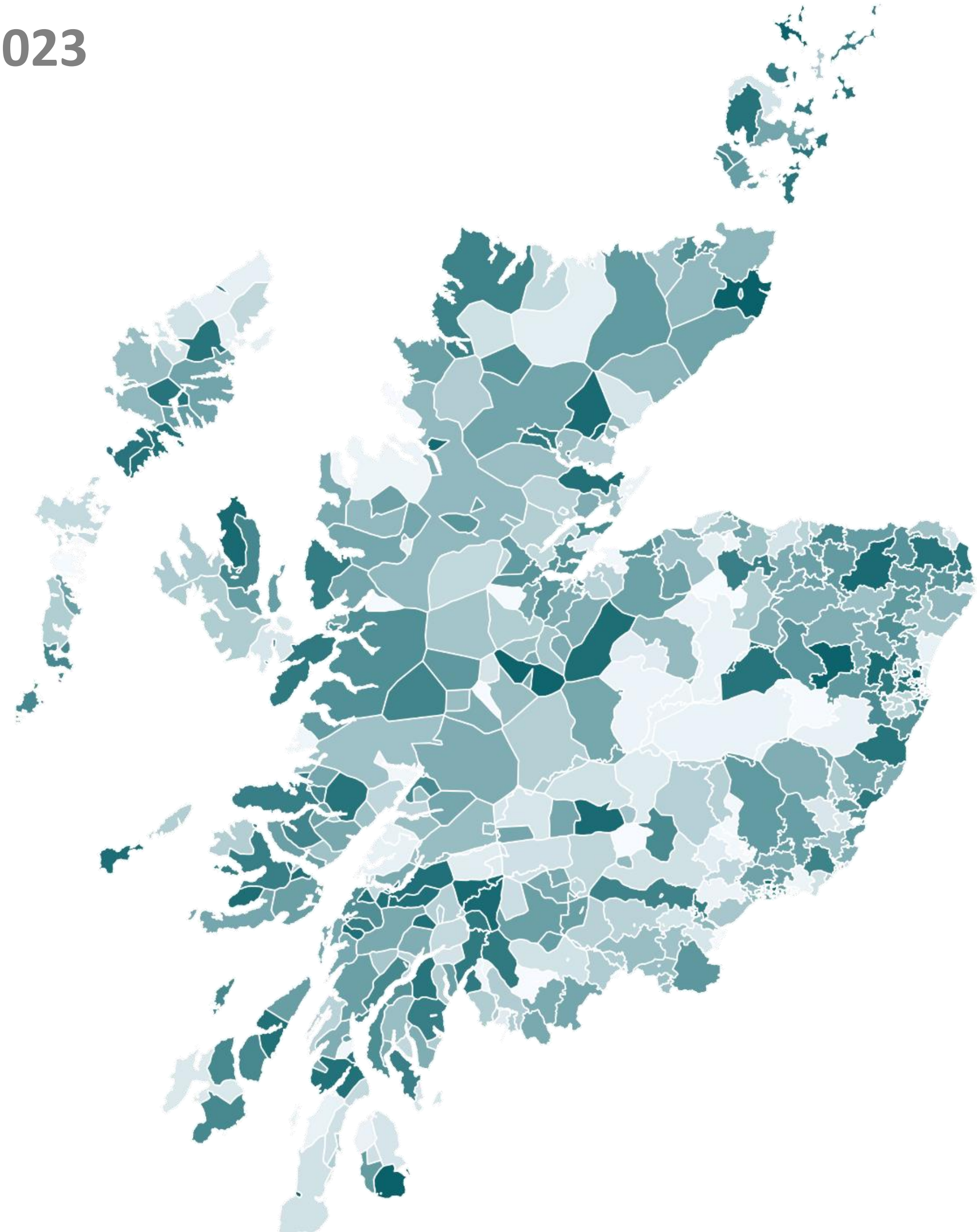
Distribution Future Energy Scenarios 2022

Results and methodology report

North of Scotland licence area

April 2023



regen transforming energy

Scottish & Southern Electricity Networks

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Foreword

Scottish and Southern Electricity Networks (SSEN) Distribution is the electricity distribution arm of the FTSE-50 energy company, SSE. We serve over 3.8 million customers across the diverse and unique geographies of the north of Scotland and central southern England. Our role has never been more important. The communities we serve depend on us to deliver a safe, reliable supply of electricity to their homes and businesses so they can thrive today and we are also working to deliver the infrastructure to create a net zero tomorrow. That means readying our network for the uptake in low carbon technologies such as electric vehicles, heat pumps and local renewables, which will need smart connections to be able to interact with the grid.

We welcome the UK and Scottish Governments' commitments to this transition, including their targets to decarbonise by 2050 and 2045 respectively, which provide clarity to both the market and consumers and allow SSEN to plan for the anticipated three-fold increase in electricity demand that new technologies will bring. SSEN is working to anticipate the location and timing of new demand to ensure the measures are in place to flex supply and demand to balance the grid, or to reinforce the network. The work that Regen has undertaken here and for previous reports is crucial in supporting informed decision making, which enables timely and cost-effective network management.

Our Business Plan for the current regulatory price control period, which started in April 2023, draws on these DFES figures to establish the building blocks that must be put in place to facilitate net zero by 2050. We will 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 8GW of distributed generation and storage. This will be supported by development of new market models to allow consumers to interact with the energy system and manage their own usage and costs. We are also working to empower local communities and propose mechanisms to enable strategic investment in our network.

Lastly, SSEN is committed to a fair transition that leaves nobody behind. The net zero future offers considerable opportunities but also the risk that new forms of unfairness will be embedded into the system. With the right data, forecasting, regulations, skills and investment, we can ensure a transition that is smart and fair. I'd like to thank Regen for their work on this essential and timely report and to thank all our stakeholders, including local and regional authorities, for their ongoing engagement and contributions to our research. We look forward to continuing to work closely with them to deliver net zero.

Andrew Roper

Distribution Systems Operations Director, Scottish and Southern Electricity Networks

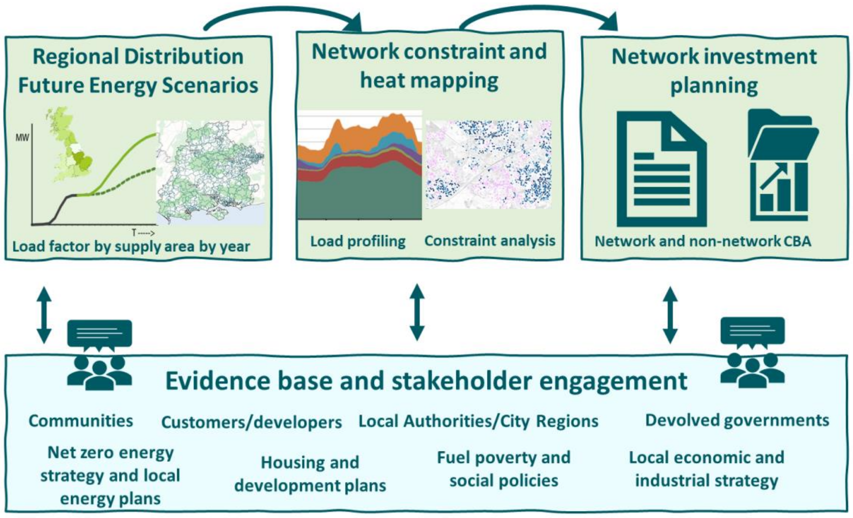
Introduction

This report summarises the methodology and results of the 2022 edition of the Distribution Future Energy Scenarios (DFES) for the North of Scotland electricity distribution network licence area[1], operated by Scottish and Southern Electricity Networks (SSEN).

The DFES analysis provides high-granularity scenarios for the energy generation (low carbon and conventional), demand and storage technologies connecting to the distribution network. In addition, this analysis helps SSEN understand how the demands on their networks will likely change over the next decade and beyond.

The DFES forms part of an integrated network planning and investment appraisal process (see Figure 1). The projections allow SSEN's network planning teams to model and analyse future load scenarios in specific geographic areas. Producing future energy scenarios is now a business-as-usual activity for electricity networks as part of their requirement to produce Network Development Plans. The 2021 DFES process supported the development and evidence base underpinning SSEN's RIIO-ED2 business plan[2].

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



DFES uses four national energy scenarios based on the National Grid ESO Future Energy Scenarios 2022 publication[3]. The DFES provides a granular, bottom-up assessment of the impact of the net zero energy transition and is heavily influenced by local and regional stakeholders. A detailed analysis of the pipeline of projects within SSEN's North of Scotland licence area underpins the scenario projections, building on the DFES 2021 publication[4].

This report provides an overview of Regen's DFES methodology, a summary of the stakeholder engagement and scenario projections for the North of Scotland licence area. The report also includes individual technology summaries detailing the results, evidence drawn on and assumptions used.

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

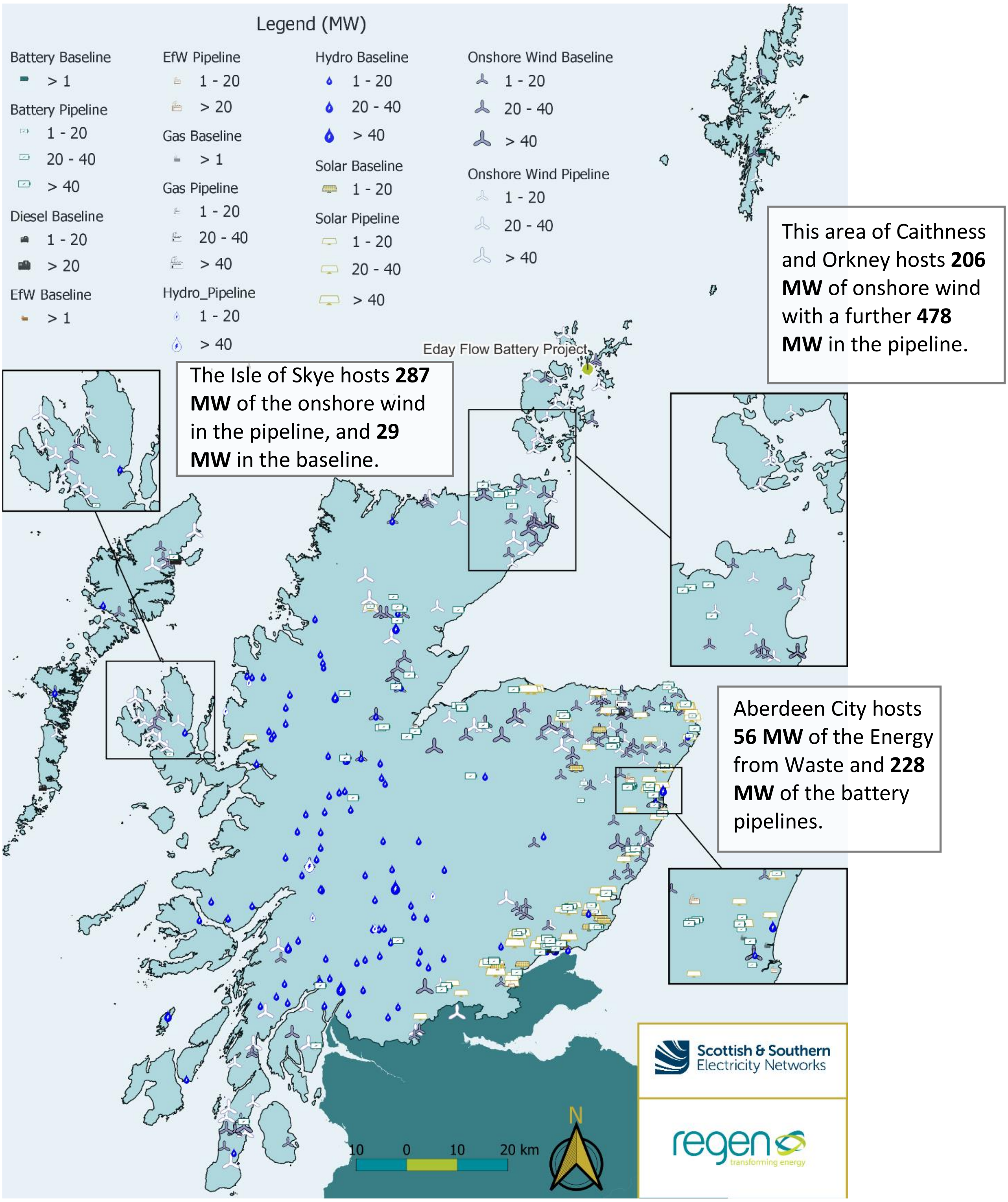
[2] See SSEN *Powering Communities to Net Zero* ED2 business plan website and document: https://ssenfuture.co.uk/

[3] National Grid 2022, *Future Energy Scenarios 2022.* https://www.nationalgrideso.com/future-energy/future-energy-scenarios

[4] Regen 2021, *SSEN Distribution Future Energy Scenarios 2021.* https://www.regen.co.uk/project/ssen-distribution-future-energy-scenarios-2021/

The SSEN North of Scotland Licence Area

The North of Scotland electricity distribution licence area covers the area served by the low voltage, 11 kV and 33 kV network supplying 780,000 customers across northern Scotland and the Scottish Islands. This area spans the southern borders of Perth and Kinross, Dunblane and Loch Lomond, to the northern coastline of Scotland 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 includes 14 local authority regions (either wholly or partially). These are: Aberdeen City, Aberdeenshire, Angus, Argyll and Bute, Dundee City, Highland, Moray, Na h-Eileanan Siar, North Ayrshire, the Orkney Islands, Perth and Kinross, the Shetland Islands, Stirling and West Dunbartonshire.

