less ambitious uptake in **Consumer Transformation** and **System Transformation** by 2050 due to the assumption that not all AD facilities connect to the distribution network to replace decommissioning landfill gas and sewage sites.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Baseline and pipeline sites	Distribution is determined by the location of known baseline and pipeline sites.
Agricultural land grade	Areas with high levels of sufficient agricultural land grade are used to pinpoint locations where agricultural by-products could be used for future AD sites.

Relevant assumptions from National Grid FES 2023

Assumption number	1.1.5 - Support: incentive regime for biomethane (and other 'green gas') production	
Falling Short	Low	Support is focused on areas with greater potential volumes (UKCS/shale).
System	Medium	Bigger push for renewable gas as required to meet longer-term

Transformation		decarbonisation targets.
Consumer Transformation	Medium	
Leading the Way	High	All sources of renewable fuels encouraged and biomethane used in niche areas in transport/industry.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
Local Authority Questionnaire	As part of the DFES analysis, Regen issues a questionnaire to local authorities each year to get an update on local net zero ambitions. All local authorities responding from the North of Scotland licence area had a waste collection strategy, and all local authorities collect food waste. This suggests that local authorities in Scotland have ambitious waste management targets, with a high level of devolved governance on the future of waste. The valuation of food waste by Scottish councils influenced the analysis by removing this as a spatial factor for renewable engines for the North of Scotland. As a result, only agricultural land and animal husbandry locations are considered for future AD projections.

[lii] Resource 2019, *Scottish Government to Delay Scottish Landfill Ban to 2025*. https://resource.co/article/scottish-government-delay-scottish-landfill-ban-2025

[liii] See Scottish Water Anaerobic Digestion overview. https://www.scottishwater.co.uk/about-us/energy-and-sustainability/renewable-energy-technologies/anaerobic-digestion

[liv] 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

Waste-fuelled generation

Summary of modelling assumptions and results

Technology specification

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

Network technology data building block: **Gen_BB011 – Waste Incineration (including CHP)**

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

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	35	45	85	85	76	76	76
System Transformation		45	76	76	76	76	66
Consumer Transformation		75	76	76	76	76	66
Leading the Way		75	66	66	66	66	56

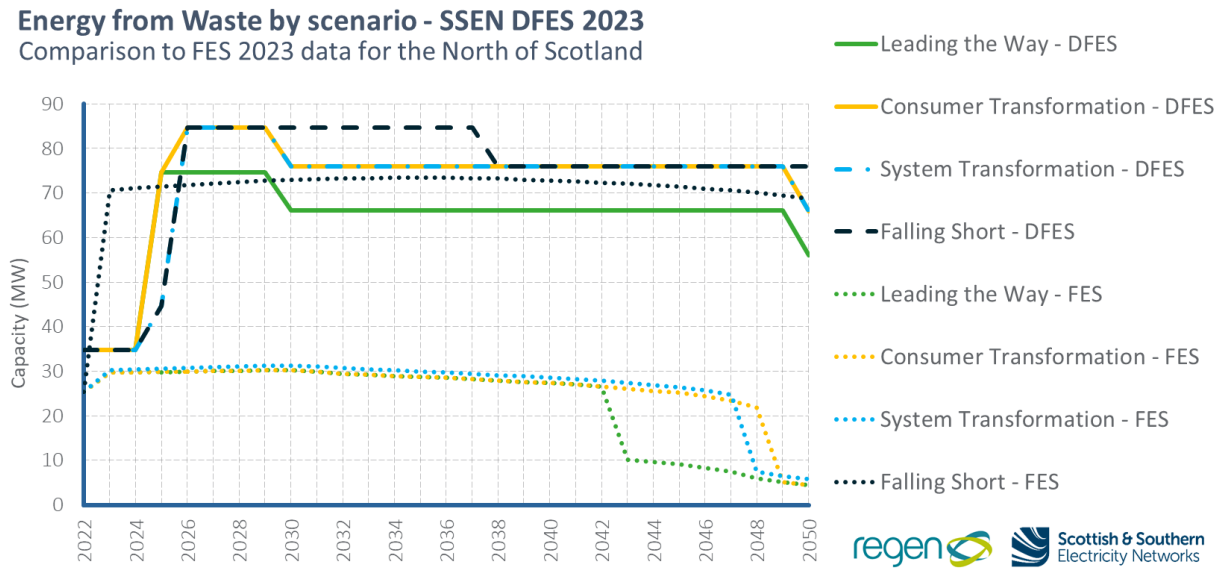


Figure 35 Waste-fuelled generation projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- There is 35 MW of waste fuelled generation operating in the licence area, all from incineration plants. There are two further waste incineration projects in the pipeline with a combined capacity of 50 MW with accepted connection offers and planning approval.
- Compared to DFES 2022, the amount of capacity remaining online by 2050 is higher in all three net zero scenarios. This is due to updated assumptions about the operating lifespan of energy from waste sites based on recent planning applications, which are now modelled to remain online for up to 40 years after commissioning.
- The carbon emissions from older unabated waste incineration plants are not consistent with net zero emissions targets. As a result, DFES 2023 scenarios that meet net zero targets assume that connected incineration plant capacity reduces after 2030 as older facilities reach the end of their lifetime.
- Some capacity will be replaced by new ACTs, which falls in line with emissions targets so long as residual emissions are abated. ACT technology is relatively new and expensive, and therefore growth is delayed to the 2030s and 40s as costs are assumed to drop. Examples of ACTs include:

- Anaerobic digestion,[39] which breaks down organic waste material using bacteria to produce biogas.
- Gasification, which uses high temperatures to convert solid waste into a gas.
- Pyrolysis, which heats waste materials in the absence of oxygen to produce a liquid oil that can be used as a fuel, as well as other useful by-products.
- Plasma arc gasification, which uses plasma (a high-temperature, ionised gas) to convert waste into a gas that can be used for energy production.
- Key uncertainties include the extent to which energy from waste technologies are considered consistent with decarbonisation objectives, planning issues related to air quality and the volume of waste that is reduced or recycled, reducing feedstock for energy from waste projects. There is an also uncertainty as to whether projects will be distribution-network connected.
- By 2050, The three net zero scenarios see varying degrees of decrease in energy from waste capacity, with 0 MW under **Leading the Way** and 66 MW under **System Transformation**. Under **Falling Short**, waste-fuelled generation capacity continues to grow, reaching 76 MW by 2050, most of which is incineration.

Modelling and assumptions

Baseline (2022)

Number of sites	Total capacity (MW)	Description
2	35	There are three baseline entries in the licence area, two of which are at the same site; the Baldovie incineration plant in Dundee secured a 9 MW connection capacity in 1999 and increased this capacity to 19 MW in June 2020. In 2022, the 16 MW Greenbank Crescent (EFW NESS Energy Project) was commissioned.[lv]

Pipeline (2023-2030)

Number of pipeline sites	Total capacity (MW)
2	50
The two sites in the pipeline are waste incineration facilities, both of which have been granted planning applications and are highly likely to connect. This increase in active incineration pipeline projects in the licence area may be linked to the ban on biodegradable waste going to landfill, expected to be	

[39] Note that anaerobic digestion is considered in the DFES as a Renewable Engines technology.

implemented in 2025[lvi]. There were no known ACT sites in the pipeline in the North of Scotland licence area as of mid-2023.

Pipeline sites

Name	Description	Planning status	Capacity (MW)
Thainstone Energy Park	Due to its location in Inverurie in Aberdeenshire, this site is the largest in the energy from waste pipeline and is modelled to connect between 2025 and 2026 in all scenarios.	Granted	40
Binn Farm	This site is one of multiple planning applications at Binn Eco Park. The waste incinerator is modelled to connect between 2025 and 2026 in all scenarios except **Leading the Way**.	Granted	7.3

Decommissioning logic

According to the hierarchy of waste management best practice, energy from waste comes in fourth place after waste prevention, waste preparation for reuse and waste recycling. Electricity generation from unabated waste incineration has a high level of carbon emissions, making it at odds with net zero targets. Therefore, the DFES models waste incineration technologies to decommission in all scenarios to align with net zero ambitions and reflect a more waste-conscious society. According to the Department for Environment, Food and Rural Affairs (DEFRA),[lvii] the operational life of an incineration facility is typically between 20 and 30 years. However, recent planning application evidence has suggested a 40-year operating life for energy from waste sites. This has been incorporated into the decommissioning modelling assumptions for each scenario. For DFES 2023, it has been assumed that only baseline sites will decommission within the modelling period (2050) whereas pipeline sites will still be operational after this.

	Falling Short	System Transformation	Consumer Transformation	Leading the Way
Baseline	40 years	30 years	30 years	30 years

Scenario projections (2030 to 2050)

The Scottish Government looks to introduce a long-term target of 70% recycling rates for all waste arising in Scotland by 2025,[lviii] which will ultimately decrease the need for waste treatment overall. In addition, biodegradable waste going to landfill is set to be banned from 2025,[lvi] meaning that any remaining waste will require treatment by other means.

IEA Bioenergy, in its paper entitled 'Waste Incineration for the Future',[lix] recommends that the waste sector move towards innovation in energy technologies and look towards new business models to continue to create value in a carbon-efficient circular economy. At distribution voltages, ACT technologies have already come forward as low carbon replacements to traditional combustion plants and could replace legacy and new sites in years to come.

Scenario	Description	Capacity (MW) by	
		2035	2050
Falling Short	Under this scenario, waste incineration sites are assumed to operate for 40 years, with only one site decommissioning in 2049 after being commissioned in 2019. All pipeline sites are modelled to connect and remain online beyond 2050. Fewer ACT technologies are modelled to come online and displace incineration sites than in the net zero scenarios.	85	76
System Transformation	Under the three net zero scenarios, a shift towards a more sustainable society means less need for waste generation. At the same time, innovative technologies such as ACT become more widespread as investments in cleaner technologies are prioritised at a municipal level. Incinerators are modelled to be replaced by ACT facilities at a faster rate under **Consumer Transformation** and **Leading the Way** and **System Transformation**. Some incinerators remain online and are decommissioned shortly after 2050 or fitted with carbon capture technologies.	76	66
Consumer Transformation		76	66
Leading the Way		66	56

Reconciliation with National Grid FES 2023

Modelling Stage	Reconciliation
Baseline	The baseline for waste fuelled generation is 10 MW higher according to DFES 2023 at 35 MW compared to 25 MW identified by the FES. The reason for this is unclear but could be related to the technology classification of some connected sites.
Pipeline	In the near term, DFES 2023 deviates from FES 2023 in all scenarios but **Falling Short**, with sites decomissioning under **Leading the Way** and 85 MW connecting under the other scenarios. In contrast, FES only sees c. 30 MW connecting in the net zero scenarios. This variance is due to the DFES pipeline evidence, which takes a site-by-site analysis approach to determine projects that are most likely to connect. Where planning permission is granted or sites are identified to be already under construction, projects are generally modelled to connect under all scenarios in the DFES.
Projections	In the 2030s, DFES and FES projections are aligned, remaining flatlined in all scenarios. Both DFES and FES also model a reduction in capacity in the 2040s under the three net zero scenarios, reflecting the assumption of a waste-conscious society. However, the DFES scenarios see higher capacities in all scenarios by 2050 than the FES due to the pipeline sites modelled to connect in earlier years.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Known baseline and pipeline sites	Distribution is determined by known baseline and prospective sites. ACT sites are modelled to connect either at their proposed location in planning applications or at decommissioned incineration sites.

Relevant assumptions from National Grid FES 2023

Assumption number	4.1.11 – Unabated Biomass and Energy from Waste (EfW) generation	
Falling Short	High	Unabated biomass generation does not convert as rapidly to BECCS. No significant change in waste management from society; leaving waste available as a fuel source for unabated generation.
System Transformation	Medium	Unabated biomass is supported for longer than in **Leading the Way** as slower to adopt CCS. Less waste to burn in general due to a highly conscious society adapting to low waste living.
Consumer Transformation	Medium	
Leading the Way	Low	Unabated biomass drops away rapidly as BECCS and other uses for biomass increases. Less waste to burn in general due to a highly conscious society adapting to low waste living.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
As part of the DFES analysis on new property developments, Regen issues a questionnaire to all local authorities in the licence area to get an update on local net zero ambitions. The six local authorities responding from the North of Scotland licence area had waste collection strategies in place.	This suggests that local authorities in Scotland have ambitious waste management targets in place, with a high level of devolved governance on the future of waste. This has been taken into consideration in the analysis by limiting the reduction in waste-to-energy capacity out until 2050.

[lv] Aberdeen City Council n.d., *NESS Energy Project*. https://www.aberdeencity.gov.uk/ness-energy-project

[lvi] Climate Exchange, Jan 2022, *Implementing Scotland's landfill ban* https://www.climatexchange.org.uk/media/5141/cxc-implementing-scotlands-landfill-ban-final-report-jan-2022.pdf

[lvii] 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

[lviii] Scottish Government *Scotland Zero Waste Plan*. https://www.gov.scot/publications/scotlands-zero-waste-plan/pages/4/ and https://www.gov.scot/policies/managing-waste/

[lix] IEW Bioenergy 2019, *Waste Incineration for The Future: scenario analysis and action plans*. https://www.ieabioenergy.com/wp-content/uploads/2019/04/Waste-Energy-for-the-Future-IEA-version.pdf

Diesel generation

Summary of modelling assumptions and results

Technology specification

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

The analysis does not include dedicated backup 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 capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	131	137	137	72	66	66	66
System Transformation		137	137	66	66	66	66
Consumer Transformation		137	137	66	0	0	0
Leading the Way		137	137	66	66	66	66

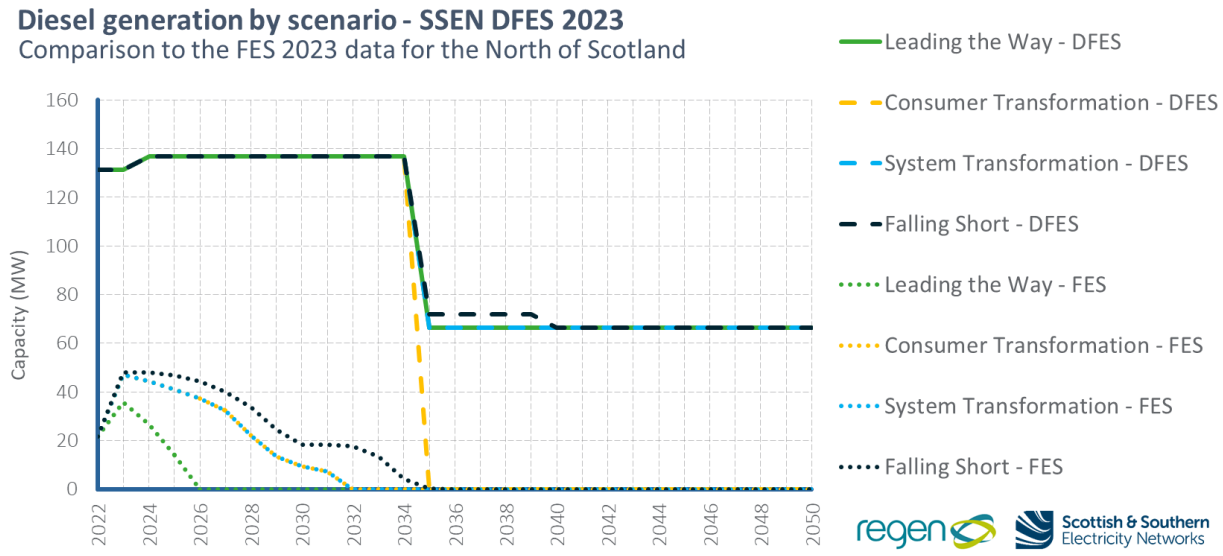


Figure 36 Diesel generation projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- Diesel generation within scope of the DFES analysis for the North of Scotland licence area comprises support generators that are sited on Scottish Islands, that are used for backup supply when the subsea cables or the main network supply to the islands are offline. In addition, there is one backup site in the pipeline.
- As of the end of 2022, the North of Scotland had nine operational diesel generation plants, totalling 131 MW. The age of these diesel plants varies significantly, with some commissioned as early as the 1940s and the latest commissioned in 2021.
- These are solely backup diesel power plants, located at Kirkwall on the Orkney Islands, Bowmore, Stornoway, Tiree, Barra and at Loch Carnan on South Uist. Lerwick Power Station on the Shetland Islands hosts two standalone diesel generation plants (Lerwick A and Lerwick B), alongside a single backup plant.
- There is one diesel site that has an accepted connection offer in the North of Scotland, a 5.5 MW behind-the-meter backup plant near Oban. This has been modelled to connect under all scenarios in late 2023.
- The continued use of unabated fossil diesel generation is expected to be time-limited due to net zero carbon emissions targets. However backup generators such as the generators supporting the Scottish Islands are exempt due to their low annual operating hours, and their provision of security of supply.

- Engagement with SSEN helped inform the assumption that backup capability would need to be maintained on the Scottish Islands in all scenarios. 2035 was provided as a target year for the decarbonisation of this capability, broadly aligned with island and network decarbonisation targets. The existing diesel sites are assumed to switch to bio-diesel in 2030 in **Leading the Way**, 2035 in **System Transformation** and 2040 in **Falling Short**. All capacities are assumed to remain the same and connections retained. Under **Consumer Transformation** diesel power stations are replaced by biomass in 2035.
- As part of SSEN's Whole System Energy Solutions for the Scottish Islands programme of work, SSEN is investigating the future of the Scottish Island diesel generators and alternative fuels,[lx] however this work is ongoing and as such is not included in this modelling.
- Lerwick Power Station A and B (totalling 65 MW) will operate in standby mode from November 2024 before being decommissioned in 2035.[lxi] The 6 MW back up engine at Lerwick is modelled to switch to biodiesel and operate through to 2050 in line with the other Scottish Island diesel backup plants.

Modelling Stages

Baseline (2022)		
Number of sites	**Total capacity (MW)**	**Description**
9	131	The diesel baseline is made up of standalone and behind-the-meter sites located on remote Scottish islands and has not changed since DFES 2022.
Planning Logic and Assumptions		
There is one behind-the-meter diesel engine with an accepted connection offer, a 5.5 MW behind-the-meter back up plant at Scottish Sea Farms near Oban. This is modelled to connect at the end of 2023 in all scenarios in accordance with data from SSEN. Beyond this, no new diesel generation sites are modelled to connect.		

Decommissioning logic

DFES analysis for diesel generation focuses largely on decommissioning existing baseline and pipeline sites. Between now and the mid-2030s, depending on the scenario, the decommissioning logic considers:

- The type of diesel site (standalone or backup).
- The year each site was installed.
- How each scenario reflects environmental permitting requirements under the MCPD and progress towards net zero targets.
- The potential for low-carbon diesel or biodiesel to enable backup generators to operate for longer under some scenarios. This has only been modelled where fuel-transition programmes have been discussed with the site operators or otherwise evidenced. For SHEPD, engagement with SSEN helped inform assumptions around fuel transition at the Scottish Island backup sites.
- The availability of replacement power on the Scottish Islands.

Scenario projections (2023 to 2050)

Scenario	Description	Capacity by 2035 (MW)	Capacity by 2050 (MW)
Falling Short	Diesel capacity falls from a peak in 2024 of 137 MW, to 72 MW when Lerwick Power Station A and B decommission in 2035.[lxi] Capacity then reduces further in 2039, when the 5.5 MW behind-the-meter pipeline site at Scottish Sea Farms decommissions. Capacity then remains at 66 MW to 2050, as other back-up sites on the islands switch to biodiesel and maintain standby operation.	72	66
System Transformation	Diesel capacity falls to 66 MW as Lerwick Power Station A and B and the behind-the-meter plant at Scottish Sea Farms all decommission in 2035. Capacity then remains at 66 MW through to 2050, as other diesel back-up stations on the island switch to biodiesel and continue to provide standby/back-up services.	66	66
Consumer Transformation	All diesel capacity is modelled to disconnect by 2035, as all diesel power stations are replaced with biomass under this scenario.	66	0
Leading the Way	Diesel capacity reduces to 66 MW, as Lerwick Power Station A and B and the behind-the-meter pipeline site at Scottish Sea Farms decommission in 2035, then remains at this capacity through to 2050 as other diesel back-up stations on the island switch to biodiesel and continue to operate in standby.	66	66

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation
Baseline	The FES 2023 baseline (22 MW) is significantly lower than the DFES (131 MW) in the North of Scotland. FES 2023 data shows that only two GSPs see any connected diesel capacity in the licence area, whereas DFES has sight of several sites across the Scottish Isles. This is likely the main basis of the variance.
Pipeline	DFES 2023 models a 5.5 MW site that holds an accepted connection offer, to come online at the end of 2023, but models no new sites under any scenarios beyond this pipeline site. FES 2023 models a notable amount of new diesel capacity under all scenarios, with **Falling Short** seeing an additional 26 MW added, **Consumer Transformation** and **System Transformation** seeing an additional 25 MW come online and **Leading the Way** seeing an additional 14 MW added. The assumptions behind this increase in the North of Scotland is unclear, but this level of near-term capacity is not reflected in SSEN's connections data and has therefore not been modelled in the near-term DFES projections.
Projections	Under all scenarios no new diesel is modelled to connect past the pipeline in DFES 2023. In **Leading the Way**, **System Transformation** and **Falling Short**, there is a drop in capacity to 66 MW, after Lerwick Power Station decommissions. Capacity remains at 66 MW under these scenarios, reflecting sites switching to biodiesel and continuing to provide back-up services. This differs from FES 2023, which forecasts much earlier decommissioning dates for all capacity, specifically 2026 for **Leading the Way**, 2032 for **System Transformation** and **Consumer Transformation** and 2035 for **Falling Short**. Under **Consumer Transformation** in DFES 2023, all diesel generation in the North of Scotland licence area is expected to be decommissioned by 2036, replaced by biomass.
Overarching Trend	All scenarios forecast a slight rise in capacity before remaining at 137 MW until 2035. Capacity under **Leading the Way** then falls to zero by 2036 as all sites are replaced with alternative technologies. The other three scenarios see capacity falling to 66 MW, as Lerwick A and B decommissions, which remains constant through to 2050.

Geographical factors affecting deployment at a local level

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

[lx] SSEN 2023, *Whole system energy solutions for the Scottish Islands* https://www.ssen.co.uk/about-ssen/our-works/whole-system-energy-solutions-for-the-scottish-islands/

[lxi] SSEN 2021, *Shetland Standby Solution – Gremista Grid Supply Point. https://www.ssen.co.uk/globalassets/about-us/projects-and-live-works/shetland/39041-shetland-standby-solution-brochure3-1.pdf*

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. The analysis does not include backup gas CHPs or engines located on some commercial and industrial sites that do not export to the network and only operate when mains supplies fail.

Technology building block: **Combined 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**

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

Installed capacity (MW)		Baseline	2025	2030	2035	2040	2045	2050
OCGT	Falling Short	10	10	10	10	0	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	Falling Short	0	55	55	55	20	20	20
	System Transformation		35	35	35	0	0	0
	Consumer Transformation		35	35	35	0	0	0

	Leading the Way		0	0	0	0	0	0
Gas CHP	**Falling Short**	35	68	69	69	18	15	15
	System Transformation		64	62	60	1	0	0
	Consumer Transformation		64	62	60	1	0	0
	Leading the Way		12	10	0	0	0	0

Note: there are no CCGT baseline or pipeline sites, or future projections in the licence area.