The total capacity of distribution network connected generation in the licence area has steadily increased over the past ten years to over 3.5 GW as of the end of 2021. Driven by strong Scottish Government policy ambition[5], the licence area is beginning to reflect some of the low-carbon technology adoption required to deliver the Scottish national net zero emissions target by 2045.

Baseline by Technology

Renewable Generation

onshore wind	2.1 GW	hydropower	835 MW	solar	157 MW	offshore wind	80 MW	marine	26 MW

With the licence area having some of the best wind speeds in the UK, just over **2.1 GW** is onshore wind. Hydropower is the next most prominent technology, with **835 MW** – a slight decrease since DFED 2021. Solar is gaining momentum from 132 MW in DFES 2021 to **157 MW** (large and small-scale). The largest individual generation site connected to the distribution network in the licence area is the 77 MW Clashindarroch onshore wind farm[6].

Waste and Bioenergy Generation

biomass	56 MW	renewable engines	35 MW	energy from waste	19 MW

Waste energy makes up c. **19 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 (**11 MW**) and sewage gas (**3 MW**).

Fossil and Gas Generation

diesel	131 MW	gas	45 MW	hydrogen generation	0 MW

The licence area also hosts a notable amount of fossil fuel generation, with **176 MW** of natural gas, gas oil and diesel generation. All diesel capacity is made up of island backup generators.

Sources of Demand / Battery Storage

Sources of Demand						Battery Storage	
EVs	6,700	heat pumps	21,000	H_2 electrolysis	2 MW	battery	8 MW

Electricity demand in the licence area is fairly typical, with an average proportion of homes heated via the gas network[7] and a mixture of urban and rural areas. The uptake of low-carbon technology is starting to speed up in the licence area, with **c. 6,700** battery electric cars currently registered in 2021. In addition, **21,000** households and businesses have a heat pump installed.

[5] Scottish Government 2020, *Securing a green recovery on a path to net zero: climate change plan 2018-2032 update.* https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/
[6] Vattenfall n.d., *Clashindarroch.* https://group.vattenfall.com/uk/what-we-do/our-projects/clashindarroch
[7] See Non Gas Map: https://www.nongasmap.org.uk/

Projection headlines

The distribution network in the North of Scotland in 2030

Renewable Generation

	wind	solar	hydropower	marine
Leading the Way	4.3 GW	1.6 GW	937 MW	34 MW
Consumer Transformation	5.4 GW	1.2 GW	957 MW	49 MW

Distribution network connected **solar**, **wind**, **hydro** and **marine** generation capacity nearly triples from c. 2.4 GW in 2021 to c. **7.6 GW** in 2030 under **Consumer Transformation**. Wind deployment accounts for almost all of the increase in connected capacity, **5.4 GW**, including 80 MW of offshore wind.

Waste and Bioenergy Generation

	waste	biomass	renewable engines
Leading the Way	75 MW	43 MW	35 MW
Consumer Transformation	83 MW	145 MW	21 MW

Waste and bioenergy generation capacity in the North of Scotland increases from 110 MW in 2021 to **248 MW** in 2030 under the **Consumer Transformation**. Growth is driven by advanced conversion technology, incineration, biomass and some small anaerobic digestion sites.

Fossil and Gas Generation

	diesel	gas	hydrogen generation
Leading the Way	0 MW	9 MW	199 MW
Consumer Transformation	83 MW	79 MW	22 MW

131 MW of unabated baseline **diesel generation** decommissions in all scenarios, and more quickly under **Leading the Way**, with **0 MW** by 2030. **Fossil gas generation** increases from c. 45 MW in 2021 to **79 MW** in 2030 under **Consumer Transformation**, driven by the connection of new gas reciprocating engines and CHPs. Under **Leading the Way**, low carbon **hydrogen-fuelled generation** takes off on the distribution network in the licence area, with **199 MW** modelled to come online by 2030.

Sources of Demand

	EVs	heat pumps	H_2 electrolysis
Leading the Way	276,000	281,000	425 MW
Consumer Transformation	279,000	243,000	179 MW

The number of **electric vehicles** registered in the North of Scotland licence area also increases significantly in all scenarios by 2030. Under **Consumer Transformation**, c. **222,000 homes** and c. **21,000 non-domestic properties** operate **heat pumps** by 2030.

Under the **Leading the Way** scenario, the capacity of distributed **hydrogen electrolysis** in the licence area reaches **425 MW**.

Battery Storage

	battery
Leading the Way	2.1 GW
Consumer Transformation	1.9 GW

From an 8 MW 2021 baseline, **battery storage** capacity (of varying asset classes/business models) significantly increases in all scenarios by 2030, reaching c. **2.2 GW** under **Leading the Way**.

New Property Developments

	domestic	non-domestic
Leading the Way	48,000	7.8 mil
Consumer Transformation	43,000	7.4 mil

Up to **43,000 new houses** could be built, and just under c. **7,400,000 sqm** of **non-domestic floorspace** could be developed by 2030 in **Consumer Transformation**.

The distribution network in the North of Scotland in 2050

Renewable Generation

	wind		solar		hydropower		marine	
Leading the Way		6.7 GW		3.4 GW		1 GW		108 MW
Consumer Transformation		7.4 GW		2.8 GW		1.1 GW		251 MW

Under the **Consumer Transformation** scenario, solar, wind, hydro and marine generation capacity in the licence area increase to **c. 11.6 GW** in 2050. Wind technologies (including 80 MW of offshore wind) continue to take the lead in the licence area, with over **7.4 GW** online by 2050. Solar capacity also sees much support under this scenario, with **2.8 GW** online by 2050.

Waste and Bioenergy Generation

	biomass		waste		renewable engines	
Leading the Way		0 MW		35 MW		41 MW
Consumer Transformation		104 MW		35 MW		24 MW

Waste and bioenergy generation sees landfill gas and waste incineration all decommissioning from the network under **Consumer Transformation**. In contrast, generation capacity from the anaerobic digestion, biomass and ACT increases to **163 MW** by 2050 under this scenario. Most of this is biomass replacing old diesel backup generators on the islands.

Fossil and Gas Generation

	diesel		gas		hydrogen generation	
Leading the Way		0 MW		0 MW		251 MW
Consumer Transformation		0 MW		0 MW		63 MW

No unabated **diesel** nor **fossil gas generation** is operating on the system by 2050 under any net zero scenario, with generators being replaced with various alternative technologies, including biomass, biomethane, electricity storage and hydrogen-fuelled generation. Under **Falling Short**, **142 MW** of fossil gas remains online, and **0 MW** of diesel remains connected. Low carbon **hydrogen-fuelled generation** capacity increases significantly by 2050 in the licence area, reaching c. **251 MW** under **Consumer Transformation**. Hydrogen is limited to **63 MW** under **Consumer Transformation**.

Sources of Demand

	EVs		heat pumps		H_2 electrolysis	
Leading the Way		701,000		499,000		820 MW
Consumer Transformation		805,000		558,000		395 MW

The number of registered **EVs** in the licence area accelerates by 2050. However, a general reduction in vehicle numbers is seen by 2050 in the net zero scenarios, driven by increased public transport use, average mileage, and the introduction of autonomous vehicles. The number of homes and businesses with a **heat pump** installed significantly accelerates to 2050 under all scenarios. This is highest under **Consumer Transformation**, with c. **527,000 homes** and c. **31,000 non-domestic properties** operating a type of **heat pump** by 2050. Deployment of **hydrogen electrolysis** by 2050 is highest in **Leading the Way**, with c. **820 MW** operating on the distribution network.

Battery Storage

	Battery	
Leading the Way		3.1 GW
Consumer Transformation		2.7 GW

Domestic, commercial and grid-scale **battery storage** assets total c. **3.1 GW** under **Leading the Way**.

New Property Developments

Domestic		Non-domestic	
	88,000		10.3 mil
	79,000		10.3 mil

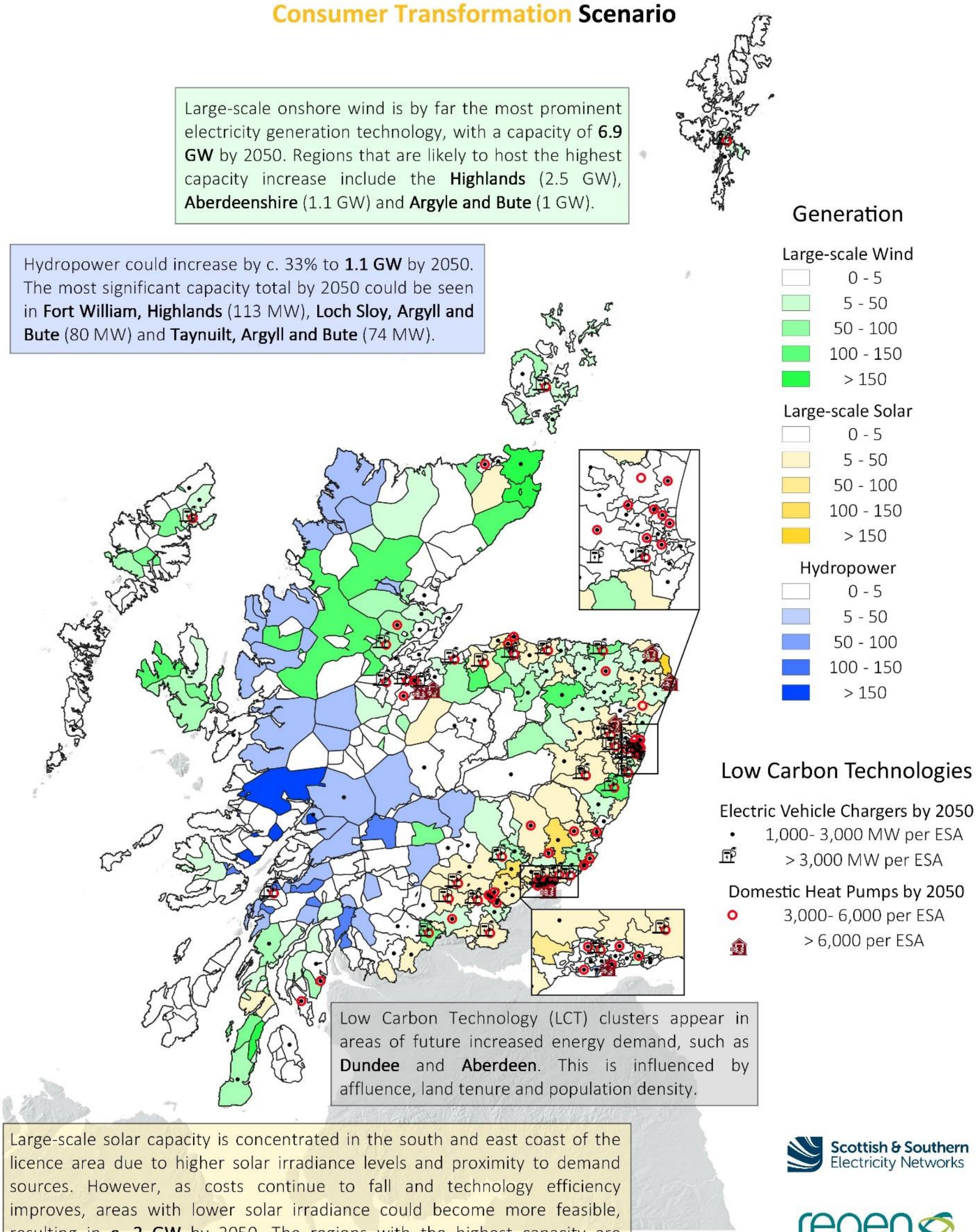
Up to **79,000 new houses** could be built, and just under c. **10,300,000 sqm** of **non-domestic floorspace** could be developed in **Consumer Transformation**.

2050 Technology Projection Headlines - North of Scotland

Consumer Transformation Scenario

Large-scale onshore wind is by far the most prominent electricity generation technology, with a capacity of **6.9 GW** by 2050. Regions that are likely to host the highest capacity increase include the **Highlands** (2.5 GW), **Aberdeenshire** (1.1 GW) and **Argyle and Bute** (1 GW).

Hydropower could increase by c. 33% to **1.1 GW** by 2050. The most significant capacity total by 2050 could be seen in **Fort William, Highlands** (113 MW), **Loch Sloy, Argyll and Bute** (80 MW) and **Taynuilt, Argyll and Bute** (74 MW).



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

Large-scale solar capacity is concentrated in the south and east coast of the licence area due to higher solar irradiance levels and proximity to demand sources. However, as costs continue to fall and technology efficiency improves, areas with lower solar irradiance could become more feasible, resulting in **c. 2 GW** by 2050. The regions with the highest capacity are **Aberdeenshire** (484 MW), **Angus** (480 MW) and **Perth and Kinross** (347 MW).

Note: The above map displays Electricity Supply Areas (ESA) where each technology could be present by 2050 under the Consumer Transformation Scenario. Where an ESA hosts a great deal of several generation technologies, only one, usually the most prominent, is displayed.

Wider context for SSEN DFES 2022

The invasion of Russia in Ukraine has had far-reaching impacts on the energy market, including driving up electricity prices in the UK. Energy and Climate Intelligence Unit analysis estimates that the UK spent an additional £50-60bn on energy.[8] Government policy responses have included the Energy Price Guarantee to cap household energy bills.

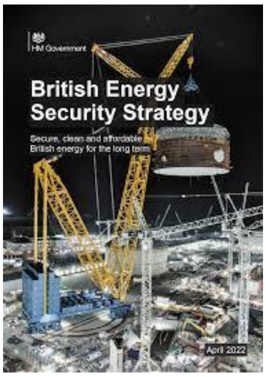
The cost of living crisis has pressured consumers to reduce demand and magnified pre-existing fuel poverty issues. Energy costs have also led more consumers to take up low-carbon technologies and more energy-efficient appliances to reduce energy bills, including increased EV sales year-on-year[9]. This, in turn, has impacted the distribution networks, as they must adapt to shifting consumer needs.

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

The political focus on energy in the past year has led to an extensive range of new energy policies and targets issued by the UK and Scottish governments.

Relevant UK Energy Policy and Consultations in 2022

The Government announced new energy policies in 2022 that were considered in the DFES 2022 analysis as having a potential impact on the uptake of technologies in scope.



The **British Energy Security Strategy**[10], released in April 2022, included several new commitments. Up to 50 GW of offshore wind is aimed for by 2030, of which 5 GW is to be floating wind. The strategy also increased the UK's ambition for low-carbon hydrogen production from 5 to 10 GW by 2030.

Building on the British Energy Security Strategy, the UK Government and Ofgem published the **Electricity Network Strategic Framework**[11] to ensure that the electricity cables serving the country are upgraded to meet the needs of a growing, decentralised electricity system. The strategic framework outlines plans to develop the Future System Operator, remove barriers to grid flexibility via digitalisation, and unlock infrastructure development through reformed planning and consenting.

In December 2021, the UK released its response to a consultation on Part L and Part F of the **Future Buildings Standard** for non-domestic buildings and on standards for overheating in new residential buildings. As a result, key parts of the Future Buildings Standard were adapted into DFES scenario modelling for 2022. For instance, the approach states that all new builds will incorporate passive cooling, which has had implications for DFES 2022 assumptions used to model air conditioning uptake in new builds.

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[8] Energy & Climate Intelligence Unit 2023, *The Cost of Gas since the Russian Invasion of Ukraine.* https://eciu.net/analysis/reports/2023/the-cost-of-gas-since-the-russian-invasion-of-ukraine

[9] Zap Map 2023, *EV Market Statistics.* https://www.zap-map.com/ev-market-statistics/

[10] Department for Business, Energy & Industrial Strategy 2022, *British Energy Security Strategy.* https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

[11] Department for Business, Energy & Industrial Strategy & Ofgem 2022, *Electricity Networks Strategic Framework: Enabling a secure, net zero energy system.* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1096283/electricity-networks-strategic-framework.pdf

The UK Government has been consulting on changes to the National Planning Policy Framework under the **Levelling-up and Regeneration Bill**[12]. DFES 2022 scenarios cover the possibility that getting planning permission for onshore wind and a world where those barriers loosen remains difficult.

In 2022, the Government published draft legislation on an **Electricity Generator Levy**[13], which seeks to employ a windfall tax on excessive revenues for renewable, nuclear and biomass generators. Regen has published an insight paper suggesting that the wholesale price threshold is set too low at £75 per MW and lasts too far out into the future until 2028, becoming a disincentive to energy generation investment in the UK and in the medium-term[14]. However, it is too soon to see how the Levy will influence investment in new generation projects.

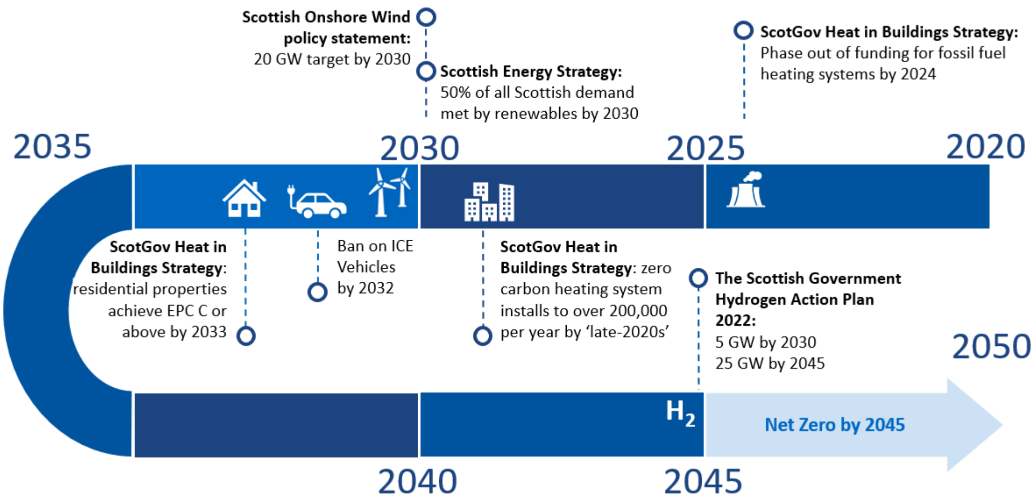
Scottish Government strategy

The Scottish Government's draft **Energy Strategy and Just Transition Plan**[15], published in 2023, provides an overview of Scottish energy policy and brings together key targets. Scotland has an overall target to achieve net zero by 2045.

Sector-specific targets include those set in the **Scottish Government Hydrogen Action Plan**[16] and the **Onshore Wind Policy Statement**[17] which sets a target of 20 GW by 2023. The draft Energy Strategy also includes consultations on the future solar policy. Some organisations, such as Solar Energy Scotland, propose a target of 4-5 GW of solar by the end of the decade[18].

The DFES aims to reflect this higher ambition towards net zero in Scotland at national and local authority levels. Following consultations with the Scottish Government, it was agreed that **Consumer Transformation** would be the scenario used to reflect Scottish policy ambition and technology-specific targets. Regional actions taken under the Local Heat and Energy Efficiency Strategies (LHEES) have been reflected in a higher uptake of low-carbon heating technologies.

Figure 2: Scottish Government's high-level energy and decarbonisation policy targets



[12] Department for Levelling Up, Housing & Communities 2022, *Levelling-up and Regeneration Bill: reforms to national planning policy*. https://www.gov.uk/government/consultations/levelling-up-and-regeneration-bill-reforms-to-national-planning-policy/levelling-up-and-regeneration-bill-reforms-to-national-planning-policy#chapter-8--onshore-wind-and-energy-efficiency

[13] UK Government 2022, *Electricity Generator Levy (draft)*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1125790/Draft-Electricity-Generator-Levy.pdf

[14] Regen 2023, *Electricity generator levy – less like a windfall tax, more like a super-tax*. https://regensw.wpenginepowered.com/wp-content/uploads/Regen-Insight-Electricity-Generator-Levy.pdf

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

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

[17] Scottish Government 2022, *Onshore Wind: policy statement 2022.* https://www.gov.scot/publications/onshore-wind-policy-statement-2022/

[18] Solar Energy UK 2022, *Cross-party MSPs jointly call for solar target.* https://solarenergyuk.org/news/cross-party-msps-jointly-call-for-solar-target/

Changes to network connection rules

In May 2022, Ofgem published its final decision on **Access and Forward-Looking Charges Significant Code Review**[19]. From April 2023, connection charges for network reinforcement will be removed for demand customers and reduced for generation connections. The reduction in upfront connection costs could increase the deployment rate of low-carbon projects. A further decision on future distribution use of system charges (DUoS) is yet to be made as of Q1 2023, with a decision expected in 2023[20].

Figure 3: Illustrative examples of the impact of SCR reforms

User Type	Impact of distribution network connection charging reforms	Impact of distribution network access rights reforms
Small distribution connected solar farm	• Overall connection charge reduced. • Charge for wider distribution network reinforcement (above the voltage level of connection) is removed, with limited exceptions. • Connection charges will remain as they are currently for any required 'extension assets', ie for sole-use.	• Flexible access option available that may enable a quicker and cheaper connection in congested areas of the network. • Curtailment limits and end date provide more certainty about the extent to which the connection may be restricted.
Electric vehicle charging station for fleet delivery vehicles	• Overall connection charge reduced. • Charge for wider distribution network reinforcement is removed altogether, with limited exceptions. • Connection charges will remain as they are currently for any required 'extension assets', ie for sole-use.	• Flexible network access option made available based on an agreed curtailment threshold. • Charging station may be able to agree to some curtailment in exchange for a faster connection. • End date gives certainty of future capacity being made available.
Large distribution connected wind farm	• Overall connection charge reduced. • Charge for wider distribution network reinforcement (above the voltage level of connection) is removed, with limited exceptions. • Connection charges will remain as they are currently for any required 'extension assets', ie for sole-use.	• Flexible access option available that may enable quicker and cheaper connection in congested areas of the network. • Curtailment limits and end date provide more certainty about the extent to which the connection may be restricted.
Domestic household installing a heat pump and electric vehicle charger	• Overall connection charge reduced. • Charge for any wider distribution network reinforcement removed altogether, with limited exceptions. • Connection charges will remain as they are currently for any required 'extension assets', ie for sole-use.	• Flexible access arrangements are complex agreements with varying costs and benefits that must be assessed by individual connecting customers. • We do not think they are suitable for domestic consumers, and they will not be made available for this group.

Source: Ofgem 2022, Access and Forward-Looking Charges Significant Code Review: Decision and Direction.

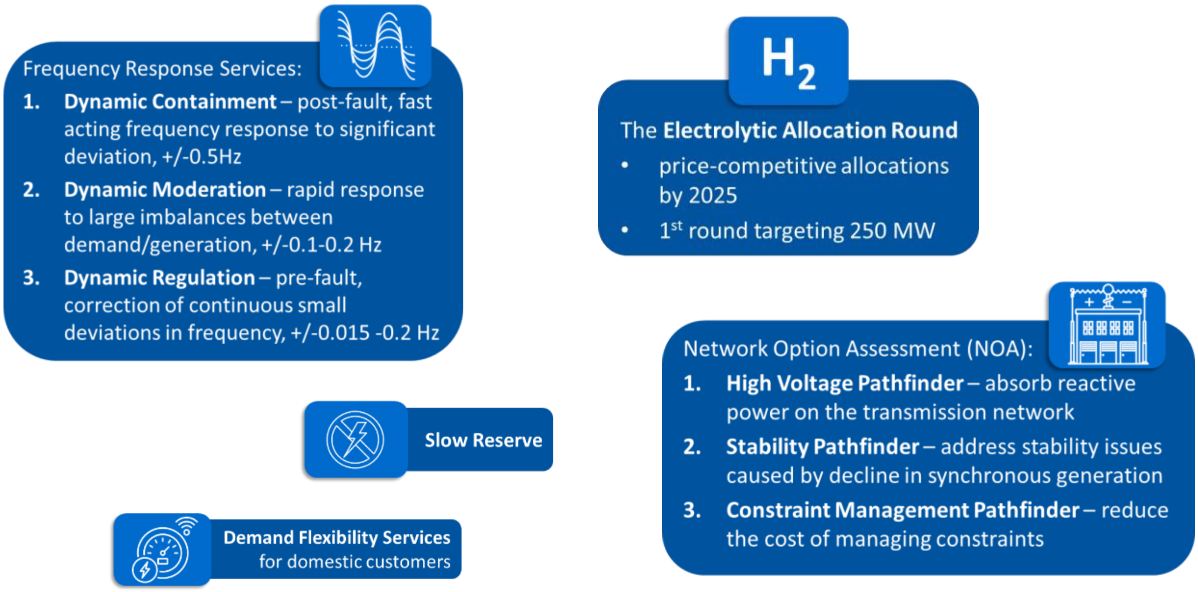
[19] Ofgem 2022, *Access and Forward-Looking Charges Significant Code Review: Decision and Direction.* https://www.ofgem.gov.uk/publications/access-and-forward-looking-charges-significant-code-review-decision-and-direction

[20] Ofgem 2022, *Decision to descope the wide-ranging review of Distribution Use of System (DUoS) charges from the current Electricity Network Access and Forward-Looking Charges Significant Code Review (SCR) and take it forward under a dedicated SCR with a revised timescale.* https://www.ofgem.gov.uk/sites/default/files/2022-02/Decision%20on%20DUoS%20SCR.pdf

Developing markets for flexibility

The support and market mechanisms for flexible generation and demand are developing. This has helped lead to very strong activity in the battery storage development sector. The **Frequency Response Services**[21] offer options for generation and network to react to changes in network frequency. To address stability issues brought about by the increase of renewable and low-carbon assets, the **Network Options Assessment (NOA) Pathfinders**[22] were established. Dedicated subsidy mechanisms have also been announced to fund electrolytic hydrogen and long-duration storage.