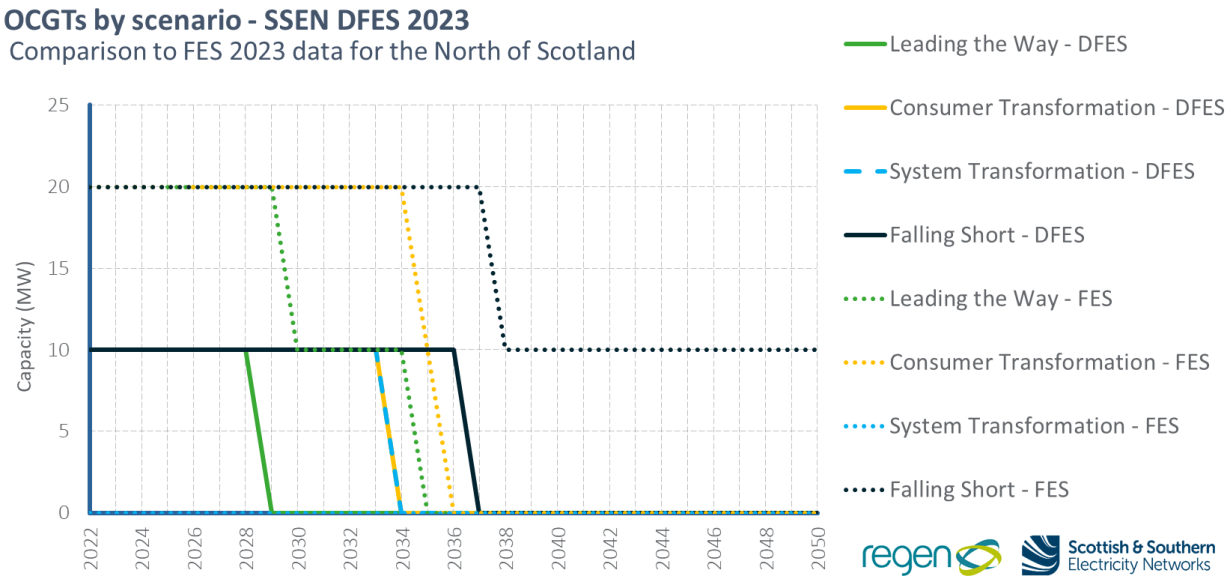


Figure 37 OCGT projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

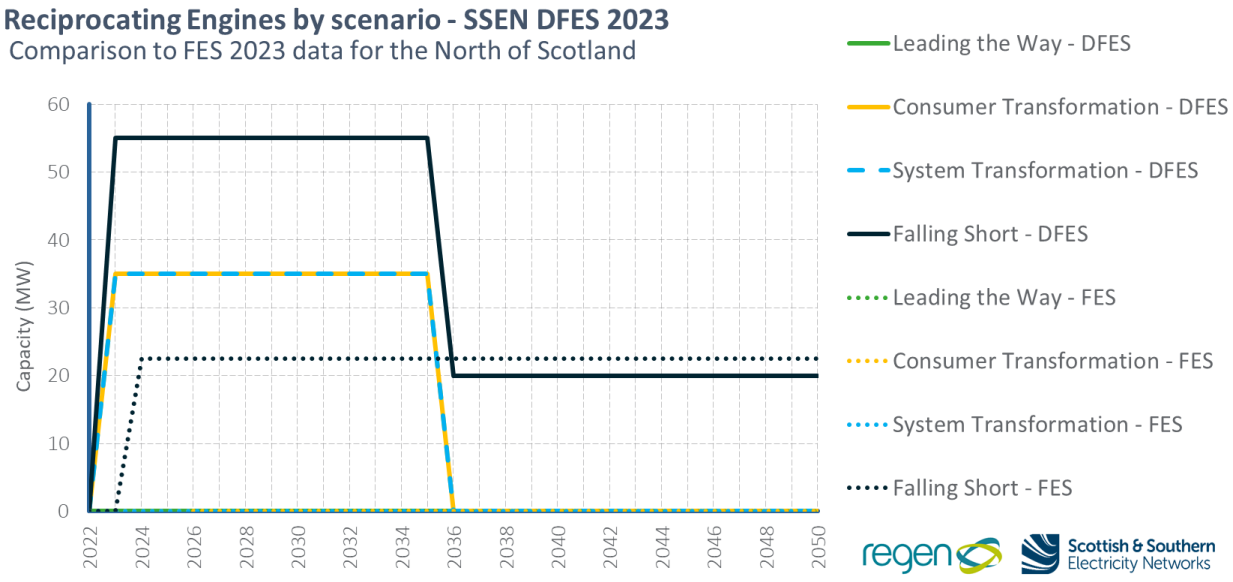


Figure 38 Reciprocating Engine projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

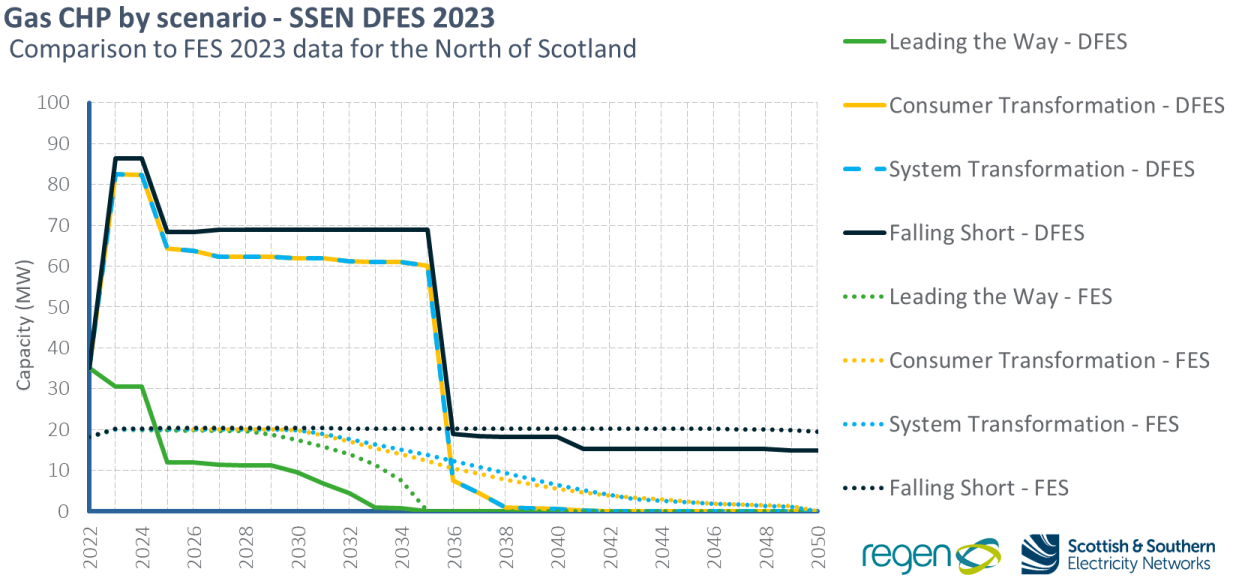


Figure 39 Gas CHP projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- There are currently 45 fossil gas sites connected to the distribution network in the North of Scotland licence area, totalling 45 MW. This is the same as was seen in DFES 2022.
- This baseline is dominated by gas CHPs, accounting for 35 MW of the total baseline capacity. The only non-CHP site is the 10 MW OCGT plant located at Flotta Oil Terminal on Orkney.
- In addition to this baseline, there is a pipeline of ten prospective new fossil gas sites with accepted connection offers, totalling 108 MW. Of this:
    - Three are reciprocating engine sites, totalling c. 56 MW.
    - The remaining seven are gas CHP sites, totalling c. 52 MW.
- Sites with planning approval or those that have successfully contracted in recent Capacity Market auctions[lxii] have been modelled to come online in the near term, depending on the scenario. The majority of the pipeline is modelled to connect under **Falling Short**.
- Unabated fossil gas-fired generation is a technology that is at odds with UK and Scottish Government net zero targets. As a result of this, under the three net zero scenarios, fossil gas capacity in the licence area declines in the near and medium term, and all generators are modelled to come offline by the late 2030s.
- On the Scottish islands, the Sullom Voe and Flotta oil and gas terminals both host operational fossil gas sites. The future of these sites is potentially tied to developments in transmission network infrastructure, as well as the potential future use of these terminals within a decarbonised economy.
- Continuing volatility in gas prices[lxiii] could also impact the financial viability of new gas peaking plants and gas-fired generation assets. This further justifies the limited capacity growth modelled in the three net zero scenarios.
- Contrary to this, the UK government's granting of additional North Sea oil and gas licences in July 2023[lxiv] indicates a level of continued fossil gas use over the coming decade, with no targets for a full phase out.
- Under **Falling Short**, whilst some older sites decommission, unabated fossil fuel generation remains a significant part of the electricity system overall, with the majority of pipeline sites modelled to come online and further capacity growth of gas reciprocating engines providing flexibility services throughout the scenario timeframe. Total fossil gas generation capacity in this scenario reaches 121 MW by 2050.

Modelling Stages

Baseline (2022)			
Technology	**Number of sites**	**Total capacity (MW)**	**Description**
Total	45	45	There are 45 fossil-gas generation sites connected in the SHEPD licence area, totalling 45 MW. This has not changed since DFES 2022.
OCGT	1	10	The 10 MW OCGT asset located onsite at the Flotta Oil Terminal on Orkney was commissioned in 1988.
Gas CHP	44	35	The rest of the baseline of fossil gas generation in the licence area are gas CHPs. Most of these are small <1MW assets located onsite at schools, swimming pools, hotels, farms and on university campuses. There are also a small number of larger CHPs located in industrial areas of Aberdeen and Dundee.

Pipeline (2023-2030)	
Number of pipeline sites	**Total capacity (MW)**
10	108
As with previous years of analysis, there are no OCGT or CCGT sites in the pipeline in the licence area. This is evidence of the continuing shift to a pipeline formed of a higher number of smaller scale reciprocating engines and CHP plants.	

Pipeline analysis			
Technology	**Description**	**Sites**	**Capacity (MW)**
Reciprocating engines	There is a 1.2 MW site located in Inverness, and two sites in Aberdeenshire of 20 MW and 35 MW respectively. The largest of these sites submitted a planning application in 2018 but is currently under further consultation.	3	56
Gas CHP	The gas CHP pipeline is primarily composed of the 50 MW Cairnandrew CHP scheme in Aberdeenshire. Planning permission was granted for this site in 2018 though no evidence of commissioning has been found. The remaining capacity is contributed by sub-1 MW projects. While DFES 2022 reported the same number of gas CHP sites in the pipeline, they totalled an additional 22 MW of capacity. This reduction is due to three sites leaving the pipeline, among them the 22 MW Cleaverhouse Gas project, and three small scale sites entering the pipeline in 2023.	7	52

Planning logic

The assumptions around the proportion of pipeline sites and capacity that is modelled to connect under each scenario, are based on an analysis of planning applications and activity in recent Capacity Market T-1 and T-4 auctions:

- Sites with planning approval or Capacity Market agreements are modelled to connect under all scenarios.
- Sites prequalified in the Capacity Market are modelled under all scenarios except **Leading the Way**.
- Sites with planning permission refused or that did not prequalify in the Capacity Market are not modelled to progress under any scenario.
- Sites with little or no development information are only modelled to progress under **Falling Short**.

Decommissioning Logic

The operation of all types of unabated fossil gas generation significantly reduces in the three net zero scenarios out to 2050 as the use of fossil gas for electricity generation is at odds with the UK's net zero targets.

Under the three net zero scenarios, the DFES analysis for fossil gas generation focuses heavily on the decommissioning of existing baseline sites and pipeline sites that are modelled to come online in the near term. Between now and the mid-2030s, depending on the scenario, the scenario analysis considers the following factors:

- The type of gas sub-technology (OCGT, reciprocating engines or gas CHPs).
- The age of the site and reasonable operating lifetime assumptions.
- How each scenario reflects policies such as the Industrial Emissions Directive, how flexibility is treated in the scenarios, wider progress towards a net zero power system and wider net zero targets.

Scenario Projections

Technology	Scenario	Description	Capacity by 2035 (MW)	Capacity by 2050 (MW)
OCGT	**Falling Short**	The Flotta Terminal OCGT site on Orkney is modelled to decommission in the 2030s in all four scenarios. This occurs in 2030 under **Leading the Way**, 2035 under **Consumer Transformation** and **System Transformation**, and 2038 under **Falling Short**. This reflects continuing oil and gas operations at Flotta Terminal.[lxv]	10	0
	System Transformation		0	0

	Consumer Transformation	The terminal is seeking to shift towards catering for offshore wind, green hydrogen and CCUS, through the proposed Flotta Hydrogen Hub.[lxvi] While no specific evidence has been found regarding plans for the OCGT plant, a repurposing to hydrogen generation is a potential decarbonisation pathway which has been modelled under net zero scenarios.	0	0
	Leading the Way		0	0
Reciprocating Engines	**Falling Short**	A significant proportion of the pipeline of reciprocating engine sites is modelled to build out under this scenario, reflecting a future in which rapid-response technology continues to secure balancing service and flexibility contracts. As a result, capacity reaches 55 MW in the 2030s and remains at that capacity out to 2050.	55	55
	System Transformation	Several reciprocating engine sites with connection offers with SSEN and evidence of planning or capacity market agreements are modelled to connect across the 2020s and early 2030s. This reflects a relatively slower transition to low carbon flexibility than seen in **Leading the Way**. Capacity then steadily reduces as fossil gas sites decommission from the network, with no capacity remaining online by 2036.	35	0
	Consumer Transformation		35	0

	Leading the Way	Reflecting a rapid transition to low carbon flexibility and limited positive development evidence, none of the pipeline sites are modelled to connect under this scenario. The projections for reciprocating engines align closely with DFES 2022.	0	0
Gas CHP	**Falling Short**	Under this scenario, a number of pipeline CHP sites connect across the licence area in the near term. Whilst the baseline of gas CHP engines continue to operate. Across all scenarios, the 18 MW Gas CHP site at the Sullom Voe oil and gas terminal on Shetland is modelled to decommission in 2025. This is currently based on the completion of the subsea transmission link to the mainland.[lxvii] Only a few other older sites are modelled to disconnect in the longer term. As a result, 15 MW of fossil gas capacity remains online in the licence area by 2050. The reduced capacity of the gas CHP pipeline relative to DFES 2022 has resulted in an overall decrease in projected capacity by 2050.	69	66
	System Transformation	Several pipeline sites with planning approval are modelled to connect in the near term. A notable number of the gas CHP sites in the licence area are located onsite at businesses and commercial premises. These have therefore not been modelled to disconnect in the near term, due to the onsite/backup services they are providing. Capacity begins to decommission from the 2030s, resulting in all capacity being modelled to disconnect by 2040. In these scenarios, as well as under	60	0
	Consumer Transformation		60	0

		Leading the Way, the Sullom Voe Gas CHP site is assumed to repower using hydrogen in 2030. These projections are significantly higher in the near and medium term compared to DFES 2022. This is a result of a greater amount of planning evidence found for pipeline sites in the 2023 DFES analysis.		
	Leading the Way	Reflecting a rapid transition to low carbon flexibility, none of the pipeline fossil gas sites are modelled to connect. All gas CHP capacity is modelled to disconnect by the mid-2030s. This projection aligns closely with the 2022 DFES projection.	0	0

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation
Baseline	The FES 2023 and DFES 2023 baseline both reflect the 10 MW Flotta OCGT site. However, the FES OCGT baseline has increased 10 MW since 2022. The reason for this is not detailed in the FES assumptions. Both the DFES and FES show no reciprocating engine sites connected in the licence area. The FES Gas CHP baseline has dropped to 20 MW where in 2022 it was 40 MW; closely aligned with the current DFES baseline. Again, the reason for this is not detailed in the FES assumptions.
Pipeline	The DFES and FES both reflect no pipeline OCGT sites in the licence area. Both the FES and DFES model some reciprocating engines coming online in **Falling Short**, but the DFES has also modelled some contracted sites with positive development evidence coming online under **Consumer Transformation** and **System Transformation**. The FES models no additional gas CHP capacity connecting. Whereas, based on DFES pipeline analysis, the **Falling Short**, **Consumer Transformation** and **System Transformation** scenarios see several gas CHP pipeline sites connecting in the near term. The DFES projections are based on a site-specific analysis of planning and Capacity Market activity for sites with accepted connection offers.

Projections	Under the net zero scenarios, the FES and DFES align in projecting no OCGT capacity by 2050. In **Falling Short** the FES has 10 MW of OCGT capacity still operating in 2050, where the DFES does not. This variance is due to the additional 10 MW of baseline capacity in the FES 2023 that is not seen in SSEN's connections data. The DFES and FES both model the continued operation of gas reciprocating engines under **Falling Short**, though the DFES projects a larger deployment, based on the current pipeline. Under net zero scenarios, there is alignment that no reciprocating engine capacity remains deployed by 2050. Under **Falling Short** the FES models no change in gas CHP capacity across the period to 2050, while the DFES has modelled the decommissioning of the gas CHP at Sullom Voe, as well as some older baseline sites in the 2040s. In the three net zero scenarios, the DFES and FES both model decommissioning of all gas CHP sites across the 2030s and 2040s.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Location of baseline and pipeline sites	The majority of the fossil gas distribution modelling is based on the location of the known baseline and pipeline sites.
Proximity to electricity and gas network infrastructure	Where some additional capacity is projected under **Falling Short**, the combined location of gas and electricity network infrastructure and industrial land determines the potential location of future fossil gas peaking plants and CHPs.

Relevant assumptions from National Grid FES 2023

Scenario		4.1.6 – Unabated large scale fossil fuelled generation
Falling Short	High	Low gas price and lower focus on decarbonisation promotes gas as the source of flexible generation.
System Transformation	Medium	High levels of decarbonisation, plus other sources of flexibility reduce the need for unabated gas.
Consumer Transformation	Medium	High levels of decarbonisation, plus other sources of flexibility reduce the need for unabated gas.
Leading the Way	Low	Highest level of decarbonisation significantly reduces the amount of unabated gas.

Scenario		4.1.32 – Dispatchable peaking generation
Falling Short	High	Initial strong growth in unabated gas reciprocating engines and stays high as gas generations (small and large) plays an increasingly important role as flexible generation in the absence of strong growth in other technologies (e.g. storage, interconnection).
System Transformation	Medium	Initial slow growth (low deployment of gas reciprocating engines). Later strong growth in hydrogen plant to support system flexibility.
Consumer Transformation	Medium	Initial slow growth (low deployment of gas reciprocating engines). Later moderate growth in hydrogen plant to support system flexibility.
Leading the Way	Low	Low throughout: initial growth of gas reciprocating engines is low as not aligned to decarbonisation and low long term growth as other flexible solutions dominate in this scenario.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
At the North of Scotland engagement webinar,[lxviii] local stakeholders responded to a poll on how volatility in gas prices might affect the current pipeline of gas generation projects. The most common answer given was 'Unsure', while a similar number believed this would result in reduced fossil gas deployment. The least common answer given was that the volatility would have no impact on deployment.	This result has justified the spread in the projections across the net zero scenarios, where only a select few of the known pipeline sites are modelled to build out, followed by a long-term decommissioning of all fossil gas generation.
Additional discussions took place between the Regen and SSEN project teams on the future plans for fossil gas sites on the Scottish islands.	The projections reflect an up to date understanding of the future of these sites, based on additional desk research.

[lxii] National Grid ESO n.d., *Capacity Market Registers*. https://www.emrdeliverybody.com/CM/Registers.aspx

[lxiii] See Trading Economics, UK natural gas price 2022-23: https://tradingeconomics.com/commodity/uk-natural-gas

[lxiv] UK Government, 2023, *Hundreds of new North Sea oil and gas licences to boost British energy independence and grow the economy:* https://www.gov.uk/government/news/hundreds-of-new-north-sea-oil-and-gas-licences-to-boost-british-energy-independence-and-grow-the-economy-31-july-2023

[lxv] Energy Voice, 2022, *North Sea operators confirm future for Flotta into 2030s and beyond* .https://www.energyvoice.com/oilandgas/north-sea/pipelines/403727/north-sea-operators-confirm-future-for-flotta-into-2030s-and-beyond/

[lxvi] https://www.rivieramm.com/news-content-hub/news-content-hub/repurposed-flotta-terminal-at-heart-of-scotwind-offshore-wind-to-green-hydrogen-plan-67936

[lxvii] Scottish Beacon, 2023, *Plans to connect Sullom Voe to the electricity grid:* https://www.scottishbeacon.com/news/environment/shetland-plans-to-connect-sullom-voe-terminal-to-the-electricity-grid/

[lxviii] Regen, 2022, *SSEN DFES stakeholder consultation webinars.* https://www.regen.co.uk/event/ssen-distribution-future-energy-scenarios-2022-stakeholder-consultation-webinars/

Hydrogen-fuelled electricity generation

Summary of modelling assumptions and results

Technology specification

This analysis covers hydrogen fuelled electricity generation connected to the distribution network in the North of Scotland licence area. It focuses on the conversion of existing fossil fuel peaking plants to hydrogen fuel. This technology is, therefore, intrinsically linked to the DFES analysis for fossil fuel generation.

Aside from re-powering fossil gas peaking plants, new large-scale hydrogen-fuelled power stations could also be developed. However, in the absence of any pipeline evidence and the lack of low carbon hydrogen supply infrastructure development to date, it has been assumed that large-scale plants would more likely connect to the transmission network.

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

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

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	0	0	0	0	0	0	0
System Transformation		0	18	28	121	121	121
Consumer Transformation		0	18	28	28	71	71
Leading the Way		0	42	42	138	138	138

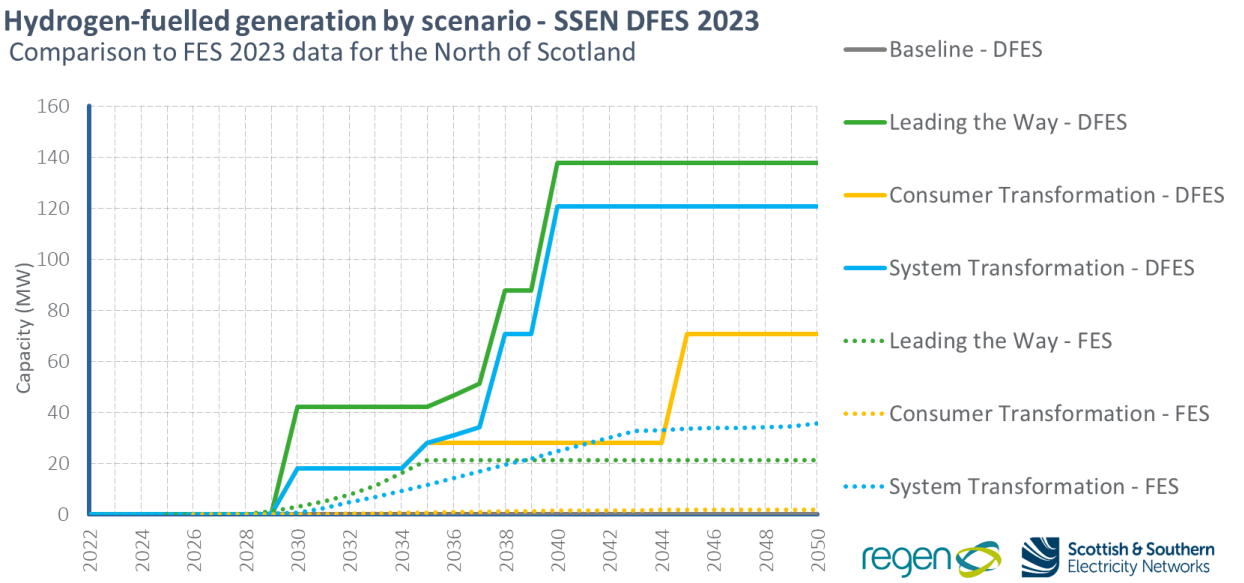


Figure 40 Hydrogen-fuelled electricity generation projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- Regen's 'A day in the life 2035' analysis[lxix] with National Grid ESO highlighted the potential role of hydrogen-fuelled generation in a net zero electricity system as a form of low carbon dispatchable generation. This analysis specifically suggested a cold, calm and cloudy winter day might require between 10-15 GW of hydrogen-fuelled generation to be available to balance the system.
- Engagement with National Grid ESO highlighted that they expect most of the UK's dedicated hydrogen fuelled generation to be new-build (albeit located at existing sites) and optimised for peak running. The DFES has, therefore, modelled the potential for existing and pipeline commercial gas generation sites to convert to run hydrogen generation instead of fossil gas.
- This is supported by the existence of a number of turbine manufacturers, including Siemens and GE,[lxx] that already offer hybrid hydrogen/methane turbines and have committed to providing 100% hydrogen plants in the near future.
- The modelling of hydrogen repowering considers the following factors:
    - Scenario and technology specific assumptions are made for the lifetime of gas generation assets. Lifetimes range from 15 years in **Leading the Way** to 45 years in **Falling Short**.
    - Only sites over 1 MW in capacity are assumed to repower with hydrogen.

  - The North of Scotland hosts a length of the gas National Transmission System which under National Gas's Project Union[lxxi] plan would be converted to transport 100% hydrogen. Sites located in close proximity to this network repower earlier.
  - While the Grangemouth industrial cluster falls outside of the licence area, there is an active hydrogen innovation sector operating on the east coast of Scotland, as well as on Orkney and the Shetlands islands.[lxxii] In the region, existing oil and gas infrastructure looking to decarbonise may aim to produce and make use of low carbon hydrogen.
- Baseline and pipeline gas generation sites in the licence area have been considered against these factors; the earliest deployments of hydrogen generation are projected in 2030.
- In the longer term, under **Leading the Way** and **System Transformation**, a national hydrogen network is assumed to be developed which enables more of the licence area to have access to hydrogen supply and therefore more opportunity for hydrogen generation sites to be developed.
- As a general consideration, the business case for hydrogen-fuelled electricity generation is likely to be challenging and may require new markets to incentivise uptake. Hydrogen is also likely to be an expensive fuel with production at scale unlikely to be developed until the 2030s at the earliest.
- However, there is strong support for the role of low carbon hydrogen in providing flexible power generation, as stated in the UK Hydrogen Strategy.[lxxiii] In October 2023, the UK government published its response to the consultation on the Hydrogen Production Business Model (HPBM)[lxxiv] which intends to incentivise the production and use of low carbon hydrogen.
- The Scottish Government Hydrogen Action Plan[lxxv] released in December 2022, also announced a target to reach 5 GW of hydrogen production capacity by 2030 (and 25 GW by 2045).
- Engagement with hydrogen sector stakeholders suggests that developers are awaiting further policy support before committing to plans for hydrogen fuelled generation. Many projects will be targeting large-scale sites and conversion of existing fossil fuel generation facilities connected to the transmission network.
- As a result of these areas of uncertainty, projected hydrogen generation capacity in the licence area by 2050 ranges significantly, from no capacity at all under **Falling Short** (due to fossil fuel generation remaining operational) to 138 MW under **Leading the Way**.

- These projections differ from those presented in DFES 2022, this due to updated analysis methods, which better considers the likely drivers of low carbon hydrogen-for-generation uptake. Specifically, the location of the proposed core hydrogen network proposed by National Gas.