Figure 4: Summary of market support mechanisms available to flexible assets



As electricity systems become decentralised, there will also be a demand for local DNO flexibility markets that incentivise flexibility services provided locally. Households and businesses will be a part of these services, often accompanied by aggregators. Services such as these could be instrumental in helping DNOs, and future Electricity System Operators (ESOs) to manage load and flexibility on low-voltage networks[23].

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[21] National Grid ESO n.d., *Frequency Response Services.* https://www.nationalgrideso.com/industry-information/balancing-services/frequency-response-services

[22] National Grid ESO n.d., *Network Option Assessment (NOA) Pathfinders*. https://www.nationalgrideso.com/future-energy/projects/pathfinders

[23] See Regen 2018, *Local flexibility markets.* https://www.regen.co.uk/wp-content/uploads/Regen_Local-flexibility-guide.pdf

DFES methodology

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

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

Technologies in-scope

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

Table 1: DFES Technologies and demand sources

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

The National Grid ESO Future Energy Scenarios 2022 framework

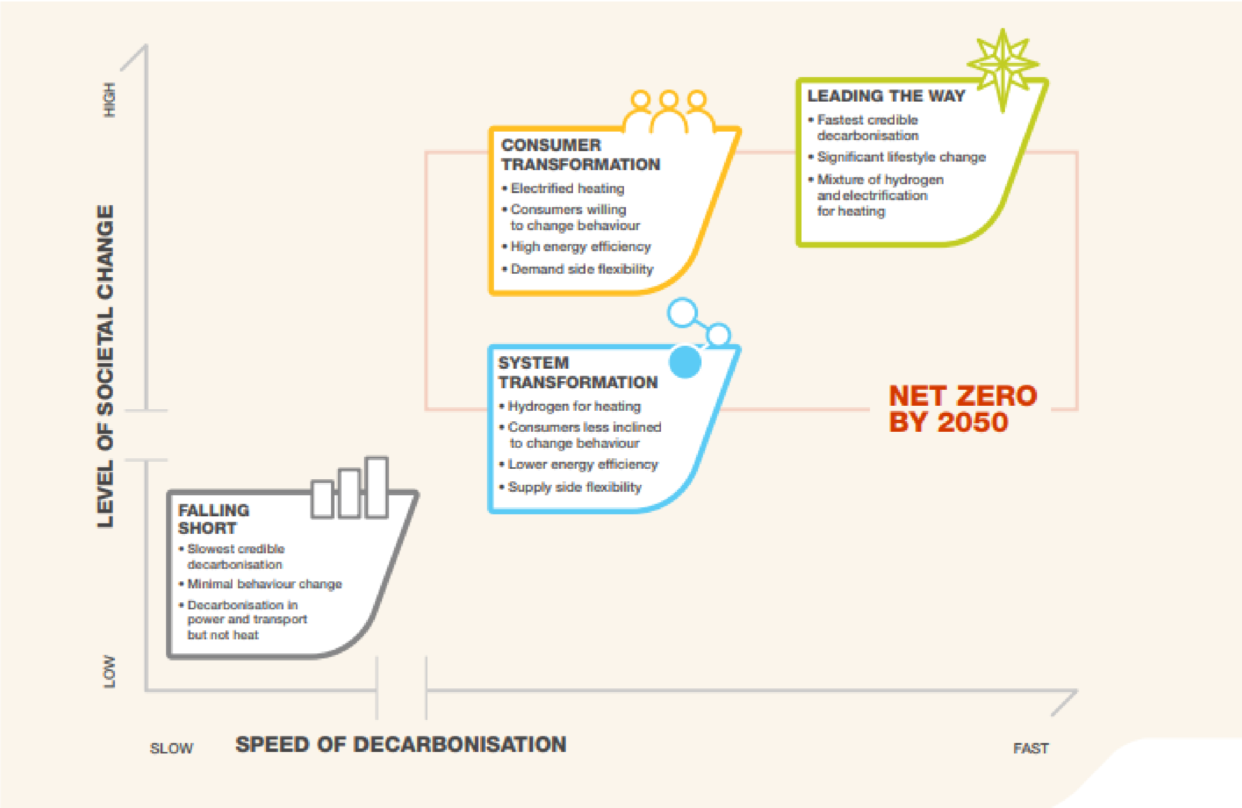
As with previous DFES assessments, the SSEN DFES 2022 has used the National Grid ESO Future Energy Scenarios 2022[24] (FES 2022) as the overarching framework. As well as a scenario framework, the FES 2022 provides:

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

The FES 2022 scenario framework is based on two key axes: decarbonisation speed and societal change level, as summarised in Figure 5. Whilst some scenarios see similar or aligned projections in the near, medium or even long term for some technologies, other aspects of the energy system have very different outcomes. A description of each of the scenarios can be found in Table 2. The technology summary sections within this report also outline specific scenario variances seen under each technology and how the DFES applies them.

Where available, FES 2022 grid supply point (GSP) projection data has been used to provide an SSEN DFES 2022 to FES 2022 reconciliation. Regional building blocks were sometimes unavailable or not directly comparable due to the sub-technology division. In these cases, national FES 2022 projections have been used for reconciliation.

Figure 5: Future Energy Scenarios 2022 framework, National Grid ESO



[24] See National Grid ESO, *Future Energy Scenarios 2022*: https://www.nationalgrideso.com/future-energy/future-energy-scenarios

Table 2: FES 2022 scenario descriptions.

National Grid ESO FES 2022 scenario	High level description *Wording sourced from National Grid ESO FES 2022 publication
Leading the Way *Meets GB net zero targets by 2047*	Assumes that Great Britain decarbonises rapidly with high levels of investment in world-leading decarbonisation technologies. FES 2022 assumptions in different areas of decarbonisation are the earliest credible dates. Consumers are highly engaged in reducing and managing their own energy consumption. This scenario includes more energy efficiency improvements to drive down energy demand, with homes retrofitted with insulation such as triple glazing and external wall insulation, and a steep increase in smart energy services. Hydrogen is used to decarbonise some of the most challenging areas such as some industrial processes, produced mainly from electrolysis powered by renewable electricity, and no hydrogen production from natural gas.
Consumer Transformation *Meets GB net zero targets by 2050*	The 2050 net zero target is met with measures that have a greater impact on consumers and is driven by greater levels of consumer engagement. A typical homeowner will use an electric heat pump with a low temperature heating system and an EV. They will have made extensive changes to improve their home's energy efficiency and most of their electricity demand will be smartly controlled to provide flexibility to the system. The system will have higher peak electricity demands managed with flexible technologies including energy storage, demand-side response and smart energy management
System Transformation *Meets GB net zero targets by 2050*	The typical domestic consumer will experience less disruption than in **Consumer Transformation** as more of the significant changes in the energy system happen on the supply side, away from the consumer. A typical consumer will use a hydrogen boiler with a mostly unchanged heating system and an EV or a fuel cell vehicle. They will have had fewer energy efficiency improvements to their home and will be less likely to provide flexibility to the system. Total hydrogen demand is high, mostly produced from natural gas with carbon capture and storage.
Falling Short *Does not meet GB net zero targets by 2050*	There is still progress on decarbonisation compared to the present day; however it is slower than in the other scenarios. While home insulation improves, there is still heavy reliance on natural gas, particularly for domestic heating. Electric Vehicle (EV) take-up grows more slowly, displacing petrol and diesel vehicles for domestic use; however decarbonisation of other vehicles is slower with continued reliance on diesel for heavy goods vehicles. In 2050 this scenario still has significant annual carbon emissions, short of the 2050 net zero target.

Source, credit and description wording: National Grid ESO FES 2022

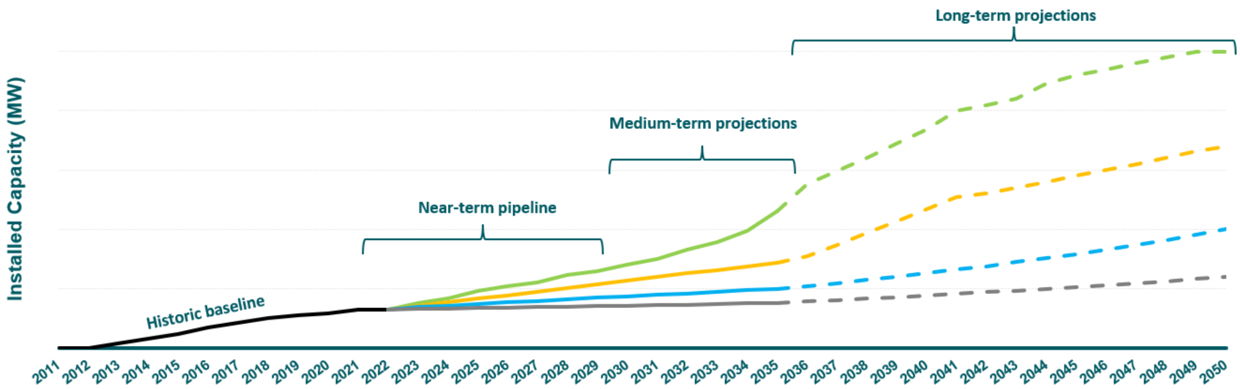
DFES analysis stages

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 2021.
2. The **near-term development pipeline** is then assessed, recording and reviewing projects with network connection offers or planning applications. For technologies with strong pipeline evidence, the range of outcomes across the scenarios may be quite narrow in the near term.
3. **Medium and long-term projections** are then modelled under each scenario out to 2050. Depending on the technology, a much higher variation can be seen across the four scenario results over the 2030s and 2040s.
4. Annual licence area projections of either MW of capacity (e.g. onshore wind) or the number of units (e.g. heat pumps) are then **geographically distributed** across the licence areas.

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 6).

Figure 6: 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 through direct discussions with project developers, sector representatives and other stakeholders.

Over the medium and longer term, projections reflect the underlying scenario assumptions defined for each technology through the FES. 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 net zero and energy strategies clarifies our future energy pathway. The key assumptions made in this analysis include the following:

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

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

1. The range of different outcomes assumed across the FES 2022 scenarios
2. The national Government, devolved Government, regional and local policy uncertainty
3. Commercial and financial uncertainty
4. Technology development and capability uncertainty
5. Consumer adoption and behaviour uncertainty
6. Local spatial distribution factors
7. Transmission vs distribution network connection uncertainty

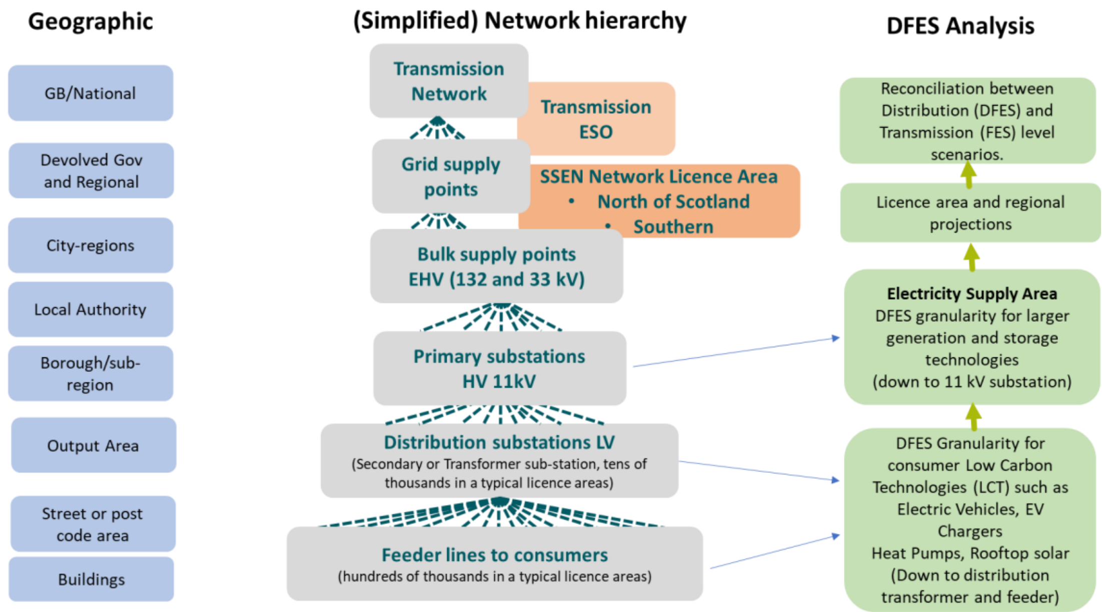
At an individual technology level, uncertainty is considered a key part of the analysis and is reflected in the range of scenario outcomes presented. The technology-specific assumptions that have been made are summarised in each technology summary chapter.

Granularity and geographical distribution of the DFES

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

The DFES geographically distributes licence area projections to **Electricity Supply Areas** (or ESAs). An ESA is a geographical zone representing a block of demand or generation sharing upstream network infrastructure.

Figure 7: Network hierarchy that informs DFES geographic distribution to ESA



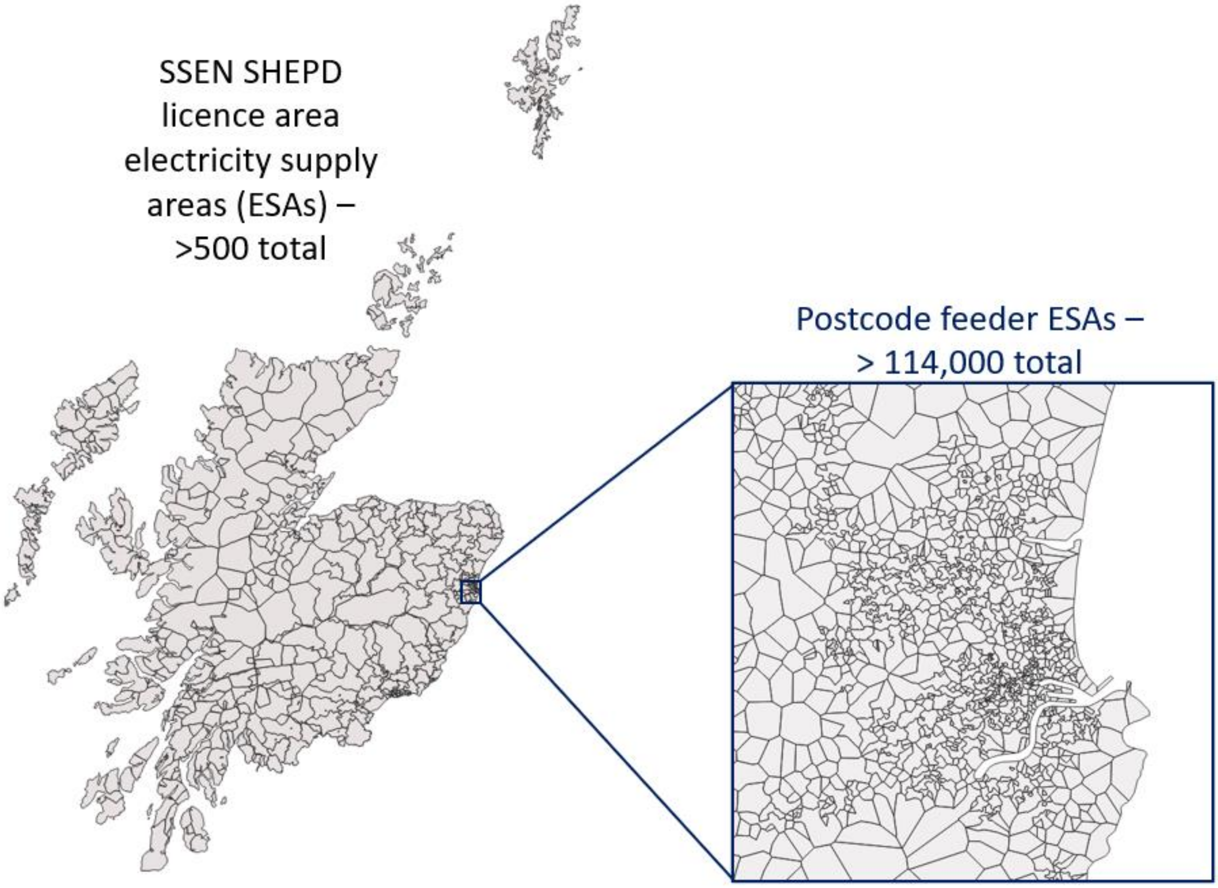
In the North of Scotland licence area for large generation and storage technologies, projections are distributed to approximately 500 individual 11 kV primary ESAs, which in urban areas such as Dundee or Aberdeen would equate to a group of postcodes or a small borough. This could equate to a wider area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

DFES 2021 scenario projections for EVs, EV charger capacity, domestic heat pumps, rooftop PV and domestic battery storage were 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. This level of analysis was out of scope for DFES 2022 but is expected to be included in future DFES projections.

The spatial distribution factors underpinning this ESA modelling are described in more detail within each technology summary. 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 the Isle of Wight stakeholders has also specifically influenced the spatial distribution factors for the SSEN DFES 2022.

Figure 8: Map of 11 kV and feeder ESAs in the North of Scotland licence area



Large-scale Battery Storage Planning Scenario

The pipeline of battery storage projects in the UK has exponentially increased over the past 2-3 years[25]. The number of projects, their scale and the geographic spread of battery storage will likely significantly impact how the future electricity system will be shaped. However, the number of these projects that will come to fruition remains uncertain.

There is an unprecedented pipeline of accepted and quoted connection offers for battery storage projects in both SSEN licence areas.

Licence area	DFES 2020 Pipeline	DFES 2021 Pipeline	DFES 2022 Pipeline (incl. Quote Issued)
Southern England	0.8 GW	1.6 GW	5.3 GW
North of Scotland	0.3 GW	0.4 GW	4.2 GW
All SSEN	**1.1 GW**	**2 GW**	**9.5 GW**

As a result, DFES 2022 includes a new scenario in addition to the four scenarios defined under the FES National Grid framework for battery technologies: the **Storage Planning** scenario. This scenario provides a view to 2050 that assumes all the known battery storage pipeline projects will connect.

The **Storage Planning** scenario is based entirely on the pipeline of projects with connection agreements with SSEN. All sites were modelled to come online. Where no SSEN anticipated connection date was available, sites were modelled to connect in randomly assigned years between 2024 and 2030. This approach highlights the growing number of projects seeking a connection compared to the four FES scenarios. Figure 9 represents the proportion of projects modelled to connect under each scenario by planning status.

Figure 9: Proportion of battery storage projects modelled to connect in SSEN licence areas by scenario

	Granted/Under Construction	Application Submitted	Pre-planning	No information/other
Storage Planning	100%	100%	100%	100%
Leading the Way	100%	100%	100%	15%
Consumer Transformation	100%	100%	100%	15%
System Transformation	100%	25%	37%[26]	6%
Falling Short	100%	25%	13%	4%

The **Storage Planning** scenario enables a view of what the electricity system would look like if all sites currently holding a connection agreement were to connect to the network. In reality, not all projects will come to fruition, as financial and planning challenges will cause setbacks, delays, or project abandonment.

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

[26] *Note: Capacity market information is also used to determine if a project is modelled to be built. For example, if a project is found to be in "pre-planning" but has a capacity market agreement, then it may be modelled to connect, while a project with more advanced planning status but no capacity market information may not be modelled.*

Supporting study

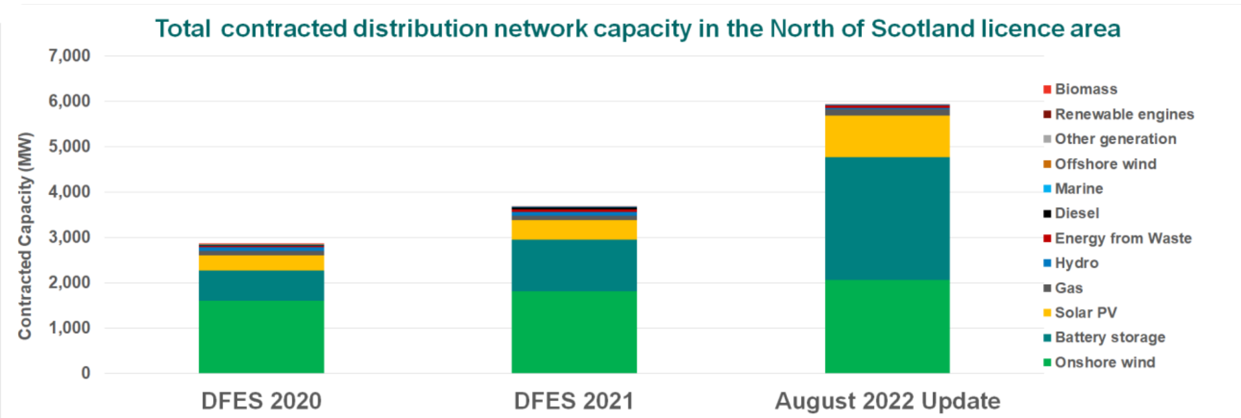
In 2022, Regen led an additional piece of work to explore load growth in the SSEN licence areas between DFES analysis periods.

2022 Near-Term Growth Review

In light of the significant changes in the energy sector, SSEN asked Regen to produce a further analysis in-between the 2021 and 2022 DFES analysis periods. Seven key technologies with the biggest load growth potential were reviewed: solar PV, battery storage, hydrogen electrolysis, data centres, electric vehicles, EV chargers and heat pumps. This evidence has contributed to the DFES 2022.

Key findings for the period from September 2021 to August 2022 included:

- The pipeline of generation and storage projects grew from 3.7 GW to 5.9 GW, indicating a continued investor appetite.
- 32 MW of wind farms, 46 MW of solar PV and 324 MW of battery storage projects had submitted planning applications and sought a grid connection as of mid-2022.
- Battery electric vehicles in the North of Scotland nearly doubled from 4,263 to 7,781 (83% increase), while heat pump installations increased from 2,000 to 4,400 (125% increase).
- Commercial battery storage installations increased to 8 MW from 0 MW.
- There is a trend of accelerated, consumer-led uptake of low-carbon technologies despite economic factors that could have slowed growth, such as the cost-of-living crisis.
- Overall, investors and project developers are continuing to focus on low-carbon technologies. No evidence of a slowing in sites seeking grid connections was found. However, the degree of uncertainty around investment is higher compared to 2021.