Modelling and assumptions

Baseline (2022)
There are no existing hydrogen fuelled generation sites operating in the licence area. Low carbon hydrogen is still a nascent sector and operational equipment running on hydrogen is limited to trial and pre-commercial demonstrator sites in the UK and beyond. However, there is 45 MW of fossil gas generation capacity currently connected to the network in the licence area, some of which has been modelled to repower to be hydrogen peaking plant in the future under the three net zero scenarios.
Pipeline (2023-2030)
There are no hydrogen-fuelled generation sites with accepted connection offers in the licence area. It is unlikely that any fossil fuel plants will convert to be powered by low carbon hydrogen in the near term, although some pilot schemes have begun to appear, including large-scale gas power station operators are trialling the injection of hydrogen at existing sites[lxxvi] and turbine manufacturers already beginning to develop and sell hydrogen-ready generation technologies.[lxxvii] Developers contacted as part of wider DFES engagement suggested that they were actively evaluating future plans but were unwilling to make final decisions before the government announces new policy support/positions around low carbon hydrogen. A government consultation on market interventions required to incentivise the shift away from unabated gas towards hydrogen-fuelled generation is expected soon.
Hydrogen repowering
The DFES analysis reflects the potential for a proportion of existing fossil gas plants to repower as hydrogen-fuelled generation assets in the future. A spatial assessment based on the National Gas Project Union[lxxi] core hydrogen network and industrial clusters informs this modelling. The North of Scotland licence area is relatively well-placed to enable fossil gas generation sites to convert to hydrogen, as the core hydrogen network proposed by National Gas extends up the east coast from Perth to Peterhead. 14 baseline gas sites and four pipeline sites currently operate within 10km of the planned route, totalling 36 MW of capacity. The only major industrial cluster in the vicinity of the North of Scotland is Grangemouth, which is located on the border between SP Energy Networks South Scotland licence area. This limits the impact it may

have in developing low carbon hydrogen for electricity generation in the North of Scotland. However, Orkney and Shetland both host oil and gas infrastructure, at the Flotta and Sullom Voe terminals respectively, which are seeking future roles in developing hydrogen production, storage and transport infrastructure. The repowering of their on-site fossil gas generation assets could also contribute to hydrogen development within the 2030s.

Hydrogen generation sites are modelled to repower at 100% of existing fossil fuel site capacity under **Consumer Transformation** and **System Transformation**, and at 150% of existing capacity under **Leading the Way**.

Scenario projections (2030 to 2050)

DFES 2023 is using an updated modelling approach which has resulted in changes to overall capacity projections compared with DFES 2022. The most significant impact is a delay in the deployment of hydrogen fuelled generation to post-2030. This approach is based on updated evidence and consideration of hydrogen network development plans. This revised approach also reflects current technology barriers and continuing uncertainty about the future role of hydrogen in the UK power system.

Scenario	Description	Capacity by 2035 (MW)	Capacity by 2050 (MW)
Falling Short	Due to unabated fossil fuel generation continuing to operate out to 2050, no sites are modelled to convert to low carbon hydrogen.	0	0
System Transformation	This scenario sees high levels of policy support for hydrogen and the development of a national hydrogen transportation network. • Existing and pipeline fossil gas sites in proximity to industrial cluster zones are modelled to convert to hydrogen from 2030. Specifically, existing sites located at both the Sullom Voe and Flotta oil terminals repower to combined 28 MW of hydrogen generation in 2030. • Sites located near the hydrogen core network (proposed by National Gas) are modelled to convert from 2035. • Remaining sites would be modelled to convert from 2040, by which point hydrogen is assumed to be widely available through a national hydrogen network. However, by this date all eligible sites in the licence area have already repowered; no additional growth has been modelled.	28	121

Consumer Transformation	Hydrogen networks are assumed to be less developed in this scenario and hydrogen is produced near to demand in industrial clusters. While in this scenario the Sullom Voe and Flotta sites repower to a combined 28 MW in 2030, there is little additional growth of new hydrogen generation capacity in the 2030s. Sites in close proximity to a core hydrogen network (as proposed by National Gas) are repowered after 2045.	28	71
Leading the Way	This scenario sees moderate to high levels of policy support for hydrogen and a national hydrogen transportation network is developed. Hydrogen-fuelled generation is assumed to dominate the low running hours segment of the flexibility market. To reflect the lower capacity factors, sites are assumed to convert to hydrogen at 50% greater capacity. As with **System Transformation**, the capacities and locations of existing and pipeline gas sites mean that no deployment is modelled before 2030. Similarly, by 2040, all eligible sites in the licence area have repowered; no additional growth has been modelled.	42	138

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation
Baseline	Both the DFES 2023 and FES 2023 are aligned. There are no existing operational hydrogen-fuelled generation sites, nor near-term developments before 2030 in the licence area.
Pipeline	
Projections	The DFES and FES are aligned with no hydrogen generation capacity being modelled to come online by 2050 under **Falling Short**. Across the net zero scenarios, the DFES 2023 projections have a notably higher uptake of hydrogen-fuelled generation in the North of Scotland licence area than the FES 2023 GSP regional data. This is most evident in **Consumer Transformation** where the FES projects zero deployed capacity by 2050. The main rationale for these higher projections is the presence of gas plants in the region that would need to be decarbonised to meet Scottish and local net zero targets. The presence of a proposed hydrogen core network in the licence area, as well as existing gas infrastructure and hydrogen innovation projects on Orkney and Shetland suggests hydrogen could be developed on these islands.

	It should be noted that for both DFES and FES projections, there is a high degree of uncertainty regarding the potential role that low carbon hydrogen-fuelled electricity generation could play in a net zero energy system.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Location of baseline and pipeline sites	The DFES projections for hydrogen-fuelled electricity generation are directly linked to connected and contracted fossil fuel (gas and diesel) generation sites located in the licence area.
Hydrogen supply areas	Spatial analysis of industrial cluster locations and National Gas plans for a core hydrogen network.

Relevant assumptions from National Grid FES 2023

Scenario		4.1.32 – Dispatchable plant generation
Falling Short	High	Initial strong growth in unabated gas reciprocating engines stays high as gas generations (small and large) plays an increasingly important role as flexible generation in the absence of strong growth in other technologies (e.g. storage, interconnection).
System Transformation	Medium	Initial slow growth (low deployment of gas reciprocating engines). Later strong growth in hydrogen plant to support system flexibility.
Consumer Transformation	Medium	Initial slow growth (low deployment of gas reciprocating engines). Later moderate growth in hydrogen plant to support system flexibility.
Leading the Way	Low	Low throughout: initial growth of gas reciprocating engines is low as not aligned to decarbonisation and low long-term growth as other flexible solutions dominate in this scenario.

[lxix] Regen, 2022, *A day in the life 2035*, https://www.regen.co.uk/project/a-day-in-the-life-2035/

[lxx] General Electric n.d., *Hydrogen fueled gas turbines*. https://www.ge.com/gas-power/future-of-energy/hydrogen-fueled-gas-turbines?utm_campaign=h2&utm_medium=cpc&utm_source=google&utm_content=rsa&utm_term=Hydrogen%20gas%20turbine&gclid=EAIaIQobChMIh5amwliq9QIV2Y1oCR2nHgqZEAAYAiAAEgLtXvD_BwE

[lxxi] National Gas, 2022, *Project Union*. https://www.nationalgas.com/document/139641/download

[lxxii] For more information on Hydrogen innovation projects in the licence area, see the section 'Hydrogen Electroylsis' within this DFES report.

[lxxiii] UK Government, 2021, *UK Hydrogen Strategy*. https://www.gov.uk/government/publications/uk-hydrogen-strategy

[lxxiv] UK Government, 2023, *Hydrogen production and carbon capture business models.* https://assets.publishing.service.gov.uk/media/654103cc46532b000d67f630/hydrogen-production-icc-business-models-government-response.pdf

[lxxv] Scottish Government 2022, *Hydrogen Action Plan.* https://www.gov.scot/publications/hydrogen-action-plan/

[lxxvi] The Guardian 2022, *Peak power: hydrogen to be injected into UK station for first time*. https://www.theguardian.com/environment/2022/oct/23/peak-power-hydrogen-injected-uk-station-centrica

[lxxvii] See GE and Siemens hydrogen gas turbines: https://www.ge.com/gas-power/future-of-energy/hydrogen-fueled-gas-turbines | https://www.siemens-energy.com/global/en/priorities/future-technologies/hydrogen/zehtc.html

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 FES technology building block.*

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

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
All scenarios	1.0	1.6	1.6	1.6	1.6	1.6	1.6

Summary

- There are nine sites of unidentified generation technology in the North of Scotland licence area, totalling 1 MW of installed capacity. This is the same as DFES 2022.
- At an average capacity of 112 kW, these sites are predominantly micro CHP plants within schools, research facilities, farms and recreational centres; however, the fuel type is uncertain. Hence these sites cannot be positively allocated to a specific DFES technology. The largest site is 210 kW.
- There are two pipeline sites for which the technology type could not be identified, these total 640 kW and are projected to connect in 2024.
- Other generation is not projected beyond the baseline and pipeline, and there is no variance between the scenarios for this technology.

Geographical factors affecting deployment at a local level

Other generation geographical factors
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, desk research, Grid Reference Finder, Renewable Energy Planning Database

Battery storage

Summary of modelling assumptions and results

Technology specification

Battery storage, comprising four business models:

- Domestic batteries – typically 5-20 kW scale batteries that households buy to operate alongside rooftop PV or provide home backup services. This aligns to the FES building block: **Srg_BB002**

For larger battery storage projects we model three business models:

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

We then combine these into "large scale" battery storage that aligns with the FES building block: **Srg_BB001**

Storage planning: This scenario demonstrates the scale of the current large-scale battery storage pipeline within SSEN's licence areas. In this scenario, all sites with connection agreements are modelled to build out, regardless of lack of evidence of progress through planning.

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

	Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Standalone network services	Falling Short	175	449	1,491	1,566	1,566	1,566	1,566
	System Transformation		549	2,074	2,274	2,274	2,274	2,274
	Consumer Transformation		966	2,422	2,422	2,422	2,422	2,422
	Leading the Way		1,660	3,351	3,795	3,795	3,795	3,795
	Storage Planning		1,660	4,183	6,721	6,721	6,721	6,721
Generation co-location	Falling Short	8	14	286	342	363	363	363
	System Transformation		103	401	446	467	467	467
	Consumer Transformation		179	578	652	741	783	795
	Leading the Way		169	542	641	641	641	641
	Storage Planning		169	542	753	753	753	753
Behind the meter - high energy user	Falling Short	1	166	166	166	166	166	166
	System Transformation		166	166	166	166	172	188
	Consumer Transformation		166	166	166	166	245	268
	Leading the Way		166	166	166	168	245	268
	Storage Planning		166	166	166	168	245	268
Domestic batteries	Falling Short	9	10	11	14	16	30	57
	System Transformation		10	20	26	30	59	66
	Consumer Transformation		12	37	60	92	145	227
	Leading the Way		19	56	91	139	216	368

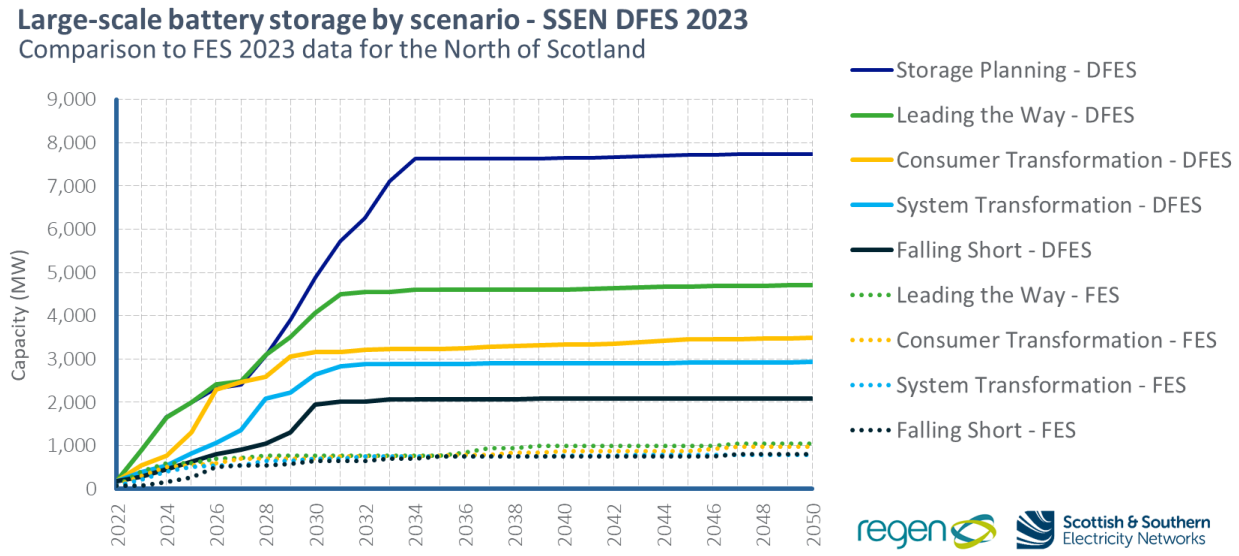


Figure 41 Battery storage projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections. Including the 'Storage Planning' scenario.

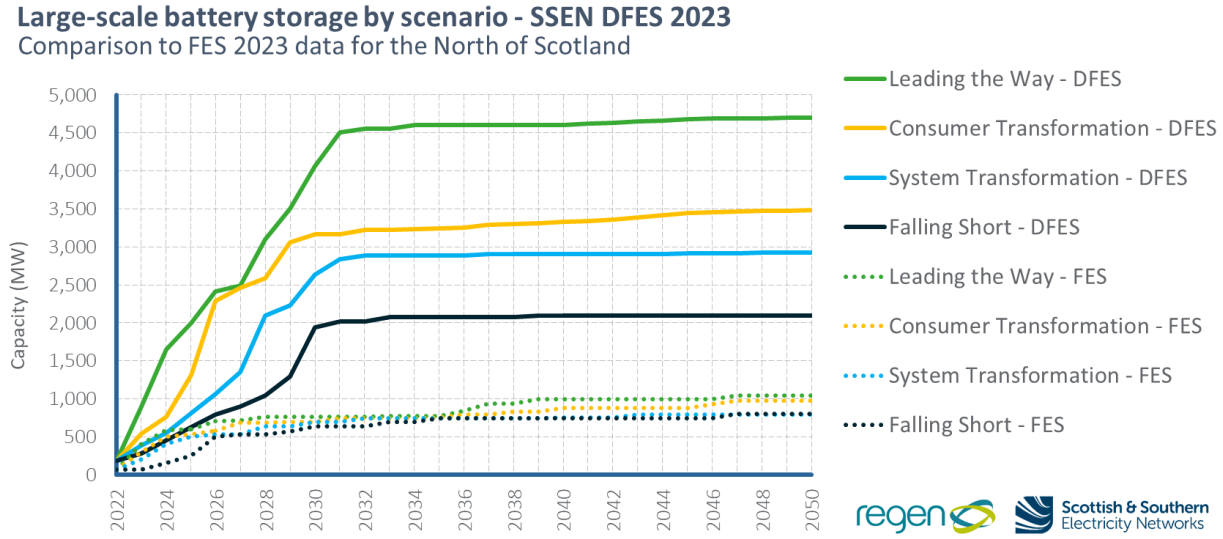


Figure 42 Battery storage projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections. Excluding the 'Storage Planning' scenario.

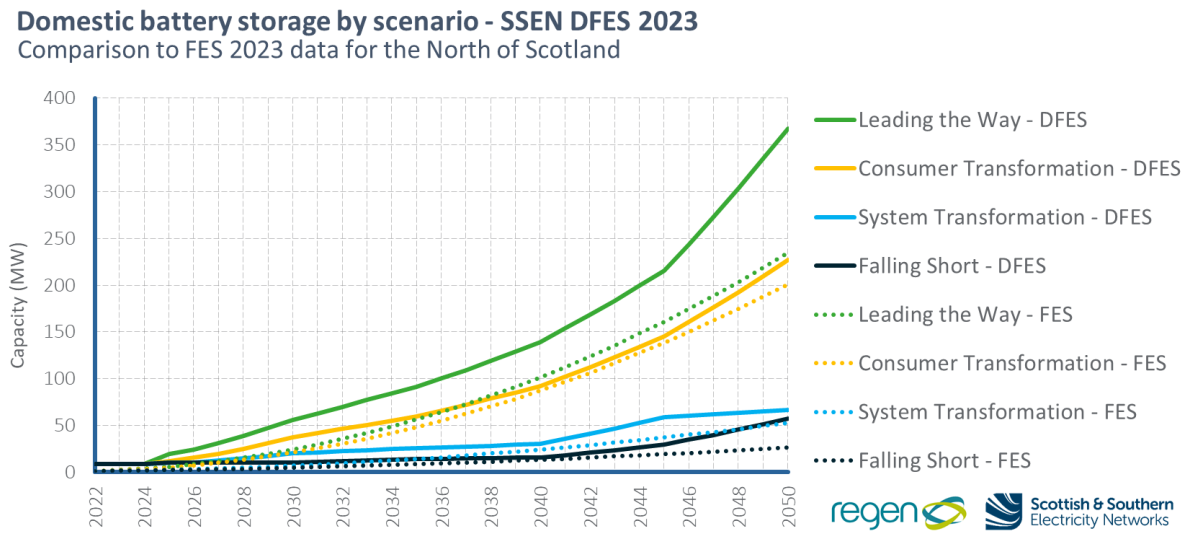


Figure 43 Domestic battery storage projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- Battery storage has developed rapidly across the UK electricity network since the first commercial-scale projects in 2016. Regen's analysis, in partnership with ESO, suggested that 80-100 GW of flexibility capacity will be needed nationally by 2035 with 20-25 GW provided by electricity storage.
- The North of Scotland licence area (SHEPD) currently has five operational large-scale battery storage sites, totalling 183 MW. This a significant increase on the two sites with 8 MW of capacity recorded for DFES 2022.
- Of all technologies included in the DFES analysis, battery storage has the largest pipeline of projects with a quote issued or accepted connection offer – now totalling 16 GW across the two SSEN licence areas. This contracted or quote issued capacity is nearly double the 9.6 GW recorded for DFES 2022.
- This 16 GW is relatively evenly split between SSEN's licence areas, with 7.8 GW located in SHEPD and 8.2 GW in the Southern England licence area (SEPD). For comparison, SSEN currently manages a portfolio of c.6.75 GW of operational fossil fuel and renewable generation assets across both licence areas.
- In SHEPD, 81% of the pipeline by capacity has a connection agreement, but this is higher in SEPD, at 91%.
- Overall deployment scenarios for large scale battery storage capacity in 2050 in SHEPD range from 2.1 GW in **Falling Short** to 4.7 GW in **Leading the Way**.

- Due to the unprecedented pipeline of large-scale battery storage projects across SSEN's licence areas, the DFES has included an additional scenario, **Storage Planning**. This fifth scenario demonstrates the absolute scale of the current contracted/quoted connection pipeline. Under this scenario, 7.7 GW of large-scale storage connects in SHEPD by 2050.
- Solutions to network constraints, large connection queues, and resulting long connection times are being sought at a national level by Ofgem and the UK Government; detailed within the November 2023 'Joint Connections Action Plan'.[lxxviii] In DFES 2023, the three net zero compliant scenarios assume varying degrees of success in reducing connection timeframes, while a **Falling Short** scenario assumes project connection times remain long. Where 'Statement of Works' information has been available as an indication of delay to connection, this has been reflected in **Falling Short**.
- SHEPD does have significant potential for long-term growth in connected storage capacity. This is due to the following:
    - Having amongst the best onshore wind resource in the UK and there is potential for significant onshore wind and battery storage co-location.
    - The Scottish Government is targeting 4-6 GW of solar capacity in Scotland by 2030,[lxxix] this deployment will present opportunities for colocation with solar PV.
    - Targeted network services, such as phase two of National Grid ESO's stability pathfinder tender, awarded tenders to large battery projects adjacent to network substations in Scotland.[lxxx]
    - The presence of commercial and industrial premises with the potential for behind-the-meter batteries, including industrial areas in Dundee and Aberdeen.
- Whilst the DFES analysis has focused on the MW power rating of battery storage, the analysis also shows that battery storage capacity duration (MWh) is also increasing with progressively more 2-4 hour duration storage in the pipeline.
- Long Duration Energy Storage (LDES) is now receiving government policy support, including the LDES demonstration competition.[lxxxi] This could give rise to new storage technologies and trial demonstration sites, which could seek to connect to the distribution network in the licence area. These technologies will be considered for inclusion in future DFES assessments.

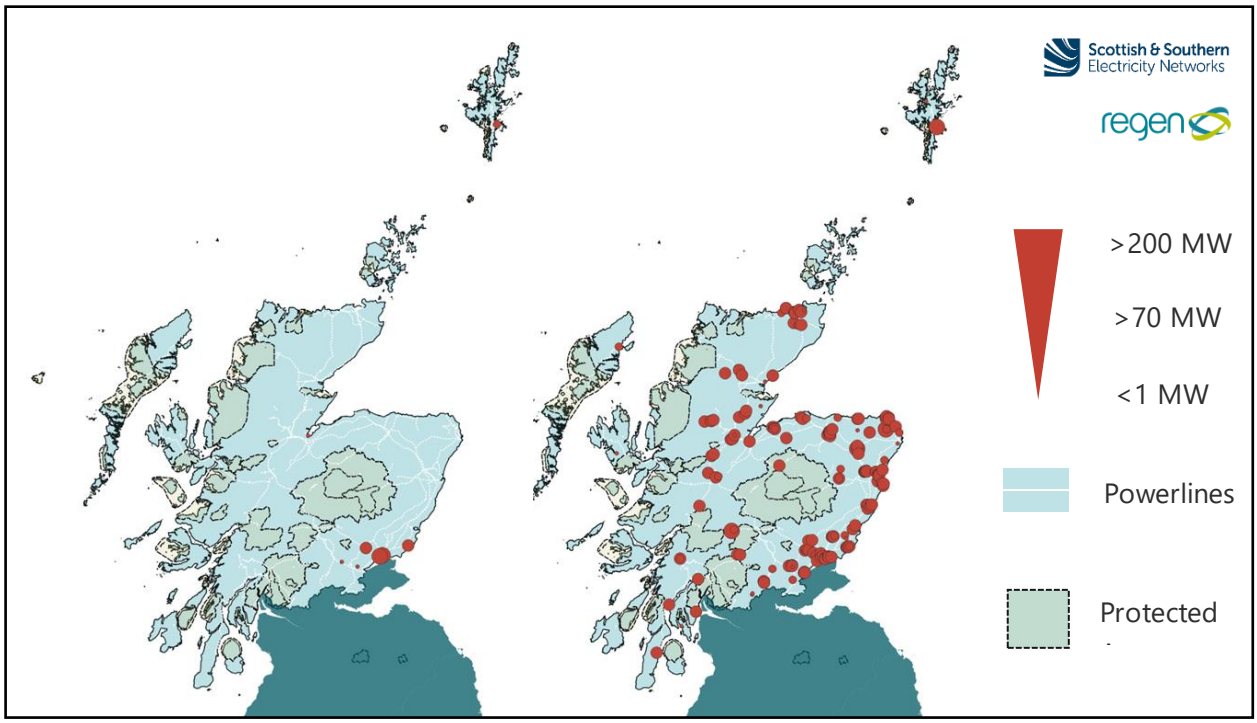


Figure 44 Baseline and pipeline battery storage sites in the North of Scotland licence area, August 2023

Modelling stages

Baseline (2022)			
Business model	**Number of sites**	**Total capacity (MW)**	**Description**
Total	1,981	192	There has been a dramatic increase in battery storage from two sites with an 8 MW capacity recorded in DFES 2022. This increase has resulted from new standalone sites connecting and additional data being available for domestic and commercial deployments.
Standalone network services	4	175	The first four standalone sites have now been deployed in the licence area. The 49.9 MW 'Lyndhurst' and 'West Gourdie' projects, located in Dundee, contribute over half of this new storage capacity, with projects in Arbroath and Blairgowrie making up the remainder.
Generation co-location	1	8	The Lerwick power station back up battery was commissioned in 2021 to supplement the 72.8 MW diesel backup engine on Shetland.[lxxxii]

Behind the meter – high energy user	31	1	Newly implemented in the DFES for 2023, SSEN LCT data has been used to provide a more accurate baseline of small scale technologies. 31 'Behind the meter (BtM) – high energy user" sites, have been identified in SHEPD data, providing 1 MW of BtM distributed storage capacity.
Domestic	1,945	9	SSEN LCT data identifies 1,945 domestic batteries in the licence area. These provide 9 MW of distributed BtM storage capacity.

Large-scale pipeline (2023-2035)

	Total	Contracted	Grid connection offered
Number of sites	189	151	38
Capacity (MW)	7,782	6,331	1,451

The total pipeline capacity of 7.7 GW is an 83% increase on the 4.2 GW recorded for DFES 2022. Every site in this pipeline was assessed for its current development status and timeline through research into local planning portals, Capacity Market T-4 and T-1 registers, project webpage summaries, and direct engagement with individual battery project developers.