Stakeholder engagement

Various inputs, evidence and data inform DFES analysis. Whilst based on four national energy scenarios, the DFES is intended to assess future energy scenarios at a regional, sub-regional and local level. The modelling is heavily influenced by what is connected today and an analysis of known pipeline projects. Consultation and stakeholder engagement are critically important to inform the modelling of individual technologies. To support the SSEN DFES 2022 analysis, the project team has engaged with a wide range of stakeholders. This includes:

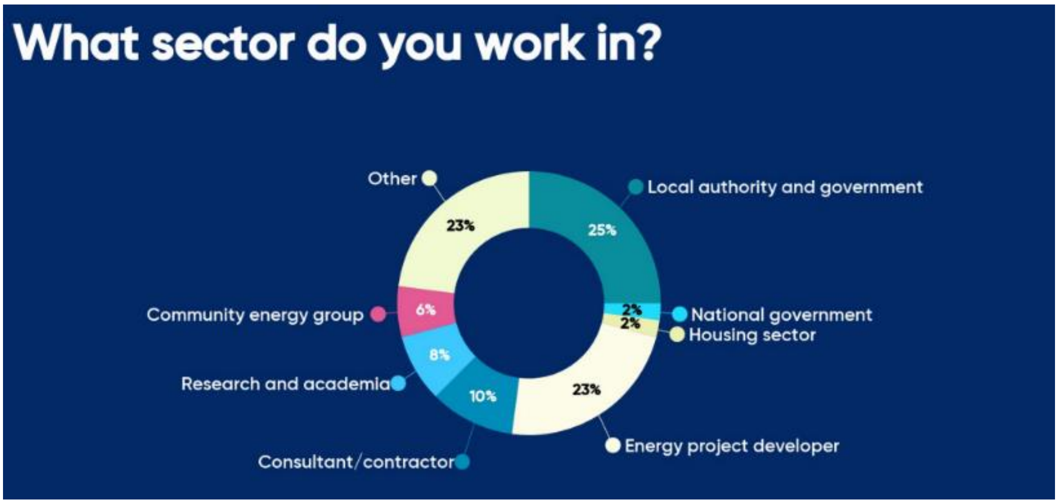
	Interactive online webinars held in November and December 2022[27] with a broad range of regional and energy sector stakeholders and members of the SSEN team. *This session used an online polling platform to capture specific views and statistical data about the future of several energy technologies.*
	A **new developments online data exchange**, 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 larger domestic property developments (100 houses or more) and non-domestic developments, such as new supermarkets, offices or airports.*
	A **local energy strategy questionnaire** was completed by wider environmental and city planning teams from a number of the regional local authorities. *Asking questions about individual council strategies and plans for zero emissions targets, renewable energy development, low carbon transport, low carbon heat, waste collection and hydrogen. The responses and accompanying documents supplied by the councils were used to inform the spatial distribution of some scenario projections.*
	Technology and sector-specific interviews with project developers, technology companies and other sector representatives. *These interviews informed the modelling of pipeline projects and testing assumptions made about specific sectors or technologies. Interviews included solar PV and battery storage project developers, ITM Power and the European Marine Energy Centre.*

[27] Regen 2022, *SSEN Distribution Future Energy Scenarios 2022- Stakeholder Consultation Webinars*. https://www.regen.co.uk/event/ssen-distribution-future-energy-scenarios-2022-stakeholder-consultation-webinars/

Regional engagement webinars

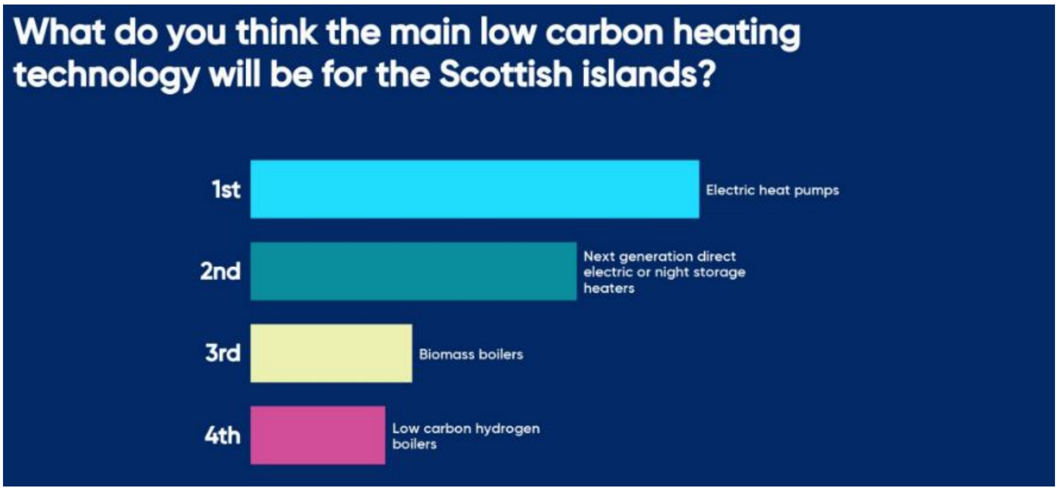
Across November and December 2022, Regen worked with members of the SSEN team to host interactive stakeholder engagement webinars. These collaborative sessions sought to:

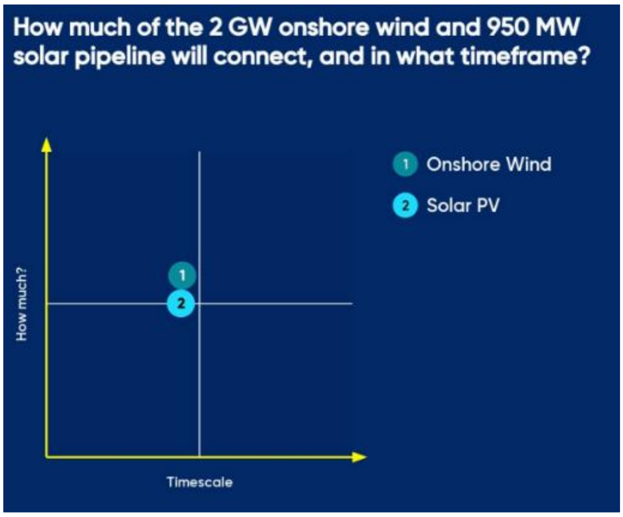
- Provide a summary of the background, method and purpose of DFES.
- Road-test assumptions around technology capacity growth and locational distribution factors that determine the scenario projections.
- Tap into local and sector knowledge, insights and ambitions relevant to the licence area.
- Discuss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

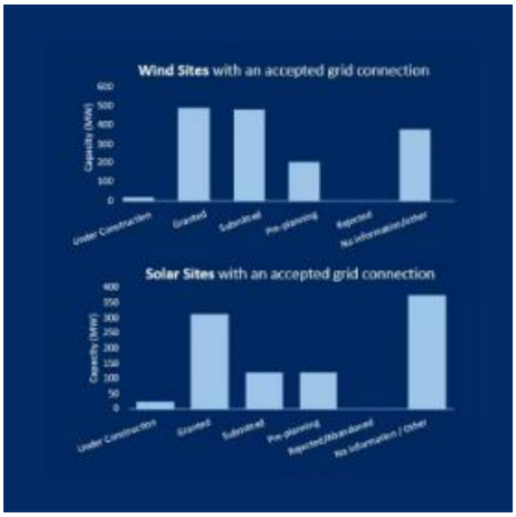


The **North of Scotland regional webinar** brought together representatives from local authorities, community energy groups, project and technology developers and other sector-specific representatives, with 256 people registering to attend and 150 on-the-day attendees. The session sought views from stakeholders that could directly apply to the scenario modelling, covering:

- An overview from SSEN around their RIIO-ED2 plan and the general purpose and use of DFES.
- An introduction to the high-level methodology and technology building blocks that form the scope of the 2021 DFES analysis.
- A series of technology-specific interactive polling sessions using the online voting and live visualisation platform ***Mentimeter***[28].







Engagement with local authorities

Building on engagement in previous DFES assessments, a core data input to this year's analysis came from an online portal of new property developments planned in the North of Scotland licence area. Regen liaised with the planning departments of those local authorities within the licence area, updating registers of:

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

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

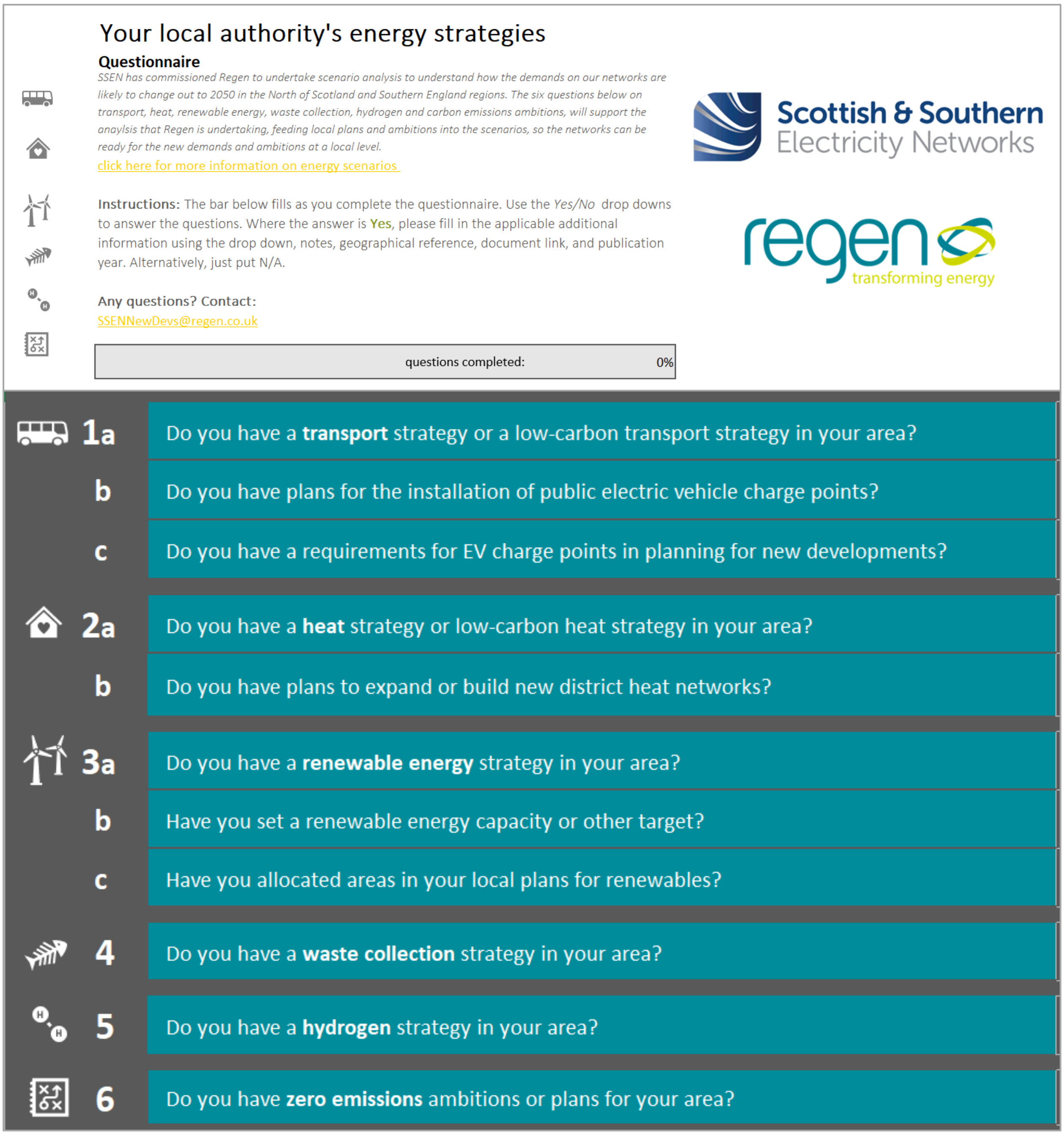
i) A potential spaceport to be located at Scolpaig on the island of North Uist[29]
ii) The conversion of Montrose Airfield in Angus
iii) The development of some land around Aberdeen Airport
iv) The proposed Hatston Marine Park in the Orkney islands.

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

[28] See https://www.menti.com/ and https://mentimeter.com/
[29] Stornoway Gazette 2021, *Scolpaig in Uist could be the next Spaceport rocket launch site if planning is approved.* https://www.stornowaygazette.co.uk/business/scolpaig-in-uist-could-be-the-next-spaceport-rocket-launch-site-if-planning-is-approved-3159622

The project team also issued a **local energy strategy survey** to broader environmental and climate change project teams within the local authorities. The response data from this survey (see Figure 10) was used to influence the spatial distribution of individual technology projections.

Figure 10: SSEN local energy strategy survey, developed by Regen for DFES 2022 analysis



Your local authority's energy strategies

Questionnaire

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

click here for more information on energy scenarios

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

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

questions completed: 0%

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

The responses to the 2021 and 2022 questionnaires are summarised in Figure 11. The number of councils that responded and the number of sector strategies that have been published, or are in development, have increased since the survey was completed to support the 2021 DFES analysis.

Figure 11: High-level responses to the 2022 and 2021 local energy questionnaire submitted by local authorities in the North of Scotland (Yes, No, or In Development)

Local Authority	Transport strategy	Public EV charger plans	EV charging in new developments	Heat strategy	Heat networks	RE strategy	RE targets	Development areas	Waste collection	Hydrogen strategy	Emissions target	Local Area Energy Plan
Aberdeen City	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y
Aberdeenshire	Y	Y	N	ID	ID	N	N	Y	Y	N	ID	ID
Angus	Y	Y	ID	ID	ID	Y	N	Y	Y	ID	Y	N
Argyll and Bute												
Dundee City	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	ID
Highland	N	Y	ID	ID	N	Y	Y	N	Y	ID	Y	
Moray	Y	Y	Y	ID	ID	Y	N	Y	Y	Y	Y	N
Na h-Eileanan Siar	Y	ID	ID	Y	N	Y	Y	Y		Y		
North Ayrshire												
Orkney Islands												
Perth and Kinross	Y	Y	Y	ID	Y	ID	ID	N		Y	Y	ID
Shetland Islands	Y	Y	N	N	N	Y	N	N		N	N	
Stirling												
West Dunbartonshire												

Y = Yes N = No ID = In Development

Targeted sector and development engagement

The project team also engaged individual companies and sector representatives. These consultations included:

- Email exchanges with project developers holding contracted connection offers for individual generation or storage projects to determine plans to build out their projects.
- Interviews with technology companies, developing emerging or innovative technologies such as cryobatteries, hydrogen electrolysers or energy from waste site operators.

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

An overview of some of the sector-specific consultations is shown in Table 3.

Table 3: Summary of sector-specific stakeholder engagement undertaken to inform DFES 2022 analysis

DFES building block technology	Organisation Engaged	Summary of the feedback received and how it was applied to the DFES analysis
Large-scale (>1 MW) solar PV	Renewable Connections, Bluestone Energy, Novergy, Wessex Solar Energy, Hive Energy, Aura Power, Bath and West Community Energy, Voltalia, Bluefield Development, Westbridge Energy, Gloucestershire County Council, Lightsource BP, RES, Ridge Clean, Low Carbon, Marlow Energy Group, Novus, Roadnight Taylor, Green Nation, Aberdeenshire Council, Dundee Council and ECO Sustainable Solutions	Provided information about deployment timelines for specific solar projects. Also discussed general challenges facing the solar sector, including network capacity, planning and local objections/NIMBYism. Discussed potentially viable sites on land in AONBs, green belt, high-grade agricultural land and flood zones etc. This feedback supported the pipeline analysis and reinforced Regen's solar methodology and in-house solar resource assessment, considering several spatial factors and land classification constraints.
Hydropower	British Hydropower Association, University of Birmingham, Raasay Renewables, Low Carbon Hub and Project LEO	Discussion around small hydropower as a business model and the barriers facing it. Feedback highlighted a lack of subsidy support after closing the Feed in Tariff programme. This is a consensus amongst hydropower developers. Other barriers included upstream transmission constraints, legal fees and unfair additional costs to community developers. This insight supported the resultantly conservative DFES capacity projections.
Onshore wind	Ecotricity, Aquatera, Orkney Community Energy, Orkney Council, Walters Group, AWEL Co-op, Infingergy/Boralex, Gray Associates, Constantine Wind Energy	As with solar and battery storage, several wind developers with identified projects in the region were contacted by email to provide additional pipeline site information. Several responded with clarifications that directly influenced the modelling of sites.
Battery storage	Foresight, Eelpower, Ili Energy, Low Carbon, RES, Noriker, Eclipse Power, Penso Power, Statera Energy, Conrad Energy, BM Solar, Balance Power, Tag UK, Clearstone Energy, Infinergy and Novus, XRenewable, Low Carbon Alliance	Provided information about the timeline and broader intention to progress individual large-scale (>40 MW) battery storage projects that have recently accepted connection offers with SSEN. The feedback guided the pipeline analysis and spatial distribution of the large battery storage pipeline across the licence area.

DFES building block technology	Organisation Engaged	Summary of the feedback received and how it was applied to the DFES analysis
Liquid air energy storage (LAES)	Highview Power	Information about broad interest in connecting LAES projects to the distribution network in SSEN's licence areas. This included specific insights around an appetite to target National Grid ESO's stability pathfinders[30] and the potential to co-locate LAES projects data centres as a potential off-taker of cooling load. This insight drove the inclusion of LAES as a separate technology projection, the scale of capacity projected, and the spatial location of future LAES sites across both SSEN's licence areas.
Hydrogen electrolysis	ITM Power, RWE	Discussed the general progress of the low carbon hydrogen sector, future electrolysis business models and any existing operational electrolyser sites. The discussion also updated views on typical electrolyser capacity scale (MW) and future use cases. This feedback was used to develop Regen's hydrogen electrolysis scenario modelling in several areas.
Offshore wind and marine generation	Simply Blue Group, UK Marine Energy Council, European Marine Energy Centre, Perpetuus Tidal Energy Centre, Offshore Renewable Energy Catapult and Hexicon	Direct engagement with marine sector professionals drew attention to post-pipeline sites likely for future development. Insight was also gathered on the future of floating offshore wind and the degree of potential development given ideal market conditions.

[30] See National Grid ESO NOA Stability Pathfinder – Phase 3 updates: https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-3

Technology sector scenario analysis – index

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

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

Onshore wind

Summary of modelling assumptions and results

Technology specification

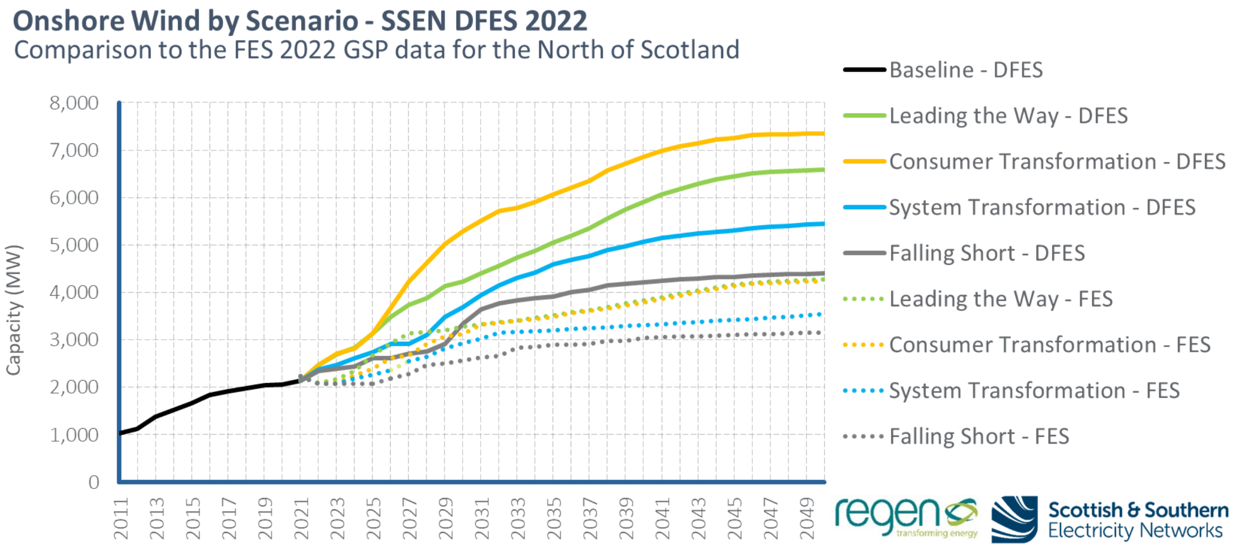
The analysis covers any onshore wind generation connecting to the distribution network in the North of Scotland licence area.

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

Data summary for offshore 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	2,009	2,467	3,197	3,764	4,061	4,170	4,231
	System Transformation		2,606	3,542	4,431	4,856	5,079	5,223
	Consumer Transformation		2,953	5,061	5,799	6,496	6,851	6,923
	Leading the Way		2,991	4,071	4,855	5,610	6,102	6,221
Small Scale (<1 MW)	Falling Short	137	142	147	152	157	163	168
	System Transformation		142	146	159	210	229	234
	Consumer Transformation		179	234	266	369	410	423
	Leading the Way		148	162	192	300	346	366

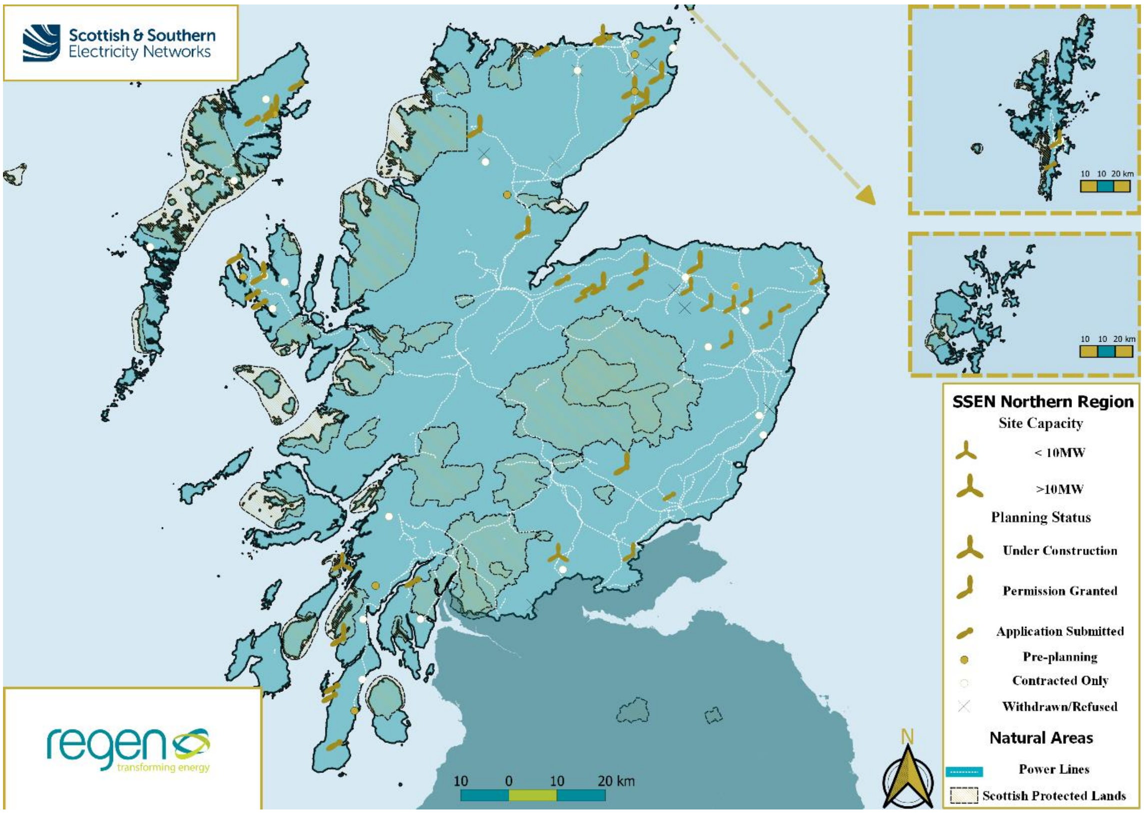
Figure 12: Onshore wind projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections



Summary

- There is currently 2,146 MW of onshore wind capacity across 482 sites deployed in the North of Scotland licence area. Deployment is centred on the east of the licence area, with a concentration of larger-scale projects (over 10 MW each) deployed around the Moray Firth.
- The pipeline of sites in the licence area totals 2,636 MW from 109 sites. This pipeline also mainly comprises larger sites (over 10 MW) around the Moray Firth and in the north region of the licence area, with some additional developments planned on Shetland, the Outer and Inner Hebrides and in the South West of the licence area.
- Projections for connected onshore wind capacity in the North of Scotland licence area see significant growth 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 wind capacity by 2030[i] and committed to establishing an Onshore Wind Strategic Leadership Group to oversee the delivery of this target.
    - In its Energy Security Strategy[ii], the UK government has committed to delivering annual rounds of Contracts for Difference (CfD) from March 2023, where previously they were biennial. This will offer larger onshore wind projects more opportunities to secure financial support through a CfD. Subsidy-free routes to market are also increasingly viable for wind projects in the licence area.
    - Ofgem's recent Access SCR[iii] has reduced overall connection charges and introduced non-firm contracts, enabling projects to connect in congested areas of the network.
- A resource assessment and feedback from engaging wind developers and sector representatives have informed long-term projections in the DFES. As a result, large-scale capacity could reach 6.9 GW by 2050 under the **Consumer Transformation** scenario. The lowest scenario, **Falling Short**, reflects 4 GW by 2050.

Figure 13: Pipeline onshore wind sites in the North of Scotland licence area



Modelling and assumptions

Baseline (2021)			
Scale	**Number of Sites**	**Total Capacity**	**Description**
Total	482	2,146 MW	There has been a 25 MW net increase compared to the DFES 2021 baseline. This is a result of the 35 MW Blary Hill wind farm being commissioned in early 2022 and the 10 MW Dunbeath pilot project decommissioning.
Above 1 MW	162	2,009 MW	The average site capacity is 12.5 MW, with 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	320	137 MW	Most small-scale onshore wind development occurred due to the Feed-in Tariff, with over 100 MW of capacity connecting between 2011 and 2016 in the licence area. Since 2017, only 14 small-scale sites, totalling c. 37 MW, have been connected.