Planning analysis

Status	Description	Sites	Capacity (MW)
Operational	In addition to the baseline sites identified in the SSEN connections data (as of August 2023) the 'Green Market Multi Storage Car Park' storage, solar and EV charging site has also been identified as operational as of November 2023.	1	0.06
Under Construction	The 49.9 MW 'Auchteraw Energy Storage – G99' site in Fort Augustus is under construction, alongside a 9.9 MW project in Angus. Both sites are standalone and have connection agreements.	2	60
Planning Permission Granted	39 sites totalling 1.6 GW have secured planning permission; they form 20% of total pipeline capacity. All but four of these sites have connection agreements. These sites are distributed throughout the licence area, though the majority are located close to the east coast. Over half of these projects are in Aberdeenshire or in the vicinity of Aberdeen City. Demonstrating the increasing average scale of battery storage projects, 23 of these sites have capacities in the range of 48-50 MW. The 67 MW 'Bilbo and Frodo' co-located site, and the 75 MW 'Rothie 3' (Quote Issued) site in Aberdeen, have greater capacities. 13 of these sites have Capacity Market agreements, with 2025 and 2026 being commencement dates for the majority.	39	1,647

	This 'construction ready' portion of the project pipeline has nearly doubled in site number and capacity since DFES 2022, strong evidence that developers are making progress through the planning system.		
Planning Application Submitted	Another 15 sites, totalling 678 MW of storage capacity, have submitted for full planning permission; all have accepted connection agreements. The average capacity of these sites is 45 MW, again indicating the popularity of sites of this scale. Notable in this group is the 100 MW Shetland Backup BESS which will operate in the event of a failure of the Shetland transmission link. This group is similar in scale to DFES 2022's equivalent. This indicates that local authority planning processes are currently coping with this volume of sites; a backlog of storage sites awaiting decisions is not building up at this stage.	15	678
Pre-planning	40 sites totalling 1.67 GW (21% of total pipeline capacity) are in early stages of planning. All but five of these sites have a connection agreement. This group is also dominated by sites of 48-50 MW capacity, with just over half of the sites being of this scale. Seven sites have Capacity Market agreements, primarily commencing in 2025 and 2026. This group of early-stage sites is significantly larger than was recorded for DFES 2022. This is due to improved DFES planning research tools allowing a re-allocation of sites previously classified as 'Planning Application Submitted'.	40	1,672
No information	The largest single category in this assessment is made up of those sites which have not yet entered the planning process; 80 sites totalling 3.3 GW, or 42% of total pipeline capacity. As a percentage of the total pipeline, this group has decreased compared to DFES 2022, where 55% of capacity had no planning information. This is in part due to improved DFES planning research tools. However, in volume terms, this group has grown by 40% since DFES 2022. This indicates the increasing volume of sites seeking connection agreements without prior progress though the planning process. New sites entering the connections data in 2023 account for the 61 of these 80 sites; approximately half of these do not yet have a connection agreement.	80	3,304
Refused, Expired, Other	Five sites have had planning applications refused or planning permission expire. An additional seven sites have been identified	12	420

	as potential duplicates or superseded in the connections data.		

Scenario based deployment logic (2023-2025)

Sites with no Capacity Market information, co-located site information, or developer feedback were subject to scenario-based logic defining various potential deployment outcomes and timeframes, detailed below. In addition, under **Falling Short**, any site with a Statement of Works completion year was assumed to connect on or after that year (if assumed to build out).

Scenario	Planning assessment status and assumed deployment years				
	Under construction	**Planning application granted**	**Planning application submitted**	**Pre-planning**	**No information**
Falling Short	2024	Granted year +7 years	-	-	-
System Transformation	2024	Granted year +5 years	Submitted year + 7 years	-	-
Consumer Transformation	2024	Granted year +3 years	Submitted year + 6 years	-	-
Leading the Way	2023	Granted year +1 years	Submitted year + 5 years	Submitted year + 7 years	-
Storage Planning	2023	Granted year +1 year delay	Submitted year + 5 year delay	Submitted year + 7 to 9 year delay	Contracted date + 8 to 11 year delay

Scenario projections

Business model	Description	Scenario	Capacity by 2035 (MW)	Capacity by 2050 (MW)
Standalone network services	Standalone storage sites in the currently visible pipeline dominate large scale storage growth by 2035. This results in c.3.8 GW of standalone capacity deployed by 2035 under **Leading the Way**. The growth in capacity stalls beyond the late	**Falling Short**	1,566	1 ,566
		System Transformation	2,274	2,274

	2030s out to 2050, reflecting market saturation following a rapid roll-out in the 2020s. These projections are significantly higher than the equivalent DFES 2022 projections. This is a result of the project pipeline, which has nearly doubled in total capacity. C.52% of this pipeline has planning evidence and is consequently modelled to deploy under **Leading the Way.**	**Consumer Transformation**	2,422	2,422
		Leading the Way	3,795	3,795
		Storage Planning	6,721	6,721
Generation co-location	Battery storage co-locating with renewable generation is likely to be in areas with high levels of wind generation and potentially in areas with grid constraints, such as the Scottish Islands. There is currently 2 GW of distributed 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 7 GW modelled to connect by 2050. The potential for co-located battery storage under this scenario is projected to reach 634 MW by 2050. These projections are higher than DFES 2022 equivalents; a result of the increased onshore wind projections for the North of Scotland.	**Falling Short**	342	363
		System Transformation	446	467
		Consumer Transformation	652	795
		Leading the Way	641	641
		Storage Planning	753	467
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 retail, port/marine and logistics premises. Feedback from stakeholders that these high-energy users could drive electricity storage deployment in the medium term has resulted in strong growth across all scenarios	**Falling Short**	166	166
		System Transformation	166	188

	by 2035. Annual capacity deployment in this business model begins to increase further in the longer term out to 2050 under **Consumer Transformation** and **Leading the Way**, as more businesses seek to manage their onsite energy use and costs through flexibility technologies. These projections have increased since DFES 2022. This is due to the consideration of SSEN low carbon technology data for DFES 2023, resulting in an updated and enlarged baseline.	**Consumer Transformation**	166	268
		Leading the Way	166	268
		Storage Planning	166	268
Domestic batteries	The licence area has c.1.2m domestic properties, and whilst solar irradiance is relatively low compared to other parts of the UK, there is the potential for increased adoption of domestic rooftop PV under **Consumer Transformation** and **Leading the Way**. Domestic battery storage could readily co-locate with domestic solar to enable households to increase their self-use of their on-site generation. By 2050, domestic battery storage capacity reaches 368 MW (equivalent to c.72,000 homes) under **Leading the Way**. These projections align closely with those made for DFES 2021. They are directly tied to domestic solar PV uptake in all four scenarios.	**Falling Short**	14	57
		System Transformation	26	66
		Consumer Transformation	60	227
		Leading the Way	91	368

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation – Large-scale batteries
Baseline	FES 2023 includes a baseline of 66 MW of large scale energy storage. Based on SSEN connections data, SSEN DFES 2023 has identified a 184 MW large scale storage baseline. The FES baseline has increased from 0 MW in 2022 and now aligns more closely with the DFES. The DFES 2023 baseline is based on SSEN connections data provided in August 2023.
Pipeline	The DFES 2023 projections diverge from FES 2023 projections in all scenarios; more ambitions scenarios diverge earlier with higher annual growth rates. These growth rates are driven by the increased pipeline of accepted connection offers evidenced in SSEN's connection data. Variance between FES and DFES becomes significant in the medium term in the more ambitious scenarios, reaching a 3.3 GW difference by 2030 under **Leading the Way**. The DFES pipeline analysis is based on a detailed assessment of planning status, Capacity Market auction activity and direct engagement with battery project developers.
Projections	Variance between DFES and FES is maintained in all scenarios but does not increase significantly post-2030 due to lower levels of deployment projected out to 2050. The DFES 2023 has a wider spread of outcomes by 2050 for large-scale battery storage, which is a direct result of the large near-term pipeline and differing build-out assumptions applied under each scenario.
Overarching Trend	In all scenarios, DFES 2023 projects significantly higher installed capacity in the licence area than the FES 2023. Variance is larger in the more ambitious scenarios. This results from the scale of the contracted pipeline and a site-specific pre-2030 pipeline assessment.
	Reconciliation – Domestic batteries
The DFES 2023 projections for domestic batteries align well with FES 2023 across the analysis period in all scenarios. The DFES projects more capacity under ambitious scenarios. This reflects strong targets for solar PV deployment (across all scales) [lxxxiii] based on engagement with the Scottish Solar Trade Association and associated potential for co-located domestic batteries – including on the Scottish Islands.	

Geographical factors affecting deployment at a local level

Modelling aspect	Description
Pipeline distribution	Location of existing and known pipeline sites in the North of Scotland licence area.
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 ground-mounted solar PV and onshore wind projects 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 2023.

Relevant assumptions from National Grid FES 2023

Scenario		4.2.24 – Short duration electricity storage
Falling Short	Medium	Moderate levels of flexibility requirements encourage new storage. Not as much deployed compared to other scenarios.
System Transformation	Low	Not as much deployed as other scenarios due to high use of Hydrogen within this scenario.
Consumer Transformation	High	High levels of variable clean generation and flexibility requirements encourage new storage technologies to emerge.
Leading the Way	High	Even higher levels of flexibility requirements encourage new storage technologies to emerge at distributed and transmission levels.
Scenario		**4.2.24 – Medium duration electricity storage**
Falling Short	Low	Lower flexibility requirements means that this technology does not come forward at the volumes seen in the other scenarios.
System Transformation	Medium	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	Medium	Flexibility requirements encourage new storage.

Leading the Way	High	High levels of flexibility requirements encourage new storage.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
At the North of Scotland stakeholder engagement webinar, local stakeholders responded to a poll on the scale of deployment of battery storage in the licence area. When asked how much of the 6.3 GW contracted pipeline of large-scale batteries were likely to connect in the North of Scotland, there was consensus among the 18 respondents that more than half of this capacity would connect. However, there was a large spread of views on the timeframe of connection, these views varied around the average position that this capacity would connect by the early 2030s.	The uncertainty around the current pipeline is reflected in the spread of scenario outcomes modelled. Feedback on the likely speed of deployment is reflected in **Leading the Way**, with known pipeline sites modelled to connect by 2034 at the latest, reflecting a middling position.
Within the Scottish Island roundtable session, the future plans for battery back-up plants on Shetland and Orkney were discussed.	The allocation of the relevant sites at Lerwick Power Station, and Battery Point Power station was given additional consideration the pipeline assessment. The Shetland backup site is assumed to have its planning refusal overturned by the Scottish Government and build out in 2026 under **Leading the Way** and **Consumer Transformation**.

[lxxviii] Ofgem & DESNES, 2023, *"Joint connections action plan"*. https://www.ofgem.gov.uk/publications/ofgem-and-desnz-announce-joint-connections-action-plan

[lxxix] Solar Energy UK, 2023, *"Scottish Solar industry welcomes commitment to boost solar energy generation in Scotland"* ,https://solarenergyuk.org/news/scottish-solar-industry-welcomes-commitment-to-boost-solar-energy-generation-in-scotland

[lxxx] National Grid ESO, 2022, *"NOA Stability Pathfinder – Phase 2 updates"*https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-2

[lxxxi] UK Government, 2021, "*Long Duration Energy Storage Competition*". https://www.gov.uk/government/collections/longer-duration-energy-storage-demonstration-lodes-competition

[lxxxii] SSEN, 2022, *Shetland Energy*. https://www.ssen.co.uk/about-ssen/our-works/shetland-energy/

[lxxxiii]Solar Power Portal, 2021, *"Solar Energy Scotland calls for 4GW by 2030 target…"*. https://www.solarpowerportal.co.uk/news/solar_energy_scotland_calls_for_4gw_by_2030_target_to_realise_solars_full_p

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 the analysis could be reconciled in part to building block: **Srg_BB004 – Other energy storage.**

Data summary for liquid air energy storage in the North of Scotland licence area

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	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

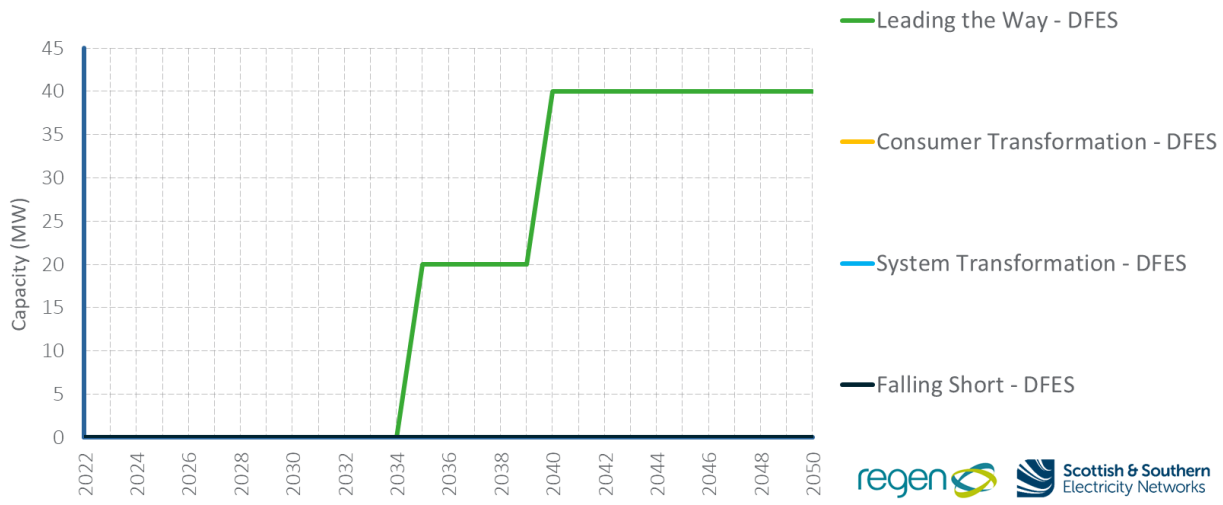


Figure 45 Liquid air energy storage projections for the North of Scotland licence area

Summary

- 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 needed, 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.
- Battery storage technologies dominate the UK storage pipeline (see the Battery Storage chapter of this report). LAES is a relatively recent technology development and is considered one of the technologies that could provide longer-duration storage services to the electricity system. However, many technology innovators and project developers are looking to move from small-scale trials to full commercial-scale plants in the UK and beyond.
- 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 required duration. When electricity is needed, 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.

- This technology could be supported by future UK grant and innovation funding schemes, following on from the UK Government's Long Duration Storage Competition[lxxxiv] fund in 2021 and 2022.
- One of the leading LAES developers in the UK, Highview Power, is developing trial and pre-commercial plants, including one in Greater Manchester.[lxxxv]
- No LAES plants are currently 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 to inform previous DFES analysis, some LAES business models are being considered, including:
    - Co-location with renewable energy generation technology (as a source of low-cost, low-carbon input electricity).
    - Co-location with large-scale data centres that require a significant cooling load (this aligns with the cryogenic aspect of the LAES storage cycle).
    - Provision of flexibility services via future grid balancing contracts, such as those issued by National Grid ESO's Stability Pathfinder.[lxxxvi]
- As a result of this feedback and the significant capacity of distributed renewable energy generation in the North of Scotland licence area (onshore wind and large-scale solar PV), both the DFES 2022 and DFES 2023 has modelled 20 MW of new distributed LAES capacity to come online by 2035 and 40 MW by 2050, under **Leading the Way**. There is also the potential for additional capacity to connect to the transmission network.
    - A more diverse group of storage technologies has the potential to see development in future, as highlighted by the results of the Long Duration Storage competition.[lxxxiv] Variations of redox flow batteries, thermal energy storage, gravitational energy storage, as well as power-to-X projects making use of surplus energy have all received funding to develop prototypes or push towards commercialisation. Successful development of these trial projects and continued policy support could see these technologies significantly impacting the electricity network in the future.
- A project funded by the Scottish Government – a 1.8 MWh flow battery has been energised at the European Marine Energy Centre in the Orkney Islands. It will smooth the power from tidal generation and feed an electrolyser to produce green hydrogen[lxxxvii]. As of August 2022, it was contracted to connect with a 0 MW capacity, which features in the battery storage chapter.

- Storage technology analysis in future DFES assessments may include a more diverse range of technologies.

Geographical factors affecting 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 could be based on a potential to co-locate with onshore wind sites and proximity to distribution network infrastructure.

[lxxxiv] UK Government 2021. *Long Duration Energy Storage Competition*. https://www.gov.uk/government/publications/longer-duration-energy-storage-demonstration-programme-successful-projects/longer-duration-energy-storage-demonstration-programme-stream-1-phase-1-details-of-successful-projects

[lxxxv] Highview Power, 2023. https://highviewpower.com/plants/

[lxxxvi] National Grid ESO 2023. *Stability Pathfinder*. https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability

[lxxxvii] Invinity 2022. *EMEC Flow battery installation*. https://invinity.com/invinity-battery-system-successfully-energised-emec-orkney-isles/

Electric vehicles and EV chargers in the North of Scotland licence area

Summary of modelling assumptions and results

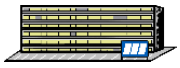
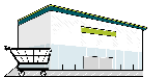
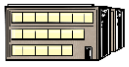
Technology specification

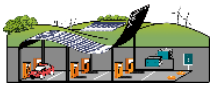
Electric vehicles (EVs) – including cars, buses and coaches, HGVs, LGVs and motorcycles, covering both battery EVs and plug-in Hybrid EVs.

Electric vehicle chargers (EV chargers) – the DFES analyses the uptake of several EV charger archetypes, as shown in the table below.

Technology building blocks: **Lct_BB001 – Pure Electric (vans, cars & motorbikes); Lct_BB002 – Plug-in-hybrid (vans, cars and motorbikes); Lct_BB003 – Pure Electric (road vehicles other than vans, cars and motorbikes); Lct_BB004 – Plug-in-hybrid (road vehicles other than vans, cars and motorbikes).**

Note: No FES building blocks are available for EV chargers.

Regen transport model EV charger archetypes			
Domestic EV chargers	**Off-street domestic**		Homes with somewhere to park a private vehicle off-street
Non-domestic EV chargers	**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

Note: The projection units for domestic and non-domestic EV chargers in the DFES 2023 analysis are different. To illustrate the scale of EV charger uptake, domestic off-street EV chargers are displayed as numbers of chargers, 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 EV charging 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 much 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.

Data summary for EVs in the North of Scotland licence area

Number of vehicles (thousands)		Baseline	2025	2030	2035	2040	2045	2050
Battery EVs (Total, numbers, thousands)	**Falling Short**	10	29	100	282	580	841	924
	System Transformation		32	134	428	785	897	847
	Consumer Transformation		62	271	654	851	868	810
	Leading the Way		60	263	711	882	841	691
Plug-in hybrid EVs (Total, numbers, thousands)	**Falling Short**	6	13	29	57	85	58	22
	System Transformation		12	27	47	35	15	0
	Consumer Transformation		11	20	30	20	8	0
	Leading the Way		13	25	25	13	0	0

Data summary for EV chargers in the North of Scotland licence area

EV chargers		Baseline	2025	2030	2035	2040	2045	2050
Domestic off-street EV chargers (Total, numbers, thousands)	Falling Short	6	20	70	178	325	411	413
	System Transformation		22	91	251	412	422	425
	Consumer Transformation		43	184	394	430	433	436
	Leading the Way		42	185	418	435	438	440
Non-domestic EV chargers[40] (Total, MW)	Falling Short	69	95	179	372	685	948	1,120
	System Transformation		102	234	582	964	1,037	1,051
	Consumer Transformation		142	443	797	928	943	996
	Leading the Way		136	387	903	1,095	1,118	1,218

[40] Non-domestic figures include on-street domestic, also called on-street residential, figures to reflect the commercial nature of on-street domestic charging.

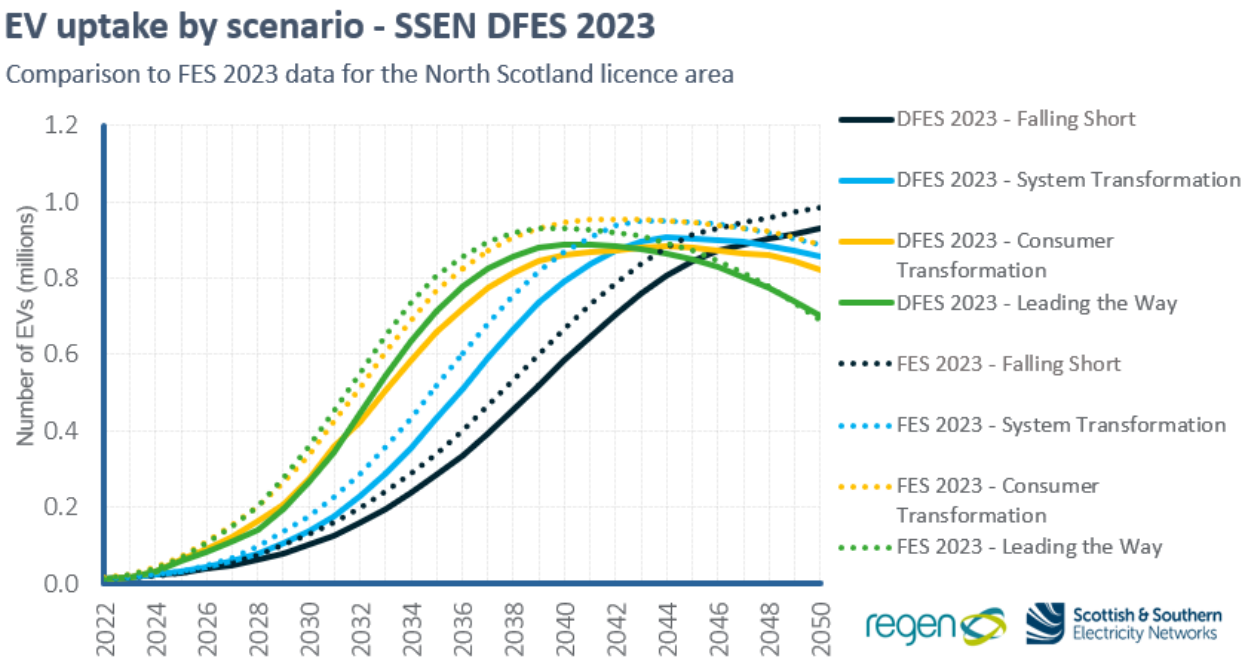


Figure 46 EV projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

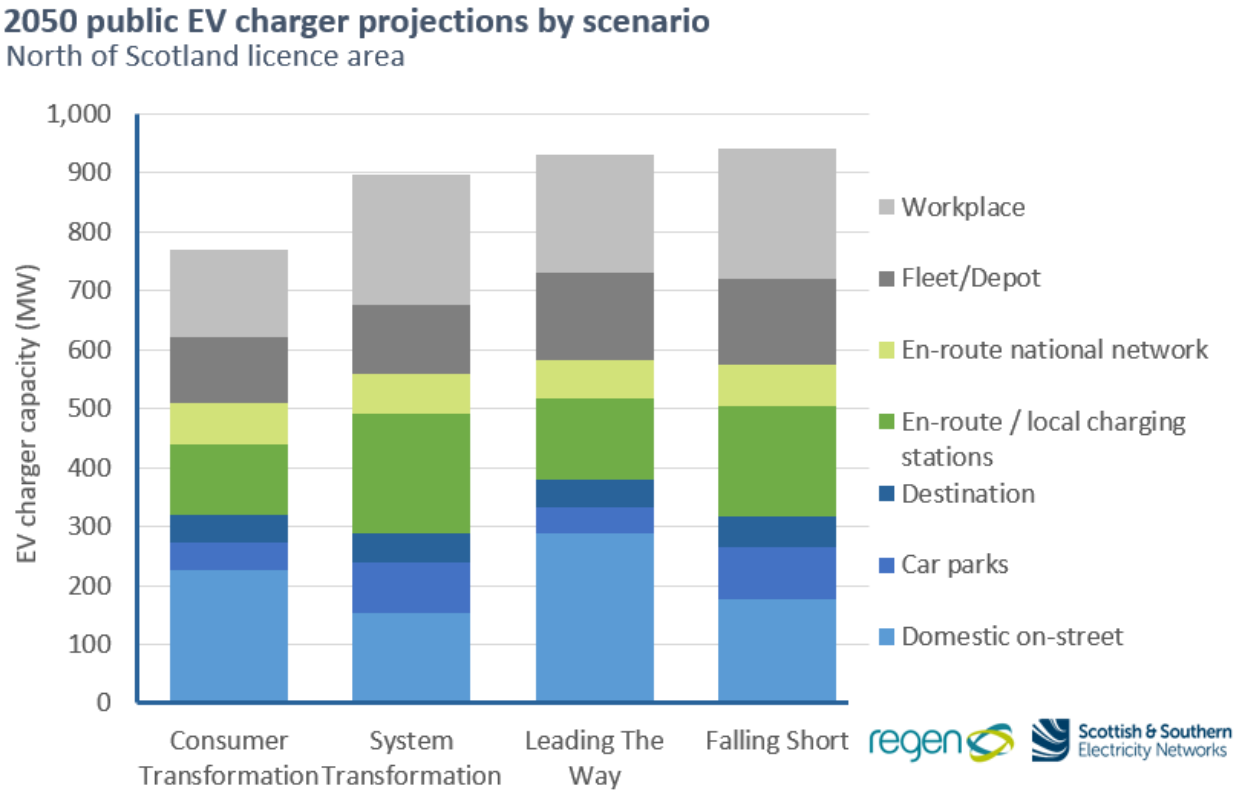


Figure 47 Non-domestic EV charger projections for the North of Scotland licence area

Summary

- The uptake of EVs in the North of Scotland licence area continues to advance at pace, with the number of battery EVs registered increasing from approximately 6,700 in DFES 2022 to over 10,000 in DFES 2023. Furthermore, the current installed capacity of non-domestic EV chargers has increased from 48 MW in DFES 2022 to 69 MW in DFES 2023, with a particular jump in chargers located at local petrol stations.
- At the end of 2022, 1.2% of vehicles (and 1.3% of cars) in the North of Scotland licence area were battery EVs and 0.6% of all vehicles were plug-in hybrids. The uptake of battery EVs and plug in hybrids is below the national uptake rate (of 1.5% and 1%, respectively).
- EV uptake rate is anticipated to increase substantially in the licence area and across the UK in every scenario, as the UK transport sector decarbonises.
- In September 2023, the UK government announced plans to push back the ban on the sale of new petrol and diesel cars and LGVs to 2035.[lxxxviii] EV uptake assumptions in the FES remain close to the CCC's 6th Carbon Budget[lxxxix] and this policy change is already considered within the envelope of the FES scenario assumptions (particularly for EV uptake under **Falling Short**) so no changes to the DFES assumptions have been made.
- The installation of public EV chargers per EV in the North of Scotland licence area is significantly above the GB average. This reflects Chargeplace Scotland's active participation in the Scottish EV charger market[41] and broader support from the Scottish Government. This trend is expected to continue in the near term.
- The uptake of EV chargers is projected to increase substantially in every scenario to facilitate EV uptake. Nevertheless, there is significant uncertainty regarding the scale and geographical distribution of a future EV charger network and future consumer behaviour. There is uncertainty regarding 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 and how this will manifest as electricity demand (in MW) on the distribution network.
- While long and medium-term projections of EVs and EV charger capacity in the licence area are closely aligned with DFES 2022 projections, short-term projections see a greater variance. To date, the uptake of EVs in the licence area is slightly below the

[41] National Chargepoint Registry data identifies approximately 72% of public EV chargers in Scotland as being ChargePlace Scotland chargers.

average of the four scenarios, and consequently short-term projections for **Falling Short** have increased, while uptake in **Consumer Transformation** have reduced.

Modelling and assumptions

Baseline (2022)		
Vehicle archetype	**Thousands of vehicles**	**Description**
Pure electric car	9.5	Although EV uptake in the North of Scotland licence area is behind the national average, the uptake of battery EVs is increasing rapidly, increasing from approximately 6,700 in DFES 2022 to over 10,000 in DFES 2023. This is due to several factors, including: • Favourable tax benefits for ultra-low emissions vehicles. • Increasing consumer confidence and awareness of EVs. • Electrification of commercial vehicle fleets. • Financial benefits of high mileage EV vehicles compared to petrol or diesel vehicles. While most EV uptake has centred on cars, other electric vehicles such as LGVs and buses are also beginning to see uptake. EV uptake in the licence area is proportionally higher in urban areas and island settings, including Dundee, Aberdeen and the Western Isles. However, evidence suggests that urban and rural uptake rates are beginning to converge.
Plug-in hybrid car	5.7	
Pure electric LGV	0.6	
Plug-in hybrid LGV	0.0	
Other electric vehicles	0.2	
EV charger baseline (2022)		
Archetype	**Capacity or numbers**	**Description**
Non-domestic EV chargers	69 MW	The baseline of non-domestic EV chargers has increased from 48 MW in DFES 2022 to 69 MW in DFES 2023. A particular increase has been seen in chargers located at local petrol stations. In addition, most domestic EV owners are assumed to have access to off-street parking, and, therefore, most are assumed to have a home off-street EV charger.[xc]
Domestic EV chargers	6,045 chargers	

EV scenario projections			
Scenario	**Description**	**Battery EVs by 2035 (thousands)**	**Battery EVs by 2050 (thousands)**
Falling Short	The electrification of transport is slowest in this scenario due to lower consumer engagement. Nevertheless, many new car and LGV sales will be EVs by the early 2030s. Approximately 1 million EVs will be registered in the licence area by 2032, four years later than the most ambitious scenarios. Plug-in hybrid vehicles see moderate uptake, but battery electric vehicles are the dominant EV technology across all vehicle classes. Harder-to-electrify vehicles such as buses and HGVs see limited uptake in the medium term. By 2050 most vehicles are electrified, but a high proportion of this electrification is modelled to occur in the 2040s, and there are still petrol and diesel vehicles on the road in 2050 in this scenario.	282	924
System Transformation	Although the ban on new sales of new petrol and diesel passenger vehicles has been pushed back to 2035, this net zero scenario assumes passenger vehicles such as cars and LGVs are rapidly electrified and the ban on the sales of new petrol and diesel vehicles is assumed to be in effect from 2032. In this scenario, the licence area reaches half a million registered EVs in 2036, three years later than the most ambitious scenarios. Plug-in hybrid vehicles see moderate uptake under this scenario, but battery EVs are the dominant EV technology. Around half of the HGVs are also electrified in this scenario, with the remainder fuelled by low-carbon hydrogen.	428	847
Consumer Transformation	The Scottish Government's ambition to have no petrol and diesel vehicles of any type by 2045 has been reflected in **Consumer Transformation**. This scenario also adopts the Scottish Government's ambition for a rapid uptake of electric buses, coaches and LGVs, in addition to its ambition for hydrogen vehicles. However, in the short term the uptake of hydrogen vehicles is modelled to be slower than Scottish Government's ambition, reflecting a slow uptake of these	654	810

	vehicles to date and a limited availability of low carbon hydrogen supply.		
Leading the Way	Although the ban on new sales of new petrol and diesel passenger vehicles has been pushed back to 2035, this scenario assumes passenger vehicles such as cars and LGVs are rapidly electrified and the ban on the sales of new petrol and diesel vehicles comes into full effect from 2030. Non-passenger vehicles, such as HGVs and buses, also electrify, but over a longer timeframe. By 2050, almost all road vehicles are electrified under **Leading the Way**. However, increased use of active travel, public transport and shared vehicles facilitates a substantial reduction in the total number of EVs between the early 2040s and 2050.	711	691

EV charger scenario projections

For non-domestic EV chargers, the DFES EV modelling determines the EV charger capacity required to charge the number of vehicles projected in each of the four DFES scenarios. This capacity is converted to a subsequent number of EV chargers, split across several domestic and non-domestic charger types, such as rapid en-route chargers and slow and fast chargers in public car parks.

This allocation is driven predominantly by the number of each vehicle type from the projections and assumptions around mileage driven and how EVs may be primarily charged under each FES scenario. Where possible, the National Grid ESO FES data has been used to inform charging behaviour assumptions in the DFES.

Domestic EV charger uptake is modelled based on EV uptake in households with off-street parking. It is assumed most households with off-street parking and an EV install a domestic EV charger.

Scenario	Description	Domestic chargers by 2035 (thousands)	Domestic chargers by 2050 (thousands)	Non-domestic capacity by 2035 (MW)	Non-domestic capacity by 2050 (MW)
Falling Short	EV adoption, and subsequent EV charger capacity, increases out to 2050 under this scenario, with almost all road vehicles modelled to be electrified. EV charger uptake is relatively rapid in en-route locations, facilitated by Scottish Government and local authority leadership. However,	178	413	372	1120

	uptake across all EV charger archetypes is slower compared to other scenarios.				
System Transformation	Both EV adoption and associated EV charger capacity peak in the late 2040s under this scenario. By this point, almost all passenger vehicles, LGVs, buses and coaches are electrified, while half of HGVs are electrified. While domestic charging is most common, rapid en-route charging also sees high uptake under this scenario.	251	425	582	1051
Consumer Transformation	**Consumer Transformation** has been modelled to adopt the Scottish Government's ambition for a high uptake of both electric and hydrogen vehicles. Relative to the FES 2023 scenarios, hydrogen vehicles are considered to see a higher adoption in the Scottish Government's transport ambitions, particularly for HGVs, LGVs, buses and coaches. In the long-term, despite **Consumer Transformation** having more EVs than other net zero compliant scenarios, this scenario has a lower total non-domestic EV charger capacity due to significantly less electricity demand associated with those vehicles.	394	436	797	996
Leading the Way	Both EV adoption and associated EV charger capacity peak in the early 2040s in this	418	440	903	1218

	scenario. By this point, almost all road transport is electrified. **Leading the Way** sees the uptake of EV cars slow and significantly reduce, as consumers adopt new transport methods such as public transport, shared vehicles and autonomous vehicles (Avs). However, while the number of EV cars reduces, utilisation and milage per AV increases significantly. The reduction in overall energy demand is, therefore, less significant. Consequently, installed EV charger capacity remains high.				

Reconciliation with National Grid FES 2023

- Baseline EV numbers in the DFES 2023 are sourced from DfT vehicle licencing data and are slightly different to the FES 2023 baseline figures, most likely due to the time of data extraction.
- As the EV market and provision of EV charging infrastructure is heavily driven by national factors, the DFES projections for EVs and EV chargers in the licence area strongly mirror the national FES outcomes.
- The SSEN DFES 2023 projections are broadly in line with the FES 2023 projections for this licence area, except for **Consumer Transformation**, as reported for the Building Block ID numbers Lct_BB001, Lct_BB002, Lct_BB003 and Lct_BB004. This is because under the DFES 2023, **Consumer Transformation** has been modelled to directly align with the Scottish Government's ambition. It is assumed the small variations in projections between SSEN DFES 2023 and FES 2023 projections are due to similar variations found in the baseline, associated with a variance in how the total number of vehicles in the licence area are calculated.
- The different EV charger archetypes are not broken down in the FES 2023 data at a GSP, licence area or national level. As such, a reconciliation is not possible. For vehicle efficiencies, mileage and vehicle numbers, FES projections and assumptions were used to inform the DFES analysis, where available.

Geographical factors affecting deployment at a local level

EVs and EV chargers geographical factors	
Geographical factors	**Description**
The baseline of existing EVs and petrol/diesel vehicles strongly informs the uptake of future EVs.	DfT statistics
The baseline of existing EV chargers is used as an indicator for the location of projected EV chargers.	DfT data, NGED data, National Chargepoint Registry, Open Charge Map
Access to off-street and on-street parking, affluence and rurality are considered in the near-term uptake of electric vehicles and the associated off-street and on-street domestic EV chargers.	ONS Census
The location of petrol/diesel fuelling stations is used to indicate the location for projected en-route EV chargers.	OS Addressbase
The location of car parks, workplaces and fleets/depots are used to indicate the location of projected car park, workplace and fleet/depot EV chargers.	OS Addressbase
The baseline of existing EVs and petrol/diesel vehicles strongly informs the uptake of future EVs.	DfT statistics

Relevant assumptions from National Grid FES 2023

1.1.6 – Transport: Ultra Low Emission Vehicle (ULEV) subsidies	
Falling Short	Plug-in Grant for cars & vans modelled as ending in 2022.
System Transformation	Private ULEV subsidies extended to combat low consumer willingness to change. Plug-in Grant for cars & vans ends in 2023.
Consumer Transformation	Plug-in Grant for cars & vans modelled as ending in 2022.
Leading the Way	Private ULEV subsidies extended to achieve policy ambitions. Plug-in Grant for cars & vans ends in 2023.
1.3.4 – Transport: Public Road Transport	
Falling Short	Air pollution acts as a driver for urban investment but on the whole consumers are reluctant to shift from private transport.
System Transformation	Consumers are somewhat more reluctant to shift from private vehicles and reduce household car ownership, limiting growth.

Consumer Transformation	Consumers demand for public transport increases as attitudes change. Some two car households shifting to one car leads to further growth.
Leading the Way	Consumers demand for public transport increases as attitudes change. Growth is limited by the growth in Robotaxis for urban transport in this scenario.
3.3.2 – Autonomy	
Falling Short	Uptake limited by technology readiness and consumer trust. Has no effect on car ownership. Vehicle does more miles due to ease of travel. Some efficiency gains, particularly through improved off-peak motorway traffic flow.
System Transformation	Significant uptake of private vehicles. Enables some urban households to switch from two to one car families with a corresponding increase in miles for the autonomous vehicle.
Consumer Transformation	Consumer acceptance leads to earlier uptake. Allows a significant number of urban households to become one car families with a corresponding increase in miles. Cars do further increased miles e.g. serving underserved populations. Significant vehicle efficiency gains through improved traffic flow and appropriate vehicle sizing
Leading the Way	Urban areas adopt shared autonomous taxis, allowing some urban households to go car free. Vehicle does significantly more miles due to being a highly utilised asset. High efficiency gains.
3.3.5 – Battery electric vehicles (BEVs)	
Falling Short	BEV adoption is slow and doesn't meet policy ambitions. By 2035, 100% of car sales are ULEV. By 2040, 100% of van sales are ULEV. For both sectors this is dominated by BEVs. Slower uptake of BEVs in the Bus and HGV sectors out to 2050.
System Transformation	The right conditions are not fully achieved to create the consumer confidence needed for the market to achieve 100% sales of ULEVs. This is achieved for cars and vans in 2032 and 2035 respectively and dominated by BEVs. Uptake in the HGV >26t sector is limited by strong Hydrogen Fuel Cell Vehicle uptake.
Consumer Transformation	The government target of 100% of new car and van sales being ULEV by 2030 is met and dominated by BEVs. There's significant uptake in the bus sector and across all HGVs.
Leading the Way	The government target of 100% of new car and van sales being ULEV by 2030 is met and dominated by BEVs. Uptake in the HGV sector is strong across all weight classes. There's significant uptake in the bus sector.
4.1.25 – Plug-in hybrid electric vehicles (PHEVs)	
Falling Short	Availability from manufacturers to meet EU emissions standards is met from demand by fleets looking to gradually reduce emissions and drivers who are unwilling to shift to BEVs. No new sales from 2040.
System Transformation	Higher demand for PHEVs as a transitional vehicle due to a higher proportion of consumers reluctant to transition to BEVs. No new sales from 2035.

Consumer Transformation	Subsidy environment, falling battery costs and increased consumer willingness to accept BEVs limits PHEV growth. No new sales from 2035.
Leading the Way	Higher initial demand for PHEVs (in addition to BEVs) as society seeks to decarbonise quickly. Subsidy environment, falling battery costs and increased consumer willingness to accept BEVs limits PHEV growth. No new sales from 2032.
4.2.13 – Level of home charging	
Falling Short	There is a lack of solutions to residential charging for those without off-street parking and which consumers are willing to adopt. These consumers charge at destinations like work.
System Transformation	There is a lack of solutions to residential charging for those without off-street parking and which consumers are willing to adopt. Emphasis on public rollout of fast chargers allows near home rapid charging.
Consumer Transformation	Emphasis on home and on-street residential chargers (for those with adequate on-street parking), taking advantage of consumer engagement levels in flexibility. Emphasis on public rollout of fast chargers also allows near home rapid charging.
Leading the Way	Widespread innovation and behaviour change allows majority of those with on-street parking to charge overnight. This limits market for near home rapid charging.

Incorporation of stakeholder feedback

EVs and EV chargers stakeholder feedback	
Stakeholder feedback provided	**How this has influenced our analysis**
The North of Scotland stakeholders viewed several factors as barriers to the widespread uptake of Vin the licence area. However, no standout factor was viewed as significantly more impactful than other barriers.	This validated existing DFES modelling assumptions that reflects a range of factors that could limit EV uptake under some scenarios, so no further action was taken based on this feedback.
Stakeholders were asked whether the future of EV charging infrastructure would be more widely dispersed in more decentralised locations (such as a higher level of on-street residential chargers) or be less dispersed and more centralised (such as a higher level of charging hubs and en-route charging). Stakeholder responses indicated a lean towards a balanced approach, with 77% voting for a balanced approach, 15% towards a distributed approach and 8% a more centralised approach to EV charging infrastructure deployment.	Stakeholder feedback highlighted the uncertainty of the shape and scale of a future EV charger network, as well as future consumer behaviour. Therefore, to reflect this feedback, the DFES scenarios model variability in the proportion of EV charging at dispersed locations and more centralised locations, and the amount of EV charging that occurs both near and far away from home.

[lxxxviii] DfT, *Government sets out path to zero emission vehicles by 2035*. https://www.gov.uk/government/news/government-sets-out-path-to-zero-emission-vehicles-by-2035

[lxxxix] CCC, *6th Carbon Budget Surface Transport*. https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Surface-transport.pdf

[xc] Department for Business, Energy and Industrial Strategy, 2023, *Electric Vehicle Smart Charging Action Plan*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1129728/electric-vehicle-smart-charging-action-plan.pdf

Heat pumps and resistive electric heating

Summary of modelling assumptions and results

Technology specification

The analysis covers all variants of electrically powered heating technologies within the scope of the SSEN DFES 2023. 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 night storage or direct radiant electric heater.

Technology building blocks: **Lct_BB005 – Domestic non-hybrid heat pumps**; **Lct_BB006 – Domestic hybrid heat pumps**; **Lct_BB007 – Non-domestic non-hybrid heat pumps**; **Lct_BB008 – Non-domestic hybrid heat pumps**; **No corresponding DFES building block – Domestic resistive electric heating**.

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

Number of homes (thousands)			Baseline	2025	2030	2035	2040	2045	2050
Domestic	Non-hybrid heat pumps	Falling Short	23	36	67	125	212	411	390
		System Transformation		44	99	140	175	213	276
		Consumer Transformation		53	231	357	468	542	579
		Leading the Way		51	230	367	437	459	484
	Hybrid heat pumps	Falling Short	0	-	3	9	15	22	27
		System Transformation		1	7	16	66	116	148
		Consumer Transformation		1	14	21	28	38	50

		Leading the Way		1	14	30	52	73	87
Number of properties (thousands)			**Baseline**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Non-domestic	**Non-hybrid heat pumps**	**Falling Short**	6	7	9	11	14	18	21
		System Transformation		8	13	24	33	38	39
		Consumer Transformation		8	13	24	33	39	41
		Leading the Way		9	17	28	37	40	42
	Hybrid heat pumps	**Falling Short**	0	0	0	0	1	2	4
		System Transformation		0	2	5	9	12	14
		Consumer Transformation		0	3	5	8	10	12
		Leading the Way		0	2	4	7	9	11

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	**Falling Short**	98	100	89	80	69	411	51
	System Transformation		100	85	75	54	39	23
	Consumer Transformation		97	90	81	76	66	57
	Leading the Way		98	90	80	73	64	60

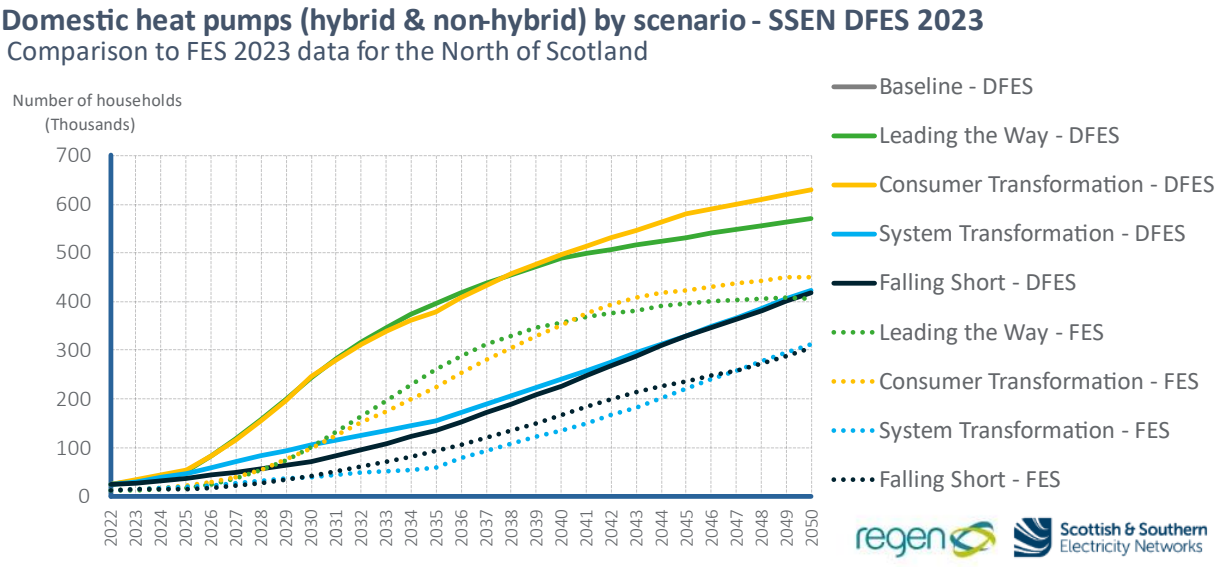


Figure 48 Domestic heat pumps (non-hybrid and hybrid42) projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

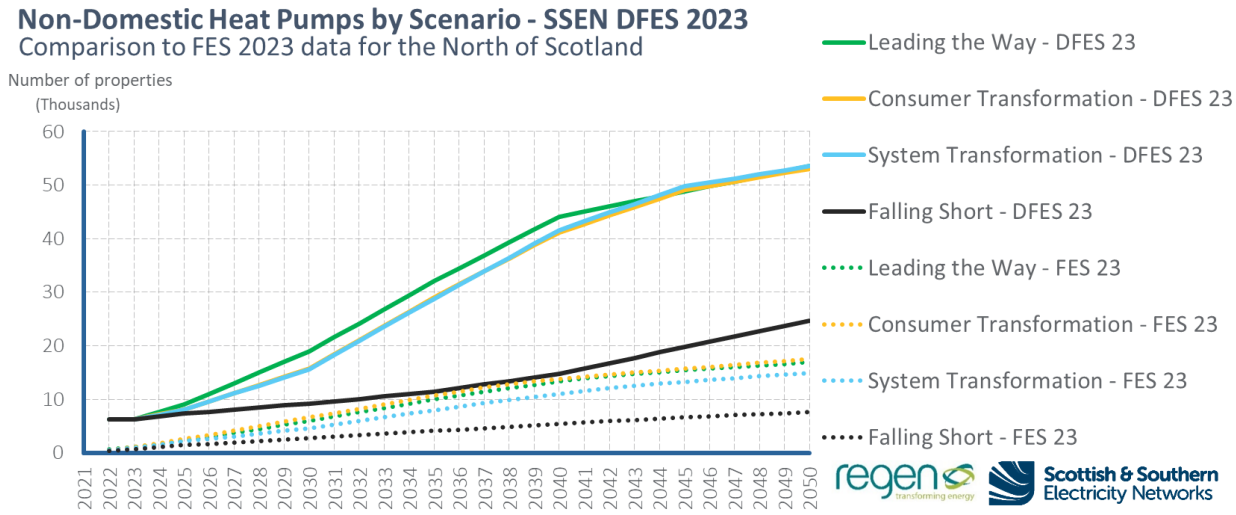


Figure 49 Non-domestic heat pumps (non-hybrid and hybrid) projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

[42] The Building Block data provided in the FES 2023 classifies an 'ASHP with a resistive heating element' as a hybrid heat pump, whereas the DFES analysis considers this to be a variation of a non-hybrid heat pump. Accordingly, the reconciliation between FES and DFES 2023 results has been undertaken using combined figures for both non-hybrid and hybrid heat pumps together.

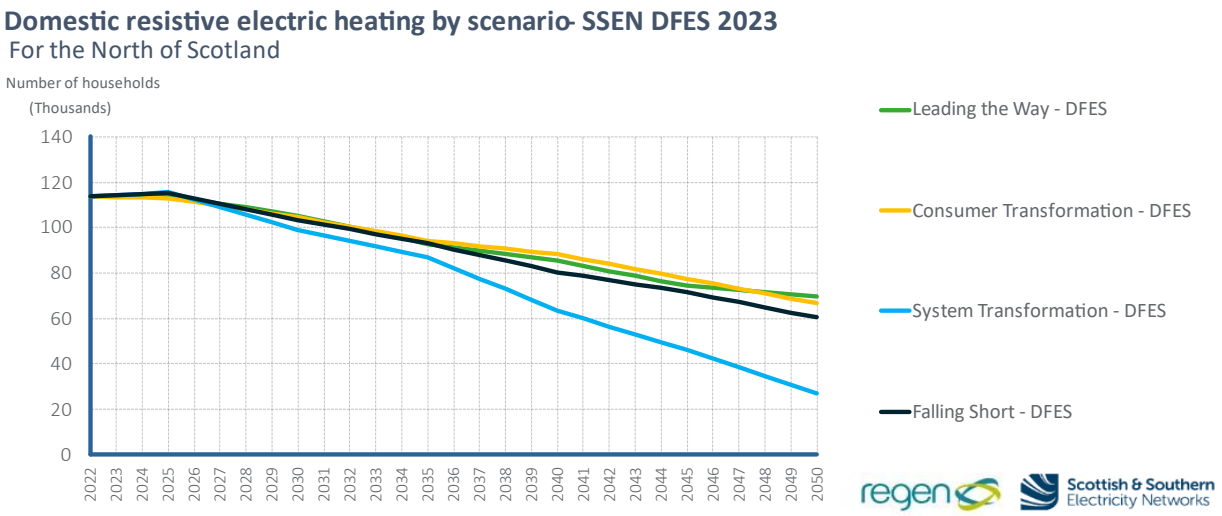


Figure 50 Domestic resistive electric heating projections for the North of Scotland licence area

Summary

- Around three-quarters of homes and businesses in the North of Scotland licence area use fossil fuel heating systems. These will require conversion to a zero-emissions heating system by 2045[xci] if Scotland and the UK are to meet their carbon reduction targets. Scotland's Heat in Buildings Strategy (2021) targets an installation rate of low carbon heating technologies that peaks at over 200,000 new systems per annum in the late-2020s. The Scottish Government has reported around 5,000 heat pump installations per year and around 33,000 buildings connected to heat networks.[xcii]
- In 2023, the Scottish Government issued a consultation on the Heat in Buildings Bill[xciii] to make new laws around the energy efficiency and heating of homes and buildings. Scottish Government amended the Home Energy Scotland Scheme[xciv] in 2022 to make it easier for households to access funding for heat and energy efficiency measures in their homes and to target additional support for those in rural areas.
- The North of Scotland licence area has a diverse range of building types, encompassing densely populated urban areas like Dundee and Aberdeen, characterised by on-gas houses and flats, to sparsely populated rural areas such as the Highlands and Islands, which are primarily off-gas.
- Overall, the licence area has a significantly higher percentage of off-gas buildings than the GB average. As a result, the adoption of heat pumps is expected to accelerate above the national trend, especially in areas where off-gas buildings are common.

- At the end of 2022, there were c.29,000 homes and businesses with a heat pump currently installed.
- Under **Consumer Transformation** and **Leading the Way**, space heating is primarily decarbonised via heat pumps in both the North of Scotland licence area and nationally. Initial uptake is mostly modelled to occur in off-gas, well-insulated buildings before a wider-scale rollout of heat pumps across most buildings are modelled out to 2050. For the North of Scotland licence area, this results in c.629,000 homes and c.53,000 non-domestic buildings operating a heat pump by 2050 under **Consumer Transformation**.
- Under **System Transformation**, the decarbonisation of heat is driven primarily by low-carbon hydrogen, fuelling a mixture of standalone hydrogen boilers and hybrid heat pumps. However, the higher proportion of off-gas buildings in the North of Scotland results in higher uptake of non-hybrid heat pumps under this scenario, as the availability of hydrogen for domestic and non-domestic heating is assumed to be in line with current fossil gas heating.
- In **Falling Short**, progress towards heat decarbonisation is slow. Despite some uptake of heat pumps in the late 2030s and the 2040s, many buildings remain heated by fossil gas boilers in 2050 as the UK fails to meet its carbon emissions reduction targets.
- The number of buildings on resistive electric heating, which includes direct electric heating and night storage heaters, decreases in all scenarios, replaced by heat pumps and district heating. As the most expensive heating method, the use of direct electric heating is a financial driver for consumers to switch in all four scenarios. There is also a shift from direct electric heating to next-generation storage heating in homes where a boiler or heat pump is less suitable, such as in very low energy efficiency properties.
- The deployment of non-domestic heat pumps show a similar trend. With a high number of businesses looking to decarbonise their space heating, but replacing fossil gas and direct electric heating with heat pump variants in all scenarios, to a varying degree, by 2050.

Implementation of Scottish Government Policies in the DFES 2023 analysis

The **Consumer Transformation** and **Leading the Way** scenarios are aligned with the Scottish Government's ambitious net zero commitments and plans for heat decarbonisation. The Scottish Government has set several targets and policy commitments to achieve net zero, including converting over one million homes to zero emissions heating systems by 2030, as outlined in the Heat in Buildings Strategy.[xcv]

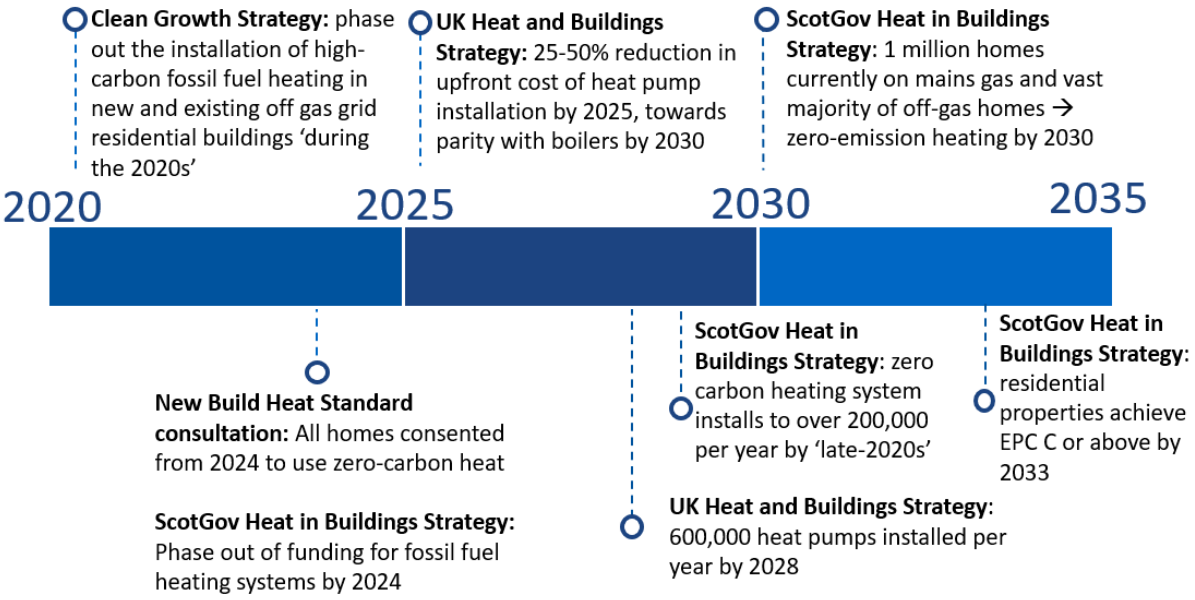


Figure 51 Heat Policies in Scotland and the UK

The role of hydrogen in heat decarbonisation looks to be increasingly limited, based on statements made by both the Scottish and UK governments. Whilst the Scottish Government's Hydrogen Policy Statement[xcvi] (2020) stated that the Scottish Government "*will explore the potential that hydrogen may offer in helping to contribute to our ambitious heat decarbonisation targets*", through publication of the Hydrogen Action Plan[xcvii] in 2022, it has since stated that:

"We do not consider that hydrogen will play a central role in the overall decarbonisation of domestic heat and therefore cannot afford to delay action to decarbonise homes this decade through other available technologies. The potential for hydrogen to play a role in heating buildings depends upon strategic decisions by the UK Government that will be made over the coming years and the Scottish Government will continue to urge the UK Government to accelerate decision-making on the role of hydrogen in the gas grid."

This call to the UK Government was reiterated in the Delivering Net Zero for Scotland's Buildings consultation[xcii] (2023) where it stated that the UK Government should "*make a clear and fast decision on the future role of our gas networks in the transition to clean heat*". At a local level, Scottish local authorities are taking the lead on heat decarbonisation through the rollout of LHEES [xcviii].

A combination of low carbon technologies will be necessary to achieve zero emissions heating in Scotland. The most cost-effective pathway will require a strategic response using multiple technology solutions. While heat pumps are the key low-carbon heating solution available today and necessary to meet the 2030 targets, their high capital cost may be a barrier for individual consumers. Therefore, government support is crucial to successfully roll out heat pumps and other low-carbon heating solutions. In 2019, the Scottish Government introduced The Fuel Poverty Act, which was passed unanimously by UK Parliament. In 2021, the Scottish Government published the Fuel Poverty Strategy,[xcix] which identified actions to address drivers of fuel poverty and address fuel poverty for those at the highest risk. In 2021, the Scottish Parliament passed the Heat Networks (Scotland) Act[c] to introduce regulation and a district and communal heating licensing system to accelerate the use of the networks across Scotland. Building on these policies, in 2023, the independent Green Heat Finance Taskforce published its first report,[ci] highlighting options that will "*allow individual property owners to access finance to cover the upfront costs for replacing polluting heating with clean heat solutions in the manner best suited to their own individual circumstances*".

Modelling Stages

Baseline (2022)			
Domestic heat pumps			
Sub-technology	**Number of homes (thousands)**	**Proportion of homes**	**Description**
Non-hybrid air source heat pumps (ASHP)	20	2.8%	Most heat pumps in existing homes were supported by the Renewable Heat Incentive (RHI) scheme, which ran from 2014 to 2022. This has since been succeeded by the Boiler Upgrade Scheme[cii] in England and Wales, with the Scottish Government continuing its existing support through the Home Energy Scotland Grant and Loan[ciii] scheme. The RHI was particularly popular in Scotland, with around 17% of all RHI accredited heat pumps located in the North of Scotland licence area. 3.2% of homes in the licence area now have a heat pump, which is above the national average. At the end of 2022, 23,000 homes were heated by domestic heat pumps, compared to 18,000 in 2021.
Non-hybrid ground source heat pumps (GSHP)	3	0.4%	
Hybrid heat pump	-	-	

Domestic resistive electric heating			
Night storage heaters	79	11%	Resistive electric heating is much more common in the North of Scotland licence area compared to the national average, heating almost 16% of homes compared to 8% nationally, according to FES 2023. This is mainly due to the high proportion of off-gas homes across the licence area and the relative lower cost of off-gas fuels such as oil and liquefied petroleum gas (LPG), compared to electric heating, in the more remote areas of the licence area, such as the Highlands and Islands. In 2023, approximately 114,000 homes were heated by resistive electric heaters, compared to 163,000 in the 2022 DFES analysis. This change in baseline data is the result of greater EPC availability, combined with a more granular methodology to characterise the licence area as an aggregation of building data at the low voltage level.
Direct electric heaters	35	4.8%	
Non-domestic heating			
Non-hybrid heat pumps	6,270	-	An estimated 6,270 non-domestic properties are currently heated by a non-hybrid heat pump. As with domestic properties, there are no non-domestic hybrid heat pumps in the baseline.
Resistive heating	34,692	-	An estimated 35,000 non-domestic properties currently also use resistive electric heaters, likely focused in off-gas industrial areas.

Near-term projections (2023-2025)

The modelling of the future uptake of different types of electric heating in the licence area is based on several key factors, including building types and sociodemographic factors. Under the **Consumer Transformation** and **Leading the Way** net zero scenarios, the uptake of heat pumps in the licence area is projected to increase significantly by 2025, primarily in off-gas homes heated by oil and LPG. Conversely, the number of homes heated by resistive electric heating is projected to decrease more slowly under every scenario in the near term.

Domestic heat pumps			
Scenario	**Description**	**Proportion of homes with a heat pump in 2025**	
		North of Scotland	**GB (FES)**
Falling Short	In these scenarios, near-term decarbonisation and electrification of heat is lowest. Heat pump uptake is restricted to areas of off-gas housing, replacing oil, LPG and resistive electric heating, and well-insulated homes. There are many examples of these types of properties in the licence area, resulting in c. 36,000-46,000 homes with a heat pump by 2025 under these scenarios. The more restricted uptake compared to other net zero scenarios is, however, linked to a longer-term strategy to introduce low-carbon hydrogen supply and hydrogen boilers under **System Transformation**.	5%	2%
System Transformation		6%	2%
Consumer Transformation	The uptake of ASHP and GSHP heat pumps is highest in these scenarios, as Scotland and the UK progress towards heat decarbonisation goals, namely: ***Heat in Buildings Strategy (Scotland, 2021):*** • At least 124,000 zero-emissions heat installations between 2021 and 2026. • The rate of zero-emissions heat installations peaks at over 200,000 new systems per annum in the late-2020s. • By 2030, the vast majority of 170,000 off-gas homes currently using high-emission oil, LPG and solid fuels, and at least 1 million homes currently using mains gas must convert to zero-emissions heating. • All new builds to have zero direct emissions heating systems by 2024 as part of New Build Zero Emissions from Heat Standard ***Heat and Buildings Strategy (UK, 2021)*** • At least 600,000 heat pump installations per year by 2028. In the licence area, areas of off-gas and well-insulated homes are modelled to see high levels of heat pump uptake. Some on-gas houses and flats also convert to heat pumps due to support from the Home Energy Scotland grant and loan[Error! Bookmark not defined.]. As a result of this and Scotland's zero emissions heat system	7%	2%
Leading the Way		7%	3%

	installation targets, the North of Scotland licence area sees higher near-term uptake of heat pumps relative to GB.		

Domestic resistive electric heating

Scenario	Description	Proportion of homes with resistive electric heating in 2025	
		North of Scotland	GB (FES)
Falling Short	In these scenarios, only a very small proportion of homes with resistive electric heating are modelled to convert to a heat pump in the near term. However, whilst current gas prices remain higher than the historical average, with the licence area hosting a notable number of on-gas households, some additional houses move onto the mains gas network to reduce heating costs. Some properties are also modelled to install next-generation night storage heaters. Under these scenarios, around 5% of houses and flats heated by resistive electric heating convert to a heat pump by 2025. Some direct electric heated homes also convert to night storage heaters to reduce heating costs. The North of Scotland has a much higher baseline proportion of homes heated by resistive electric heating, which is still much higher than the GB average in 2025.	16%	8%
System Transformation		16%	8%
Consumer Transformation		15%	8%
Leading the Way		15%	8%

Non-domestic heat pumps

Scenario	Description	Installations in 2025	
		Non-hybrid	Hybrid
Falling Short	The uptake of non-domestic heat pumps varies slightly by scenario in the near-term. The highest uptake occurs under **Leading the Way**, where smaller-scale businesses rapidly adopt low carbon heating to reduce their business carbon footprint and energy costs.	7,294	46
System Transformation		7,858	182
Consumer Transformation		7,663	447

Leading the Way		8,615	467

Medium and long-term projections (2025-2050)

Heat decarbonisation accelerates in the North of Scotland licence area in the medium term, especially under the three net zero scenarios, as the country seeks to meet heat decarbonisation targets. Under **Consumer Transformation** and **Leading the Way**, heat pumps are modelled to become the main heating technology in both on-gas and off-gas properties. District heat networks are also modelled to come online in some urban areas in the North of Scotland licence area, such as Aberdeen, Dundee and Inverness. These are driven by heat pumps or from waste heat in dense urban areas or areas near a waste heat source, such as thermal or heavy industry.

Under **Falling Short** and **System Transformation**, heat pump uptake remains low in both households and businesses. Under **Falling Short**, decarbonisation of heat is generally slower across the country, resulting in heat pump uptake mainly being limited to off-gas homes in the medium term. In **System Transformation**, hydrogen boilers become the preferred heating technology for on-gas homes, limiting heat pump adoption.

New build homes are modelled to increasingly include low-carbon heating appliances. In every scenario, this includes both heat pumps and connections to district heat networks. There are 68,000-81,000 projected new houses modelled to be built by 2050 in the North of Scotland licence area. In general, heat pump uptake is modelled to be strongly adopted in new build homes from 2025 under **Consumer Transformation** and **Leading the Way**, reflecting the successful implementation of the New Build Heat Standard.[civ]

Domestic heat pumps

Scenario	Description	Proportion of homes with a heat pump			
		2035		2050	
		North of Scotland	GB (FES)	North of Scotland	GB (FES)
Falling Short	Under **Falling Short**, overall progress towards net zero remains low, and fossil gas heating remains the most common form of heating out to 2050. The majority of heat pump uptake is in off-gas houses under this scenario. As a result, the North of Scotland heat pump uptake is significantly ahead of the GB trend.	17%	9%	53%	35%

System Transformation	Under **System Transformation**, a small subset of properties are modelled to install hybrid hydrogen heat pumps, reflecting low carbon hydrogen being available in some areas and replacing the fossil gas network in the 2030s and 2040s. As a result, by 2050, almost a third of all heat pumps modelled in this scenario are hydrogen hybrid systems. Non-hybrid heat pump uptake is focused on off-gas houses and new build homes. With a high proportion of off-gas houses, the North of Scotland's heat pump uptake is ahead of the GB trend. The remaining homes are heated by hydrogen boilers.	20%	5%	53%	16%
Consumer Transformation	The North of Scotland remains ahead of the medium-term national trajectory for heat pump uptake under both **Consumer Transformation** and **Leading the Way** with its ambitious zero carbon heat system installation targets. Under these scenarios, many more	49%	28%	79%	52%

Leading the Way	on-gas homes convert to a heat pump by 2035 (49-51%); a national shift in heating technologies drives this. By 2050, almost all properties are heated by standalone heat pumps, district heating or resistive electric heating in both scenarios. Standalone heat pump uptake is ahead of the GB average trend in the North of Scotland licence area. This is due to the number of properties that are outside built-up areas and so less likely to have access to a district heat network. Under **Leading the Way**, hydrogen boilers become available in some population centres, modelled to be installed in 10% of domestic properties in 2050. As a result, c.570,000-630,000 properties are operating a heat pump by 2050 under these scenarios.	51%	34%	71%	41%

Domestic resistive electric heating

Scenario	Description	Proportion of homes with resistive electric heating			
		2035		2050	
		North of Scotland	GB (FES)	North of Scotland	GB (FES)
Falling Short	The number of resistive heated homes decreases in the medium term under these scenarios, with homes connecting to the fossil gas or hydrogen network. Direct electric	12%	6%	8%	5%

System Transformation	heated homes that cannot convert to these technologies have been assumed to shift to next-generation night storage heating, which enables them to shift their electricity demand to lower cost periods. **System Transformation** sees a more rapid decrease out to 2050 due to a higher uptake of hydrogen boilers and hybrid heat pumps.	11%	6%	3%	2%
Consumer Transformation	The number of resistive heated homes decreases in the medium and long term under these scenarios. Homes in denser urban areas and flats connect to district heat networks, and other homes install standalone heat pumps. By 2050, direct electric heated homes that cannot convert to these technologies generally shift to next-generation night storage heating. As a result, c.70,000 homes (9%) could operate a resistive electric heater by 2050 under these scenarios.	12%	7%	8%	5%
Leading the Way		12%	6%	9%	5%

Non-domestic heat pumps

Scenario	Description	Installations in 2035		Installations in 2050	
		Non-hybrid	Hybrid	Non-hybrid	Hybrid
Falling Short	Most non-domestic heat pumps are pure electric in all scenarios by 2050. **System Transformation** sees a more ambitious uptake than with domestic heat pumps by 2050, as well as a moderately higher uptake of hybrid heat pumps overall.	11,108	201	20,968	3,743
System Transformation		23,733	5,042	39,435	14,066
Consumer Transformation		24,029	5,019	40,967	12,075

Leading the Way	Under **Consumer Transformation** and **Leading the Way**, >40,000 non-domestic premises install a type of heat pump by 2050, reflecting more businesses focusing on electrification to meet their net zero plans.	28,050	4,008	42,321	11,180

Reconciliation with National Grid FES 2023

Modelling Stage	Reconciliation
Baseline	**Domestic heat pumps:** The DFES baseline is approximately double that of the FES. The DFES figure is based on an analysis of EPC and DEC data. **Non-domestic heat pumps:** The DFES baseline is markedly higher than the FES. The DFES figure is based on an analysis of EPC and DEC data.
Near-medium term projections	**Domestic heat pumps and non-domestic heat pumps:** DFES shows a larger number of domestic heat pumps than the FES. The North of Scotland licence area is above the national average for several attributes and factors, resulting in a faster near-term uptake of domestic heat pumps, particularly when combined with Scotland's ambitious heat decarbonisation targets in **Leading the Way** and **Consumer Transformation**.
Medium-long term projections	**Domestic heat pumps:** DFES uptake is higher than in every scenario. Licence area attributes lead to a higher *proportion* of homes with heat pumps in the DFES compared to the FES. **Non-domestic heat pumps:** DFES uptake is substantially higher than the FES in every scenario. This is most likely due to differences in the number of heated properties modelled in the DFES and FES. In the DFES, heated properties are modelled based on SSEN customer data combined, with DEC and non-domestic EPC records to understand the local characteristics of the building stock on the low voltage network, including properties that have potential to be heated by a heat pump in the future.
Overarching trend	The DFES outcomes for heat pumps in each scenario show a higher uptake than FES. The DFES non-domestic heat pump projections are higher in all scenarios than seen in FES 2023. As discussed above, this is likely most likely due to differences in the number of heated properties modelled in the DFES and FES.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Current heating technology is categorised into on-gas, resistive electric heating, and off-gas (predominantly heating oil). This is the main geographical factor for the modelling of non-domestic heat pumps.	EPC data[cv], ONS Census
Building type is categorised into semi-detached and detached houses, terraced houses, and flats.	EPC data, ONS Census
Tenure is categorised into owner-occupied, privately rented and socially rented.	EPC data, ONS Census
Current and potential future levels of energy efficiency, based on building age (pre/post-1930 construction).	EPC data

Relevant assumptions from National Grid FES 2023

Scenario	3.1.3 – Heat pump adoption rates	
Falling Short	Low	Low disposable income and low willingness to change lifestyle means consumers buy similar appliances to today.
System Transformation	Medium	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	High	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	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.
Scenario	**4.2.27 – Uptake of hybrid heating system units***	
Falling Short	Low	Gas boilers still dominant and very low levels of hybridisation.
System Transformation	Medium	Hydrogen boilers dominant. Higher amounts of hybrid hydrogen boilers + ASHP systems than FES21. However, low levels of other hybrid technologies.
Consumer Transformation	Medium	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	High	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 backup heater, considered non-hybrid heat pumps in the DFES.

Incorporation of stakeholder feedback

Stakeholder feedback provided	How this has influenced our analysis
In the context of the Scottish Government's 2030 target for zero carbon heating uptake, stakeholders thought that heat pump deployment would focus on new homes, social housing and off-gas with fossil fuel heating.	Heat pump uptake is weighted towards these housing types and demographics in the near- and medium-term.
Local authorities were engaged to ascertain those with a low carbon heat strategy established or in development. However, this formed a minority of local authorities.	Heat pump uptake is accelerated in local authorities with low-carbon heat strategies in the near-to-medium term.
Scottish Government's Heat in Buildings Strategy policy commitments, targets and projections.	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.
Stakeholders thought electric heat pumps and next-generation direct electric or night storage heaters would be the Scottish Islands' main low-carbon heating technology. Representatives for the Islands were specifically consulted in 2021 about their unique heating challenges and drivers.	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 analysis's range of the four future scenarios.

[xci] Scottish Government 2021, *Heat in Buildings Strategy*. https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/pages/3/

[xcii] Scottish Government 2023, *Delivering Net Zero for Scotland's Buildings - A Consultation on proposals for a Heat in Buildings Bill*. https://www.gov.scot/publications/delivering-net-zero-scotlands-buildings-consultation-proposals-heat-buildings-bill/documents/

[xciii] Scottish Government 2023, *Delivering net zero for Scotland's buildings - Heat in Buildings Bill: consultation*. https://www.gov.scot/publications/delivering-net-zero-scotlands-buildings-consultation-proposals-heat-buildings-bill/pages/2/

[xciv] Scottish Government 2022, *News: Enhanced support to make homes warmer and greener*. https://www.gov.scot/news/embargoed-enhanced-support-to-make-homes-warmer-and-greener/

[xcv] Scottish Government 2021, *Heat in Buildings Strategy*. https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/

[xcvi] Scottish Government 2020, *Hydrogen Policy Statement*. https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/

[xcvii] Scottish Government 2022, *Hydrogen Action Plan*. https://www.gov.scot/publications/hydrogen-action-plan/documents/

[xcviii] Scottish Government 2022, *Local Heat and Energy Efficiency Strategies (LHEES) and delivery plans: guidance*. https://www.gov.scot/publications/local-heat-energy-efficiency-strategies-delivery-plans-guidance/

[xcix] Scottish Government 2021, *Tackling fuel poverty in Scotland: a strategic approach*. https://www.gov.scot/publications/tackling-fuel-poverty-scotland-strategic-approach/

[c] UK Government 2021, *Heat Networks (Scotland) Act 2021*. https://www.legislation.gov.uk/asp/2021/9/section/1/enacted

[ci] Green Heat Finance Taskforce, *Report Part 1*. https://www.gov.scot/publications/green-heat-finance-taskforce-report-part-1-november-2023/documents/

[cii] UK Government 2022, *Notice: The Domestic Renewable Heat Incentive (DHRI) closure, and its successor, the Boiler Upgrade Scheme*. https://www.gov.uk/government/publications/changes-to-the-renewable-heat-incentive-rhi-schemes/closure-of-the-domestic-renewable-heat-incentive-dhri-and-its-successor-the-boiler-upgrade-scheme

[ciii] Scottish Government, *Home Energy Scotland Grant and Loan: overview*. https://www.homeenergyscotland.org/funding/grants-loans/overview/

[civ] Scottish Government 2022, *New Build Heat Standard: consultation - part two*. https://www.gov.scot/publications/new-build-heat-standard-consultation-part-ii/

[cv] Scottish Government 2022, *Domestic Energy Performance Certificates - Dataset to Q4 2022*. https://statistics.gov.scot/data/domestic-energy-performance-certificates

Domestic air conditioning

Summary of modelling assumptions and results

Technology specification

This analysis covers domestic air conditioning units, based on a typical portable or window-mounted unit in the North of Scotland licence area.

Network technology data building block: **Lct_BB014 – A/C domestic units**

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

Air conditioning units (thousands)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	3	5	10	21	43	89	176
System Transformation		4	8	15	29	51	92
Consumer Transformation		4	8	15	29	51	92
Leading the Way		3	4	4	4	4	4

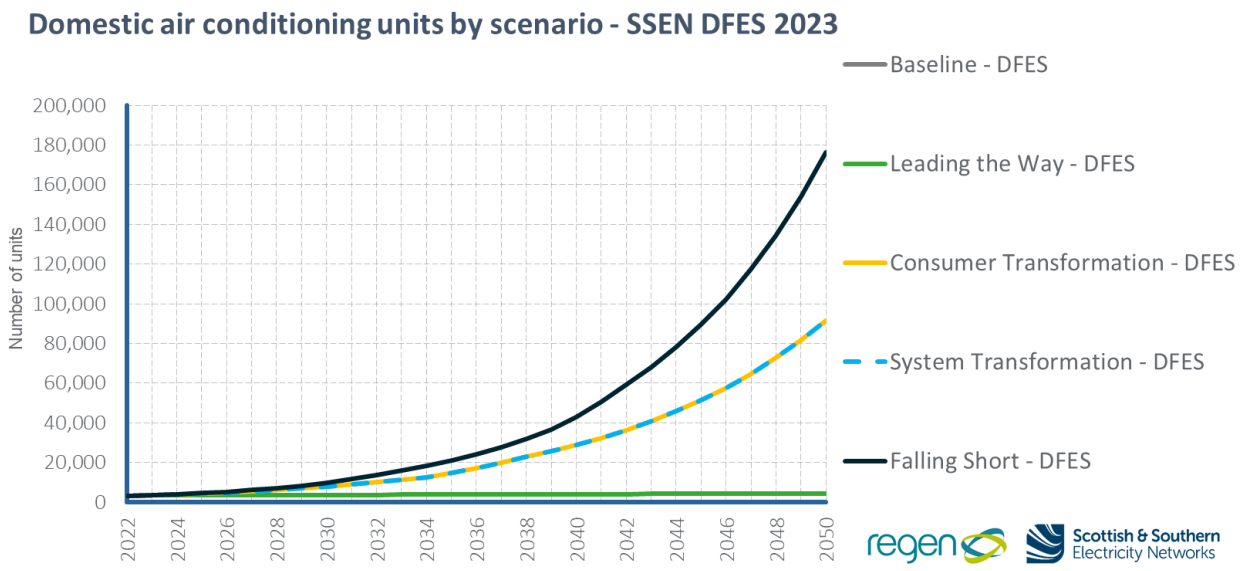


Figure 52 Air conditioning projections for the North of Scotland licence area

Summary

- Currently, 3,086 air conditioning (AC) units are installed in properties in the North of Scotland licence area. This represents 0.50% of homes in the licence area and is an increase from 0.44% from DFES 2022. However, this is less than the national baseline of c. 1% of UK homes currently containing AC units.[cvi]
- The number of cooling degree days[cvii] at 18.5 °C in the North of Scotland licence area is considerably lower than in many other parts of the UK.
- Based on assumptions in relevant Building Regulations,[cviii] it has been assumed that domestic AC units will not be added to new developments in the licence area.
- There is a broad range of scenario outcomes for air conditioning in this licence area. The baseline number is relatively small and there is still high uncertainty around the future of domestic cooling. **Leading the Way** sees the lowest uptake of AC units (c.4,427) by 2050 whilst **Falling Short** models domestic AC becoming much more common, with a projection of c.176,325 new units by 2050.
- In all scenarios there is an increased projection of domestic air conditioning units when compared to the 2022 DFES projections.

Modelling stages

Baseline (2022)	
Number of domestic units	**The proportion of homes with AC unit**
3,086	0.50%

Modelling assumptions

We have aligned with the National Grid FES 2023 data,[l] which provides a national baseline of around 296,000 domestic air conditioning units, equivalent to around 1%[cix] of homes in the UK.

The national figure was distributed based on regional temperate data and housing density to estimate the licence area baseline. For example, the North of Scotland licence area was found to have very few cooling degree days at or above 18.5 °C (4 days in North East Scotland and 21 days in North West Scotland). The licence area also has a population density that is significantly lower than the national average. As a result, the North of Scotland's baseline of 0.50% of homes was modelled, equating to c. 3,086 AC units. These cooling degree days and population metrics were used to determine domestic AC units in all scenarios.

Future Home and Building Standards

The Scottish Government's Building Standards Technical Handbook[cx] mandates that the form and fabric of every building should be designed to minimise the use of air conditioning units but, where these units are necessary, they must be energy efficient and controllable by the user. The Future Homes Standard Document O[iii] stipulates high energy efficiency for air conditioning and limits oversizing cooling systems in new homes. As a result, the DFES 2023 modelling assumes that the vast majority of domestic AC uptake is retrofitted in existing homes (and not new buildings) in every scenario.

Scenario projections

Scenario	Description	In 2035		In 2050	
		Homes with AC units (1000s)	% Of housing stock in North of Scotland	Homes with AC units (1000s)	% Of housing stock in North of Scotland
Falling Short	Uptake in domestic AC units increases in the near term in this scenario, due to more frequent summer heat waves. Most of these units are assumed to be in denser urban areas due to the "heat island	21	3.4%	176	28.7%

	effect". In the medium and long term, the increasing frequency of heat waves and societal reluctance to adopt passive cooling leads to a more significant uptake of domestic AC, even in colder regions, as the 'easiest' route to comfortable internal temperatures.				
System Transformation **Consumer Transformation**	Uptake in domestic AC units increases in the near term due to more frequent summer heat waves under these scenarios. Most units are assumed to be in denser urban areas due to the "heat island effect". In the medium and long term, the uptake of domestic AC continues to accelerate in urban areas due to heat island effects and the prevalence of smaller dwellings like flats.	15	2.4%	92	14.9%
Leading the Way	In the near term, the uptake of domestic AC is minimal, with households opting for passive cooling methods such as shading, ventilation and insulation. As a result, only 366 AC units are installed between 2022 and 2025 under this scenario. This scenario aims to limit carbon emissions and electricity consumption using passive cooling measures. As a result, additional AC uptake is resultantly minimal in the licence area by 2050.	4	0.6%	4	0.7%

Reconciliation with National Grid FES 2023

- The FES 2023 does not directly detail the numbers of domestic AC units; thus, a comparison is not possible. However, annual electricity demand for domestic AC is provided at a national level, alongside typical annual electricity consumption values of 500 kWh/year for domestic AC units. This allows for high-level reconciliation against national figures.
- The North of Scotland licence area has far fewer cooling degree days and a lower population density than other parts of the UK. As a result, the licence area is significantly below the FES 2023 national average in every scenario.

Geographical factors affecting deployment at a local level

Geographical factors	Description

Population Density	Urban areas experience a 'heat island effect' as asphalt, pavement, and other built areas replace natural landscapes, causing heat to be absorbed rather than reflected. Therefore, population density (persons per hectare, pph) was used to determine the proportion of the licence area considered urban.
	Three density factors were used:
	• Very Dense: >100 pph. Used in every scenario.
	  ○ 7% of the North of Scotland licence population live in very densely populated areas, including Aberdeen, and Dundee
	• Fairly Dense: >50 pph–- Used in every scenario except **Leading the Way**.
	  ○ 32% of the population resides in fairly dense areas, including Perth, the outskirts of Dundee and the sections of mainland Orkney Island.
	• Dense: >25 pph–- Only used in **Falling Short**
	  ○ Most of the North of Scotland licence area (60%) live in dense areas. This includes the city of Inverbervie and surrounding areas, Callander, Fort William and portions of the Shetland Islands near Hillswick.
	
	In the DFES analysis, early uptake of air conditioning units is focused in denser urban areas because of the 'heat island effect'. Later uptake then expands to areas of lower housing density in scenarios where domestic AC becomes more prevalent.

Relevant assumptions from National Grid FES 2023

Scenario		Uptake of residential air conditioning[cxi]
Falling Short	High	Low willingness to change means society takes the easiest route to maintain comfort levels, therefore increased levels of air con.
System Transformation	Medium	Medium aircon as society takes a mix of actions to maintain comfort levels (mix of aircon, tolerance of higher temperatures, changes to building design).
Consumer Transformation		
Leading the Way	Low	Low aircon as society changes to minimise uptake (e.g. personal tolerance of higher temperatures, changes to building design).

[cvi] National Grid FES 2023, *Data workbook V003, ED2 worksheet Data Item for Residential Air Conditioning*. https://www.nationalgrideso.com/future-energy/future-energy-scenarios/documents

[cvii] Stark 2022, *Degree Days for Free*. https://www.stark.co.uk/degree-days-for-free/

[cviii] HM Government 2021, *Building Regulations 2010 Overheating: Approved Document O*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1057374/ADO.pdf

[cix] Figure for number of households in the UK taken from Office of National Statistics, Families and Households in the UK: 2022 https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/bulletins/familiesandhouseholds/2022

[cx] Scottish Government Building Standards Technical Handbook 2022: Domestic. Section 6.6 Mechanical ventilation and air conditioning https://www.gov.scot/publications/building-standards-technical-handbook-2022-domestic/6-energy/6-6-mechanical-ventilation-air-conditioning

[cxi] National Grid FES 2023 Scenario Assumptions, Assumptions worksheet, *Data Item for Residential Air Conditioning*. *https://www.nationalgrideso.com/future-energy/future-energy-scenarios/documents*

Hydrogen Electrolysis

Summary of modelling assumptions and results

Technology specification

The analysis covers 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 grid connection ''off-grid''), electrolysers connected to the transmission network, or Carbon Capture, Utilisation and Storage (CCUS)-enabled hydrogen produced via the reformation of fossil fuels.

Network technology data building block: **Dem_BB009–- hydrogen electrolysis**

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

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	0	1	44	73	74	76	93
System Transformation		3	58	86	187	307	416
Consumer Transformation		3	83	107	134	167	203
Leading the Way		38	227	235	307	419	536

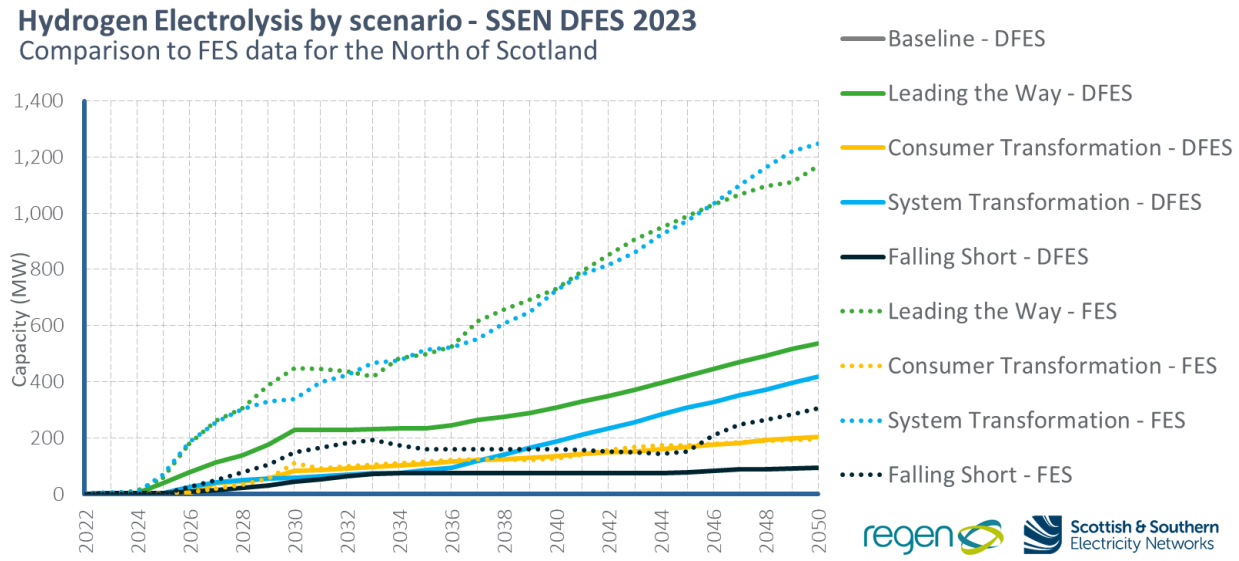


Figure 53 Hydrogen electrolysis projections for the North of Scotland licence area, compared to National Grid FES 2023 regional projections

Summary

- There is a degree of uncertainty around the direction of travel for hydrogen electrolysis as an emerging technology, resulting in some key differences between DFES 2022 and DFES 2023. FES 2023 projections in the North of Scotland licence area have decreased significantly, and as a result, DFES 2023 projections are also decreased. As in DFES 2022, the DFES are much lower than the FES under **Leading the Way** and **System Transformation**.
- This uncertainty results in a wide range of future capacity projections under the three net zero scenarios and limited growth under **Falling Short**. These sources of uncertainty include:
    - The split between distribution and transmission-connected electrolysis capacity.
    - The production of low-carbon hydrogen via electrolysis versus CCUS-enabled methane reformation.
    - The degree to which electrolysers will be located near storage facilities or sites associated with potential end-users: transport, industrial processes, aviation, shipping, power generation and heat.
    - The presence of import connection agreements for hydrogen electrolysers, where projects co-locate with on-site renewable generation behind-the-meter.
    - How far and how quickly hydrogen production costs will fall.

- There are several potential electrolysers in the pipeline across Scotland as a whole, with the Orkney Islands and Aberdeen hosting an array of trials and demonstration projects with the potential to expand into larger centres of demand. Some renewable generation sites, particularly those fuelled by the offshore-generated electricity connected to the European Marine Energy Centre (EMEC), are seeking grid import connections to ensure the security of supply when on-site renewables are''t generating.
- The British Energy Security Strategy[cxii] outlines a need for 10 GW of low carbon hydrogen, of which 5 GW will be from electrolysis, by 2030. The Scottish Government's Hydrogen Action Plan[cxiii] confirms an ambition to install 5 GW of hydrogen capacity from low-carbon sources by 2030 and 25 GW by 2045. The Scottish Government has also committed £100m in funding towards developing a Scottish hydrogen economy.
- In May 2023, the Scottish Government announced the winners of a £7 million fund to drive innovation in production of storage and distribution of renewable hydrogen.[cxiv] The DFES has reflected these results and included projects that are confirmed to be distribution network connected in this year'' analysis.
- The UK governmen''s electrolytic allocation round[cxv] will provide government subsidy support from 2023 onwards for both capital expenditure (CAPEX), via capital grants, and operational expenditure (OPEX), via ongoing revenue payments. Projects over 5 MW were eligible for support, with successful applicants announced in early 2023, and have been considered in the analysis.
- Using several locational factors, FES 2023 distribution-connected projections are reallocated across all DNO licence areas across in UK. The North of Scotland is modelled to host between 5-7% of distribution-connected hydrogen electrolysis across GB by 2050, depending on the scenario and regional considerations.
- The largest capacity of distribution-connected hydrogen electrolysers in 2050 is modelled under **Leading the Way** (536 MW) and **System Transformation** (416 MW). This reflects the large-scale rollout of hydrogen as a low-carbon fuel for transport, industry and heat and the establishment of a national hydrogen network to deliver the low-carbon hydrogen to end consumers in the licence area.

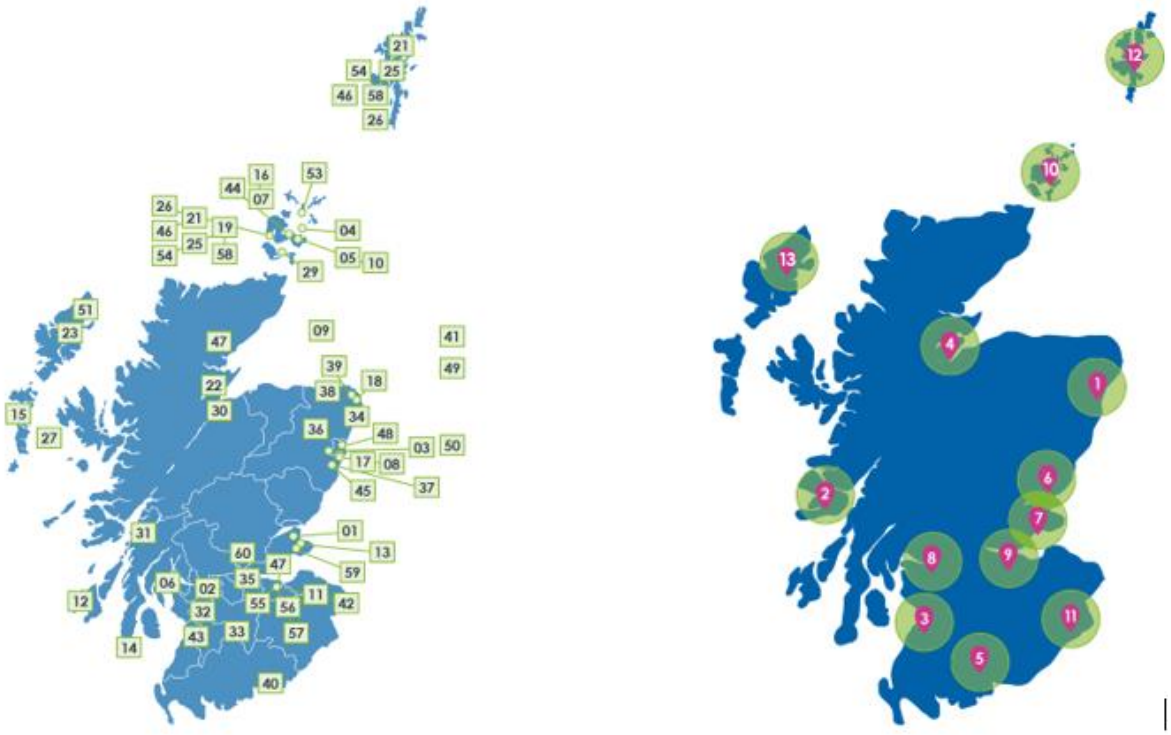


Figure 54 Maps of current and planned hydrogen projects and regional hydrogen hubs in Scotland (Source: Scottish Government Hydrogen Action Plan[cxiii])

Modelling and assumptions

Baseline (2022)		
Number of sites	**Total capacity (MW)**	**Description**
0	0	No new sites have been commissioned to the distribution network since DFES 2022. As of the end of 2022, there were four known electricity networked hydrogen electrolysis sites, the largest of which is the 1 MW refuelling station at Kittybrewster.[cxvi] This site is part of the HyTransit project in Aberdeen, which will begin with a grid connection and look to transition to on-site renewable generation. Another hydrogen refuelling station is at the Aberdeen Hydrogen Centre (0.35 MW). A smaller 30 kW electrolyser is located at the Creed Integrated Waste Management Facility and is part of the Outer Hebrides Local Energy Hub.[cxvii] EMEC runs a 670 kW electrolyser at the ITEG facility on Orkney, a vanadium flow battery is used onsite to allow the use of tidal energy in hydrogen production.[cxviii] We have not included in DFES projections sites where it is not clear whether they will be connected to the grid or just use on-site, behind-the-meter renewable generation (e.g. JIVE[cxix] and ACHES refuelling station[cxx]). The

		BIG HIT demonstration,[cxxi] which concluded in 2022, was also excluded as it consumed limited curtailed on-site renewable energy generation.[cxxii] As a result, due to further analysis and new site-specific information, the baseline from DFES 2022 of 2 MW has now been revised to 0 MW.

Pipeline (2023-2030)

Number of pipeline sites	Total capacity (MW)
2	36.4

There is a pipeline of hydrogen demonstrator and pilot projects across the North of Scotland, although no new pipeline sites have been identified during DFES 2023. However, many of these sites could fall out-of-scope of the analysis due to deriving hydrogen from on-site generation and not seeking a grid connection. For example, the HyLaddie Project,[cxxiii] may connect within the existing agreed supply capacity of the site's existing connection agreements and operate as a behind-the-meter asset. Desk-based research suggested that there are at least 21 potential electrolyser projects in the licence area. Most of these are co-located with behind-the-meter renewable generation. On the other hand, some sites may seek backup electricity import agreements to complement on-site generation.[43] Some of the sites that are not modelled as network-connected include:

- Dundee Hydrogen Bus Accelerator
- Hammars Hill Wind Farm Hydrogen Extension
- Macc Business Park, Machrihanish - Hydrogen Production Facility
- Arbikie, Inverkeilor - Green Hydrogen Project & Wind Turbine
- ORION project
- HyDIME project

Where there is evidence of development, but the status of a project is unclear, we have used this evidence as a factor in the geographical distribution of the scenarios.

There is an also uncertainty as to whether hydrogen electrolysis will be largely transmission-connected in the licence area, or whether distribution network-connected electrolysers will continue to be developed after initial pilot projects and full demonstrations are fulfilled.

The Integrating Tidal Energy into the European Grid (ITEG) initiative was included as a pipeline site in DFES 2021. The project was looking to demonstrate the integration of tidal energy (2 MW) and hydrogen production (0.5 MW) on Orkney. This phase of the project ended in 2021, and seeing as the project was due to be operational for several months only[cxxiv], it has not been modelled in the analysis.

[43] Where sites were unable to be identified as having an import connection, they were not modelled. However, as the industry evolves, the Regen DFES team will look to revise this assumption if it becomes clear that most sites, regardless of on-site generation, will likely seek backup network import agreements.

Grid connected pipeline projects			
Pipeline project	**Description**	**Scenario**	**Connection Year**
Bankhead Recycling Solar Array, Battery Storage & Hydrogen, **1.4 MW**	Hydrogen electrolysis, solar PV and battery storage will all be connected to the grid with an export capacity. The site submitted a planning application in August 2022 and was approved in April 2023. (The year of connection has been revised since DFES 2022 to reflect a wider variation across scenarios and a more realistic project buildout timeframe.)	**Falling Short**	2027
		System Transformation	2025
		Consumer Transformation	2025
		Leading the Way	2025
North of Scotland Hydrogen Programme Distilleries Project, **35 MW**[cxxv]	A project led by Scottish Power, Storegga (formerly Pale Blue Dot), Port of Cromarty Firth, Glenmorangie, Whyte & Mackay and Diageo is exploring the use of green hydrogen to decarbonise Scottish distilleries. Phase 1 of the project aims to install 35 MW of electrolysers by the end of 2024 in the Port of Nigg, Cromarty Firth.	**Falling Short**	--
		System Transformation	2029
		Consumer Transformation	2027
		Leading the Way	2025

Scenario projections (2030 to 2050)

The UK government has set a target of 10 GW of low carbon hydrogen production capacity by 2030, with at least half coming from hydrogen electrolysis. From consultation with electrolyser manufacturers, 5-10 MW electrolyser units are anticipated to become commercially viable by 2030, and the demand for hydrogen from hydrogen-fuelled heavy vehicle fleets and public transport will increase across all scenarios in this timeframe.

Hydrogen could become a key technology to balance future electricity supply and demand on the distribution network. The arrival of policy support mechanisms, such as the first electrolytic hydrogen allocation round (2022), provides some impetus for the sector.[cxv] Successful projects, which must be 5 MW minimum to be eligible to apply, were announced in early 2023.

While the North of Scotland hosts numerous regional hydrogen innovation hubs, many projects are expected to be transmission connected or not to be electricity grid connected. This is the case of a site being piloted by Storegga in Cromarty (300 MW). The North East Network and Industrial Cluster estimates that 1.3 TWh of hydrogen will be needed for small-scale electricity generation by 2030, increasing to 3 TWh by 2040.[cxxvi] Initial green hydrogen production will likely come from small to medium-sized units at this cluster, after which transmission-scale projects may become the norm.

Hydrogen electrolysis capacity is projected 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.

In the longer term, hydrogen electrolysers are expected to scale up by increasing the number of modules connecting to a compressor. The total capacity of distribution-connected electrolysers rapidly increases out to 2050 under some scenarios, due to wider hydrogen sector developments, such as:

- The repurposing of large-scale geological storage facilities for hydrogen.
- A decrease in upfront capital costs to deploy electrolysers.
- An increased demand for low carbon gases such as electrolytic hydrogen from multiple consumers.
- The co-location of hydrogen electrolysers with renewable generation, to provide balancing services to a high-renewable net zero electricity system.

Scenario	Description	Capacity by 2035 (MW)	Capacity by 2050 (MW)
Falling Short	Small industrial and heavy transport demand further limit growth in the North of Scotland.	73	93
System Transformation	Moderate growth is mainly driven by the renewable generation in the licence area and demand for marine transport. Minimal industrial and heavy transport demand in the North of Scotland limits growth compared to other licence areas. The establishment of a national hydrogen network boosts potential electrolysis uptake.	86	416
Consumer Transformation	Factors determining the uptake of hydrogen electrolysis are diversified, with industrial customers and clusters being the strongest factor, followed by heavy transport and marine transport demand, the latter of which has a high potential in the North of Scotland. Electrolysers are located close to demand as a national hydrogen network is not expected to be rolled out.	107	203
Leading the Way	The Scottish Hydrogen Policy Statement's ambition to develop competitive hydrogen production at scale by the 2030s is met. By 2045, hydrogen is expanded to support export capabilities. The establishment of a national hydrogen network boosts projections. Uptake is considerably lower than in DFES 2022 due to the overall reduction in network-connected electrolysis under the FES 2023.	235	563

Network-connected electrolysis projections – methodology overview
To determine licence-area projections beyond known projects, FES 2023 projections for distribution-connected hydrogen electrolysis at a GB-level were reallocated to each DNO licence area based on propensity for hydrogen electrolysis derived from several locational factors (see table below). These regional factors, weighted based on the FES scenarios' assumptions, represent a range of possibilities across regional uptake. The result has been a re-allocation of FES projections to each licence area, considering the locational factors present within each. The factors below have been updated since DFES 2022 as the model evolved to capture new market information of still emerging technology.

Hydrogen distribution factors

Factor	Leading the Way	Consumer Transformation	System Transformation	Falling Short	Presence of this factor in the North of Scotland
Industrial energy demand	High	High	High	High	Low
Heavy transport demand	Low	Medium	Medium	High	Medium
H2 transmission network coverage	Medium	Low	Medium	Low	High
Location of maritime activity	Medium	High	High	Low	Low
Gas distribution network coverage	High	Low	High	Low	Low
Gas powered electricity generation	Medium	High	Medium	Medium	Low
Renewable energy resource	Medium	Low	Low	Low	High
Hydrogen innovation projects	High	High	High	High	High
Location of aviation activity	Low	Low	Low	Low	Medium
Existing grey hydrogen sites	Medium	Low	Low	High	Low

Reconciliation with National Grid FES 2023

Modelling stage	Reconciliation
Baseline	The DFES and FES 2023 are aligned.
Pipeline	Early pipeline years see a higher overall uptake in the North of Scotland in FES 2023 than in DFES 2023. While the North of Scotland hosts a great deal of innovation projects, the scale of near-term increase seen in the FES projections is not reflected in the DFES analysis, which considers that many projects will remain either non-networked, short-term demonstration projects or simply off-grid projects, limiting

	the amount of grid connection required.
Projections	Medium-term growth decreases under the DFES 2023, whereas growth remains quite high in the North of Scotland under FES 2023. The DFES reflects the presence of factors such as industrial demand, heavy transport demand, and availability of storage facilities, which are relatively low in the North of Scotland compared to other licence areas. As a result, the reason for the very high levels of electrolysis capacity seen in FES 2023 in the licence area by 2050 is not clearly discernible from published FES assumptions.
Overarching Trend	The DFES models hydrogen electrolysis uptake across DNO licence areas by analysing various regional factors. Due to this methodology, the North of Scotland licence area sees less distribution network connected electrolysis allocated under **Leading the Way** and **System Transformation** than the FES 2023. As the hydrogen industry develops over the next few years, better clarity of the factors driving hydrogen growth could see a more accurate approach to allocation to certain licence areas over others.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Industrial demand	Industrial demand is determined using the National Atmospheric Emissions Inventory (NAEI) point source CO_2 emissions as a proxy for industrial demand.
Heavy transport demand	Uses information on the location of heavy transport fuelling hubs and road traffic count for light commercial vehicles, heavy goods vehicles, coaches and buses.
Renewable resource	Based on in-house Regen large-scale solar and wind resource assessments.
Hydrogen ESAs and regional hub locations	As part of the analysis, Regen hand-picks electricity supply areas known to be situated in areas where proposed hydrogen hubs and innovation areas are likely to be located beyond the known pipeline and pseudo-pipeline projects.

Relevant assumptions from National Grid FES 2023

Scenario		4.2.19 - Hydrogen (electrolysis exc. from nuclear)
Falling Short	Low	High cost limits rollout of electrolysis - used mainly in transport.
System Transformation	Medium	Competition from SMR limits rollout of electrolysis - used mainly in transport. Hydrogen is produced from both networked and non-networked electrolysers, increasing with time as green hydrogen becomes more attractive compared with blue hydrogen created from natural gas.
Consumer Transformation	Medium	Electrolysis used to decarbonise heat, transport and some I&C - medium as begins later than in the high case.
Leading the Way	High	Electrolysis used to decarbonise heat, transport and I&C but rollout starts in the mid 2020's.

Incorporation of stakeholder feedback

Stakeholder feedback	How this has influenced our analysis
Storegga	During the writing of DFES 2022, a discussion of hydrogen business models revealed that some hydrogen industry actors believe the future direction of electrolysis is in large-scale transmission-connected projects. In contrast, small-scale distribution network-connected projects may be more prominent in the early years. This feedback has influenced the degree to which future demand will be placed on the networks in all modelling scenarios, especially in the medium-to-long term.
EMEC and Integrating Tidal Energy into the European Grid (ITEG) project	Engagement with EMEC and ITEG for DFES 2022 revealed that while many small-scale innovation hydrogen projects in Scotland intend to be powered by offshore renewable energy generation sites, many of these sites will seek a separate import grid connection to secure stable electricity supply where on-site electricity generation is low. The DFES has considered this feedback on site-by-site bases, modelling sites known to have or will pursue an electricity backup agreement.
Stakeholder Webinars	2023 stakeholder webinar participants provided views that the best use of hydrogen would be for decarbonising industrial processes first and foremost, followed by heavy transport, shipping and rail. All participants thought decarbonising shipping and industrial processes were the preferred uses of hydrogen, followed by heavy transport. Open ended responses reflected a general hesitancy on relying for hydrogen for heating purposes, and no responders selected hydrogen for heating as their preferred end use for hydrogen.

	In the 2022 stakeholder webinar, nine respondents identified Aberdeen as the first future hydrogen hub in the North of Scotland, while three selected Dundee, Orkney and Shetland. These views have been reflected in choosing distribution factors and identifying future hydrogen electricity supply areas, reinforcing near-term projections in known hydrogen hub areas.

[cxii] British Energy Security Strategy 2022, https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

[cxiii] Scottish Government Hydrogen Action Plan 2022, https://www.gov.scot/publications/hydrogen-action-plan/pages/2/

[cxiv] See https://www.gov.scot/publications/emerging-energy-technologies-fund-hydrogen-innovation-scheme-successful-projects/

[cxv] Hydrogen Business Model and Net Zero Hydrogen Fund: Electrolytic Allocation Round 2022, https://www.gov.uk/government/publications/hydrogen-business-model-and-net-zero-hydrogen-fund-electrolytic-allocation-round-2022

[cxvi] BOC's Kittybrewster Hydrogen Refuelling Station: Driving Net Zero in Aberdeen 2022, https://www.boconline.co.uk/en/images/Case%20study%20Kittybrewster%20Aberdeen%20hydrogen%20refuelling%20station_tcm410-563229.pdf

[cxvii] Outer Hebrides Local Energy Hub n.d., https://communityenergyscotland.org.uk/projects-innovations/ohleh/

[cxviii] Eday FLOW battery project, EMEC 2022. https://www.emec.org.uk/projects/hydrogen-projects/eday-flow-battery-project/

[cxix] JIVE n.d., https://www.fuelcellbuses.eu/projects/jive

[cxx] Hydrogen Refuelling Stations 2021, https://www.interregeurope.eu/good-practices/hydrogen-refuelling-stations

[cxxi][cxxi] BIG H_2IT n.d., https://www.bighit.eu/about

[cxxii] Business Model and Replication Study of BIG HIT 2017, https://static1.squarespace.com/static/5874afe0579fb3504bf4d87b/t/62389a15e92f912032160f08/1647876632355/D5.1+A+report+of+the+business+models+to+be+disseminated+to+OHT+and+follower+territories.pdf

[cxxiii] HyLaddie Phase 1 Feasibility Report n.d., https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/978975/HyLaddie_Phase_1_Feasibility_Report.pdf

[cxxiv] Integrating Tidal Energy Storage into the European Grid n.d., https://es.catapult.org.uk/project/integrating-tidal-energy-storage-into-the-european-grid/

[cxxv] Green Hydrogen Set for Port of Nigg 2021, https://www.scottishpower.com/news/pages/green_hydrogen_set_for_port_of_nigg.aspx

[cxxvi] North East Network and Industrial Cluster Development Summary Report 2022, https://www.sgn.co.uk/sites/default/files/media-entities/documents/2021-11/North%20East%20Network%20and%20Industrial%20Cluster%20Development%20Summary%20Report%20November%202021.pdf

New property developments

Summary of modelling assumptions and results

Technology specification

New domestic, commercial and industrial developments can have a significant impact on local electricity demand and, therefore, forecasts of new housing and commercial and industrial builds have been included in the 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.). The relevant FES technology building blocks are:

- **Gen_BB001a – number of domestic customers**
- **Gen_BB002b – meters squared of I&C (industrial and commercial) customers**

Data on planned domestic and non-domestic developments for the SSEN licence areas has been gathered through data exchange with all local authorities in the North of Scotland licence area. This process used an online data portal and individual engagement with local authority planning teams and data providers. Desk-based research and site investigation have validated and augmented the data supplied.

Alongside historic build rates and Office for National Statistics (ONS) household projections,[cxxvii] the data provided by the local authorities is used to inform licence area projections for future housing numbers and non-domestic floor space (sqm).

Data summary for new domestic developments in the North of Scotland licence area

Houses (cumulative; thousands)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	--	12	36	57	69	75	80
System Transformation		15	43	62	74	79	84
Consumer Transformation		15	43	62	74	79	84
Leading the Way		18	47	66	76	82	88

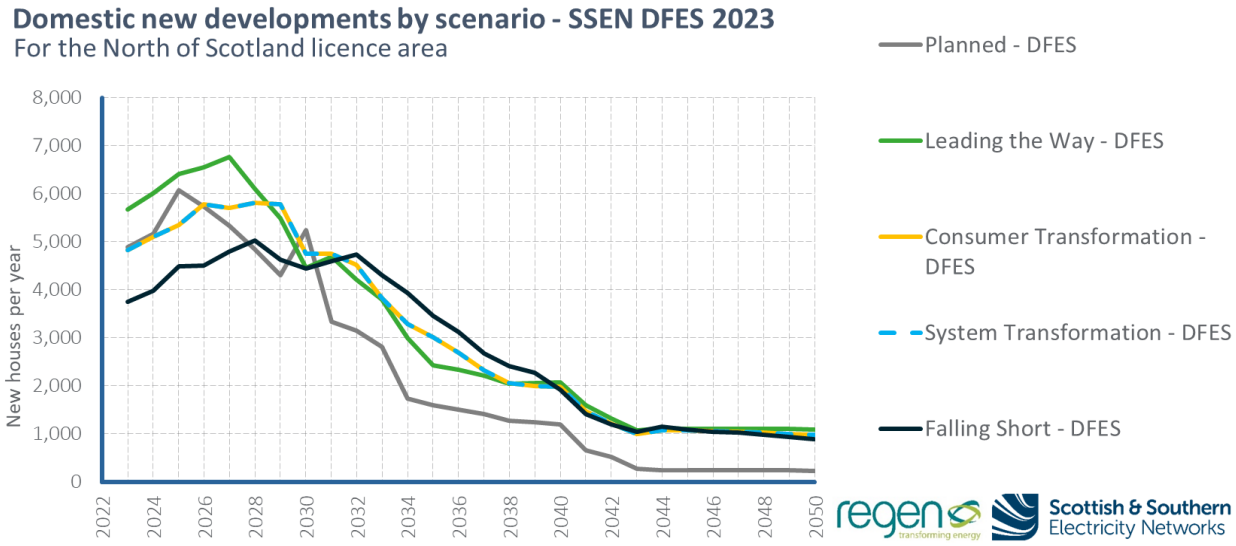


Figure 55 Non-cumulative new domestic development projections for the North of Scotland licence area

Data summary for new non-domestic developments in the North of Scotland licence area

Floorspace (sqm; millions)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	0	1.8	4.6	7.3	9.1	9.6	9.7
System Transformation		2.3	5.8	8.9	9.4	9.6	9.7
Consumer Transformation		2.3	5.8	8.9	9.4	9.6	9.7
Leading the Way		2.8	6.1	8.9	9.4	9.6	9.7

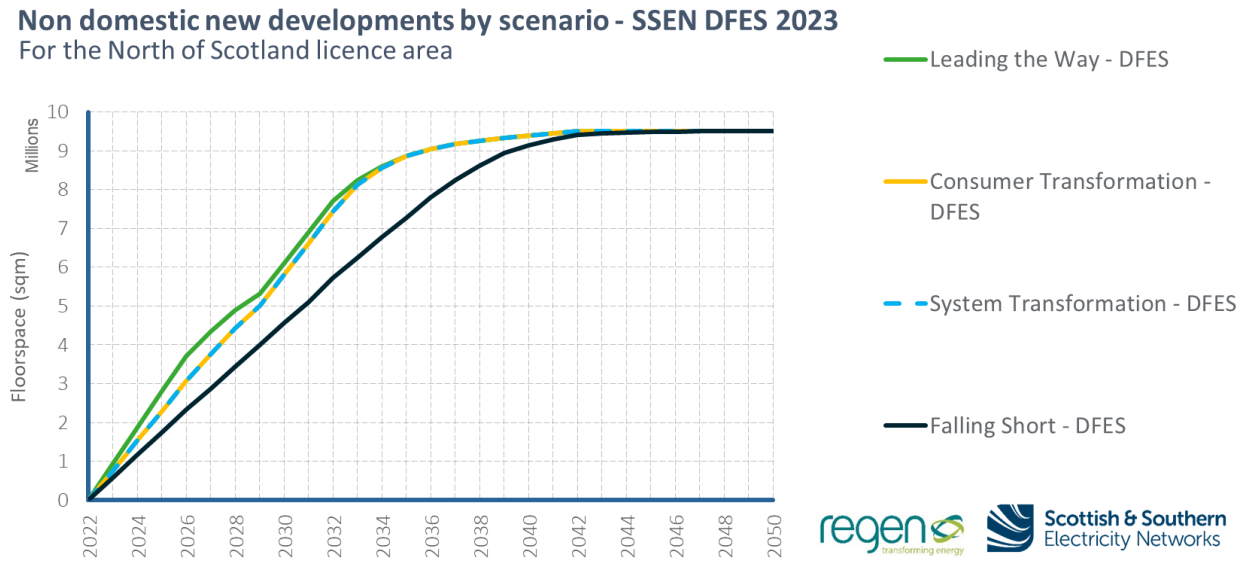


Figure 56 Cumulative non-domestic development projections for the North of Scotland licence area

Summary

- The development of new housing and non-domestic sites represents future hotspots of conventional electricity demand, as these new developments are constructed and occupied over the scenario timeframe.
- The modelling of new developments is based on direct engagement with local authorities planning departments and analysis of local planning documents submitted to Regen via a SharePoint data exchange.
- These documents detail the planning stages of each new development, i.e., 'under construction', 'full planning permission', or allocated packets of land for future use.
- The local planning documents provided data for new developments out to 2042, so new longer-term housing developments out to 2050 were modelled based on an analysis of ONS household projections.[cxxvii]
- This modelling results in between 80,000 and 88,000 new homes in the North Scotland licence area, representing an 8%-9% increase in domestic customers by 2050.
- An additional 9.5 million square meters of non-domestic floor space is also modelled to be in the North of Scotland licence area by 2050 under each DFES scenario.

Modelling stages

Baseline (2022)	
The analysis of new developments in the DFES is on additional future domestic and non-domestic buildings. Therefore, no baseline is defined for this technology.	
Methodology for planned developments analysis (October 2023 to September 2050)	
Data exchange with all local authorities in the licence area	A SharePoint database hosts individual registers for all local authorities within the North of Scotland licence area. Regen engages with the local authority planning departments to ensure these registers of new property developments are updated and refreshed for the DFES analysis, where possible. 79% of local authorities within the North of Scotland licence area have provided updated datasheets from the last three years.
Database update	The data provided by the local authorities is checked, supplemented where necessary from other online data sources and added to the DFES database. Where updates were not provided, data is obtained from publicly available planning documents, such as 5-year housing land supplies and local plans.
Database cleaning	The new developments dataset is then cleaned by removing the following: • Site developments that have already been completed • Domestic developments with less than 20 homes (total or left to build) • 'Windfall' sites with no location data or not currently under construction - these are used for modelling by the council and not actual developments • Non-domestic developments of less than 1,000 sqm
ESA assignment	All sites are assigned an Electricity Supply Area (ESA) and spatially mapped to SSEN network infrastructure in the licence area based on locational data. Where locational data is not provided, address information or manual searches are used to assign sites.
Scenario projections	The buildout profile of the new developments is adjusted to produce three scenarios, **High** (**Leading the Way**), **Central** (**System Transformation** and **Consumer Transformation**) and **Low** (**Falling Short**).

Domestic housing pipeline			
Number of development sites identified		**Total number of homes**	
290		49,288	
The local authorities with the highest number of planned homes are detailed below:			
Local authority	**Number of homes**	**Number of Sites**	**Largest development site**
Aberdeen City	18,684	54	Grandhome (4,700

			houses)
Perth and Kinross	12,082	71	Bertha Park 1 (1,790 houses)
Highland	8,771	69	Dalcross (1,278 houses)

Aberdeen City has 54 housing development sites planned, averaging 346 homes per site. In addition to the Grandhome site, four other large sites of 1,000 homes or greater are planned in the area:

- A 3,000-home site under construction.
- One site is under construction with 1,700 homes, and another has full planning permission for 1,600 homes.

The 71 planned housing development sites in **Perth and Kinross** average 170 homes per site. Aside from the Bertha Park development currently under construction, adding ~100 homes per year, Perth and Kinross have two other housing sites greater than 1,000 homes:

- A 1,100 site has been allocated, set to begin construction in 2026.
- A 1,200-housing site that has outline planning permission.

In addition to the Dalcross new settlement, of the 69 housing sites planned in the **Highland Council** area**,** there is only one site larger than 1,000 homes. The local authority has developments with an average of 127 homes per site. However, no buildout data has been provided.
There are 10 housing sites across the North Scotland licence area with housing developments over 1,000 homes but all within the three named local authorities above.

Non-domestic development pipeline

Regen category	Sites		Non-domestic floorspace (sqm)	
	Number	Proportion	Total per category*	Proportion of total
Factory and warehouse	332	50.8%	5,650,236	58.4%
Office	294	45.0%	3,635,316	37.6%
School and College	4	0.6%	68,489	0.7%
Retail	4	0.4%	15,442	0.2%
Other (e.g., medical, hotel, restaurant, sport & leisure)	44	6.8%	311,737	3.2%

The majority of planned non-domestic developments in the North of Scotland licence area consist of 'employment land'. These are sites designated as factory and warehouse or office space, accounting for 95.9% of the planned non-domestic build. **Aberdeenshire** is the local authority with the most planned non-domestic developments in the licence area, with 211 sites totalling 1,404,373 sqm.

Unclassified "other" developments total c. 229,904 sqm. This is an adjusted number to recognise that

some development's floorspaces are given in total site area not building floorspace and as such can lead to an inaccurate representation of future electricity demand. For example, c. 1,091 sqm is designated to 'Scolpaig' spaceport on North Uist in the Outer Hebrides. This is intended to be a spaceport with a site size of 278 ha but was allocated a smaller floorspace in the modelling to reflect a more accurate picture of the future electricity demand of this site.

**non-domestic floorspace numbers are adjusted to reflect a more accurate representation of site sizes based on similar building categories.*

Planning logic and assumptions

Buildout-Timeline: The buildout start year is assigned based on the status and development stage provided by the local authorities. A construction year is assigned to each site within an assumed year range, depending on the development stage. Below shows the year range for each development stage.

Development stage	Under construction	Full planning permission	Outline planning permission	Land allocated	No information
Year Range	2023	2024-2026	2027-2029	2030-2032	2023-2032

Buildout rate: The rate at which a site is constructed is modelled, using data from the pipeline site registers provided. For both domestic and non-domestic sites, the average annual buildout rate was calculated for each site. For domestic sites, the average annual buildout rate by the local authority was used to model the data where buildout timelines were not provided. For non-domestic sites, the average annual buildout rate was determined through analysis by Regen, categorised by development type, i.e. Factory and Warehouse, Office etc. and applied.

Non-domestic floorspace buildout: Each non-domestic site was assigned a Regen category based on the development name and categories provided by the local authorities. Using current and historical DFES data for sites with both a site area and floorspace, a ratio was calculated for each development category. This ratio was then used to assign a floorspace to any site where this was not directly provided, by dividing the given site size (converted to sqm) by the individual category's ratio.

Delay factors: The timeline and build out rate of new developments is a key source of uncertainty. Regen applies scenario-specific delay factors to allow for varying degrees of delay in the completion of local authority plans. Average 'as-planned' buildout rates over varying periods are used to help define the three trajectories.

For domestic and non-domestic developments:

- **Low Trajectory**, with near term alignment to the 15-year average buildout rate of planned developments.
- **Central Trajectory**, with near term alignment to the 10-year average buildout rate of planned developments.
- **High Trajectory**, with near term alignment to the 8-year average buildout rate of planned developments.

By creating three trajectories, very ambitious development can be captured in the **Leading the Way** scenario, and heavy unforeseen delays are captured under **Falling Short**.

<table>
<tr><th colspan="2">Long term modelled developments (October 2023 to September 2050)</th></tr>
<tr><th colspan="2">Domestic housing</th></tr>
<tr><td colspan="2">Two forms of new housing are not captured through reviewing current planned developments. As such, these are modelled to ensure the scenarios capture a range of housebuilding trends between 2023 and 2050.</td></tr>
<tr><td>Residual developments</td><td>These are small-scale developments of less than 100 homes, which is under the threshold of the data that is collected from local authorities. Analysis of previous new developments data suggests that these developments could account for approximately 5% of total new-build housing. As a result, a 5% uplift was applied to the planned projections throughout the scenario timeframe to account for these residual developments.</td></tr>
<tr><td>Post-planned developments</td><td>This accounts for housing developments that could occur in the medium and long term, beyond the current timescales of local authority planning. As planned developments tail off in the 2020s and 2030s, post-plan developments are modelled to account for additional future housebuilding out to 2050. These post-plan development projections are tailored to each local authority and are based on ONS household projections.</td></tr>
<tr><th colspan="2">Non-domestic</th></tr>
<tr><td colspan="2">The non-domestic scenario projections are based on planned developments only.</td></tr>
<tr><th colspan="2">Reconciliation to DFES 2022</th></tr>
<tr><td colspan="2">Historic domestic house building data[cxxviii] has previously been used to inform the three domestic trajectories (High, Central, Low). However, the historic averages for the North of Scotland licence area were significantly higher than this year's planned housing levels. This is an indicator that either a full picture of housing development across the licence area isn't being collected though engagement with local authorities, or that significantly fewer houses are currently being planned. As such the historic averages were not used for the 2023 projections, instead, the same methodology for non-domestic developments was used. This involves determining the 8-year, 10-year, and 15-year averages of planned domestic developments within the 2023 local authority provided evidence.

The number of planned non-domestic sites across the North of Scotland stayed largely the same, decreasing by only five sites. 'Factory and warehouse buildings' remained the largest category, though a higher number of sites in 'Other' category were recorded this year. This reflects a range of new project types for 2023, such as infrastructure with airfields and ports. These are more comparable sites, allowing for more accurate adjustments in the modelling. Aberdeenshire remains the local authority with the largest planned floorspace of non-domestic developments. Adjustments to projects in the 'other' category and a drop in retail, and schools and colleges results in a reduction of floorspace from 10.3</td></tr>
</table>

million in 2022 to 9 million in 2023.

There has been a reduction in domestic housing projections, a result of a reduced number of sites within the data provided by local authorities. This results in lower projections across all four scenarios compared to DFES 2022. In addition, the number of domestic development sites in the Highlands dropped significantly, almost halving from 120 sites and 14,861 homes in DFES 2022, to 69 sites and 8,771 homes in DFES 2023. This is due to a correction in the DFES 2023 data for the Highland local authority. The number of development sites (and thus overall houses) in Aberdeen City increased from 27 to 54 and those in Perth and Kinross remained relatively stable.

Reconciliation with National Grid FES 2023

- The FES scenarios do not include a section on new property developments that can be directly reconciled against. The FES building block **DEM_BB001a** for new domestic customers shows a similar proportional growth of new housing compared to the DFES analysis of domestic developments. In the DFES, a range of scenario outcomes have been modelled for 2023, to aid distribution network planning, as new domestic customers can represent key bulk loads of conventional demand on the network.
- Non-domestic floorspace is not detailed in the FES data and cannot be directly compared.

Geographical factors affecting deployment at a local level

Geographical factors	Description
Known planned sites	Through local authority engagement, planned sites are located based on their address or the description of their location and directly assigned to the ESA that they fall within.
Housing density	The DFES analysis also incorporates long term theoretical development (based on historic build trends in the area) once the current pipeline of new developments is complete. This is to ensure that housing development doesn't come to a halt once the current pipeline is complete but instead assumes development will continue out to 2050. Domestic developments that do not yet have locational data (including this long term theoretical development) are distributed across all areas, weighted to areas with moderate housing density, such as town and city suburbs. Analysis of historic housing development shows these areas see higher levels of housebuilding than denser city centres or highly rural areas.

Incorporation of stakeholder feedback

Stakeholder feedback	How this has influenced our analysis
Local authority data exchange	A central part of the new developments analysis relies on ongoing engagement with local authorities in the licence area. Four of the 14 local authorities in the licence area provided updated or new data through a SharePoint site or directly to the project team for 2023. For the remaining local authorities, Regen's existing project database was used.

[cxxvii] National Records of Scotland, 2018, *Household Projections by Local Authority*. https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/households/household-projections/2018-based-household-projections

[cxxviii] Office of National Statistics, 2023, *House building, UK: permanent dwellings started and completed by local authority* https://www.ons.gov.uk/peoplepopulationandcommunity/housing/datasets/housebuildingukpermanentdwellingsstartedandcompletedbylocalauthority