Pipeline (2022-2030)	
Number of pipeline sites	**Total capacity**
109	2,635 MW

The pipeline of prospective future onshore wind sites in the licence area has grown to 2.6 GW. Most of this pipeline, 2 GW, comprises sites with an accepted connection agreement with SSEN. This is an increase on the pipeline in DFES 2021, which only had sight of 1.7 GW of wind projects with accepted connection agreements. An additional 340 MW represents sites which have been offered a connection which has not yet been accepted.

In addition to sites from the SSEN connections data, this year, the DFES has identified sites in the Renewable Energy Planning Database[iv] that have not yet applied for a distribution connection. 11 sites, totalling 244 MW, have been identified as having the potential to seek a distribution network connection in future.

The average capacity of all sites in the pipeline is around 27 MW. This is significantly larger than the baseline average of 12 MW. This trend is evidence of developers pursuing larger sites with improved economics to increase their likelihood of securing a CfD while making subsidy-free routes to market more viable. Only one site in this pipeline currently has a CfD, the 30 MW Hoy site on Orkney, secured in Allocation Round 4.

Three onshore wind sites, totalling 82 MW, are proposed to co-locate with solar PV or battery storage, including the 50 MW Glenrossal Energy Park, though these sites have yet to come into planning.

Pipeline planning status analysis			
Status	**Description**	**Sites**	**Capacity**
Under Construction	Tacher[v], a 15 MW site in the Highlands, and Greenscares, an 8 MW site in Perth & Kinross, are both under construction, along with an upgrade to an existing kW scale site. This constitutes less than 1% of the total pipeline capacity.	3	23 MW
Planning Permission Granted	Sites with planning permission constitute 21% of the pipeline capacity. This includes nine 35-50 MW sites, five in the Highlands and one in the Western Isles, Moray, Argyll & Bute and Perth & Kinross, respectively.	29	565 MW
Planning Application Submitted	Sites which have submitted for planning permission constitute 30% of pipeline capacity. Nine of these sites are 45-80 MW in size, four in the Highlands, two in the Western Isles and three in Argyll & Bute.	23	777 MW
Pre-planning	Sites in pre-planning make up 11% of the pipeline capacity. This includes the 68 MW Strathcarron (Braelangwell) site in the Highlands[vi].	9	281 MW

No information	448 MW, or 17% of the pipeline capacity, could not be associated with planning information. Roughly half of this capacity comprises four sites between 40 – 50 GW. Relative to solar and battery storage, this is a smaller percentage of capacity with no visibility in planning. These sites are only modelled to build out under **Leading the Way**.	24	448 MW
Planning refused, withdrawn or expired	541 MW, or 20% of the pipeline, has seen planning applications rejected, withdrawn or expired. These sites are not modelled to build out under any scenario.	21	541 MW

Planning Logic and Assumptions (percentage of projects 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 Renewable Energy Planning Database.

Scenario	Planning Granted or Under Construction	Planning Application Submitted	Pre-planning	No information	Years from planning submitted to completion
Falling Short	100%	40%	No capacity taken forward	No capacity taken forward	6-10 years
System Transformation	100%	60%	50%	No capacity taken forward	5-9 years
Consumer Transformation	100%	80%	60%	No capacity taken forward	3-7 years
Leading the Way	100%	80%	60%	50%	5-9 years

Repowering

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 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
Year delay	30	25	25	25
Large-scale repowering	+25%	+25%	+50%	+40%
Small-scale repowering	--	+50%	+100%	+100%
Repowering capacity by 2050	500 MW	500 MW	1,000 MW	1,000 MW

Scenario Projections (2030 to 2050)			
The medium and long-term projections hinge on scenario assumptions around the levels of societal change, the impact of renewables targets, and the viability of different business models. In the medium term, there are continued high levels of deployment in all net zero scenarios, driven by pipeline sites already in development and new projects in areas of high wind resource and fewer planning constraints. A differentiator 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 accelerated onshore development. 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. Regen's longer-term analysis is driven by our in-house onshore wind resource assessment. This 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 continues to be a frontrunner for distributed onshore wind in all scenarios.			
Scenario	**Description**	**Capacity by 2035**	**Capacity by 2050**
Falling Short	Under **Falling Short**, future capacity aligns with the growth rate over the past ten years. Despite the considerable project pipeline, few projects are modelled to build out. In 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 early 2030s as three large sites can connect after the SoW reinforcement is complete. **Falling Short** assumes low impact towards renewables targets, local ambition, and planning friendliness. As a result, limited growth in additional capacity is modelled, and 4.4 GW is deployed by 2050.	3,916 MW	4,399 MW
System Transformation	While more of the known development pipeline builds out than under **Falling Short**, near-term growth in **System Transformation** is consistent with the growth rate of onshore wind seen over the past ten years. Beyond 2030, assumptions around ambition, planning friendliness and repowering result in an acceleration in 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 this growth rate is not significantly higher than historic rates. By 2050, 5.5 GW is deployed under this scenario, which is 0.5 GW higher than in DFES 2021. This is due to an increased pipeline of contracted sites and sites in planning.	4,590 MW	5,457 MW

Consumer Transformation	Under **Consumer Transformation**, a large portion of the pipeline builds out, resulting in a near-term acceleration of connected capacity. Between 2025-2030, the DFES has assumed that 5GW 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 adds an additional 1.2 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 deployed by 2050. This 2050 projected deployment has grown 0.8 GW compared to DFES 2021 due to an increased pipeline and reinforced policy support through the Scottish Onshore Wind Statement[i] and Energy Security Strategy.	6,065 MW	7,346MW
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 equivalent accelerated 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 1 GW of capacity. By 2050, 6.6 GW is deployed. This 2050 projection is approximately 0.5 GW higher than in the DFES 2021. This is due to an increased project pipeline.	5,047 MW	6,585 MW

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The FES 2022 baseline for onshore wind in the North of Scotland licence area is 2.2 GW, which is slightly higher than the 2.15 GW identified in the 2022 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 than occurs in the same period in the FES 2022 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 are estimated based on direct feedback from project developers.
Projections	The FES 2022 projections under **System Transformation** and **Falling Short** see limited capacity deployment from 2032 onwards. The DFES 2022 sees moderate, continued growth in the same timeframe due to baseline projects being modelled to repower in these years. The FES 2022 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, these scenarios are modelled to reflect a more ambitious and supportive environment for wind power. 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 growth rates and eventually deployed capacities seen in the DFES 2022 scenarios reflect current data on sites coming forward, current policy direction and wind resource.

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: • 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[vii]. • The Western Isles transmission reinforcement commissions in 2027[viii]. Except for **Falling Short**, this is not assumed to delay current pipeline sites with positive planning evidence. • The Shetland transmission reinforcement commissions in late 2024[ix]. 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, as this is a snapshot that may not fully reflect local authority ambition in the long term, it was not used as a major factor in the projections in the medium and long term. Council Climate Action Scores[x] 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 2022

Scenario		4.1.3 - Wind generation (onshore)
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
Developers were contacted to discuss their pipeline projects.	Developers engaged included Grey Associates, Constantine Wind Energy and Boralex. As a result, their information was directly reflected in the near-term projections. Developers highlighted uncertainty around transmission network reinforcement works, which would impact the delivery of their projects. Potential delays out to 2027-2029 were highlighted and have therefore been reflected directly under **Falling Short**.
At the North of Scotland stakeholder engagement webinar[xi], local stakeholders responded to three polls on the future of onshore wind development in the licence area.	On the proportion of the current project pipeline that will eventually be developed and in what timeframe: 27 attendees (including 12 wind developers) 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 future balance of distribution and transmission connected onshore wind in the licence area: 25 attendees (including six wind developers) responded, with approximately 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 likelihood of 6-7 GW of distribution connected onshore wind in the licence area by 2050: 30 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 6 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] UK Government 2022, *Energy Security Strategy*. https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

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

[iv] UK Government 2022, *Renewable Energy Planning Database*. https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract

[v] Cleanearth 2021, *"Planning Consents..."* https://cleanearthenergy.com/planning-consent-4-turbines-in-scotland/

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

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

[viii] 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

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

[x] Climate Emergency UK 2022, *Council Climate Plan Scorecards*. https://councilclimatescorecards.uk/

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

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.

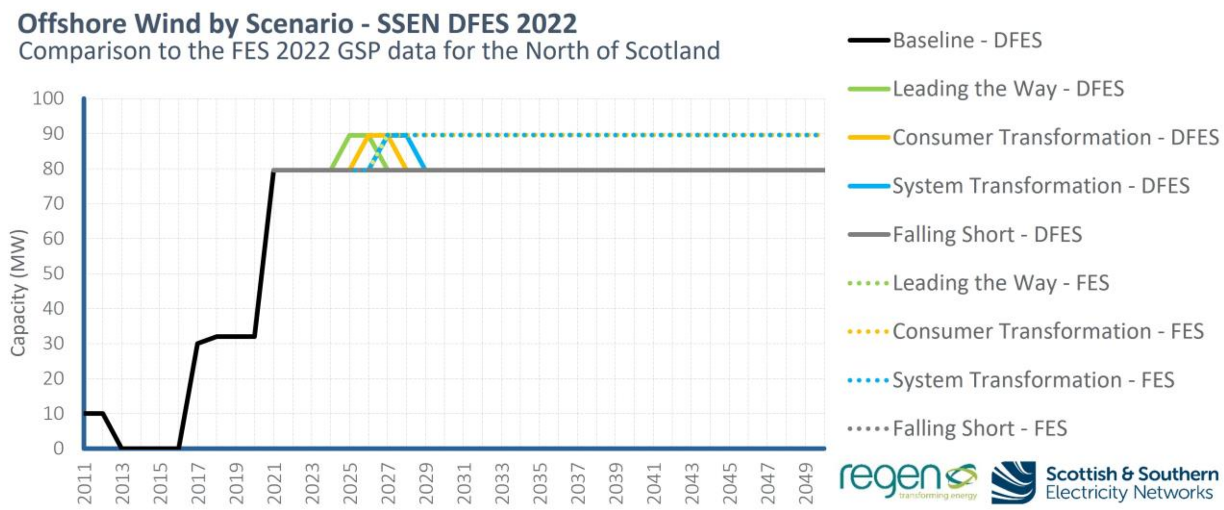
Very few large-scale offshore wind projects are expected to connect to the distribution network. Therefore, the SSEN DFES analysis has focused on small-scale demonstration and trial projects that could be distribution network-connected.

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		90	80	80	80	80	80

Figure 14: Offshore wind projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections



Summary

- The current baseline consists of the Kincardine[xii] (50 MW) and Hywind[xiii] (30 MW) floating offshore wind farms.
- One known pipeline project has been modelled to connect: the Pentland Floating Offshore Wind demonstrator site (10 MW). The nature of the Pentland project is a temporary demonstrator site for a future, larger, transmission-connected Pentland floating offshore wind site.
- The EMEC Floating Wind Test and Demonstration Site (80 MW), which has not yet applied for planning, has not been modelled since the demonstration site only connects to the distribution network as a temporary measure due to the expectation of a significant transmission network upgrade.

- The Scottish Offshore Wind Policy Statement sets out an ambition to install 8-11 GW of offshore wind capacity by 2030. The Scottish Government are consulting on setting a further offshore deployment ambition[xiv].
- The resultant expansion of offshore wind will be almost all 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, minimal additional offshore wind capacity is expected to connect to the distribution network in the licence area out to 2050.

Modelling and assumptions

Baseline (2021)		
Number of Sites	**Total Capacity**	**Description**
2	80 MW	The baseline capacity of offshore wind in the licence area comprises two sites: Kincardine (50 MW, fully commissioned 2021) and Hywind (30 MW, commissioned 2017) floating offshore wind farms. A previous 10 MW pilot project was connected from 2008 to 2013, the Dunbeath Beatrice Wind project[xv].

Pipeline and scenario projections (2022 to 2050)
Projections for offshore wind are based entirely on the modelling of pipeline and known sites for future development. Two pipeline sites have been identified as in development. The Pentland Floating Offshore Wind farm Demonstrator Site (10 MW) has submitted a planning application and is modelled to connect. The EMEC Floating Wind Test and Demonstration site has not applied for planning; up to 80 MW could theoretically connect to the distribution network if commissioning occurs before transmission network reinforcement. However, most distribution network capacity headroom at this location has been allocated, so the DFES has opted not to model the connection of the EMEC floating wind demonstrator, even temporarily, under any scenario.

Scenario	Description	Capacity by 2035	Capacity by 2050
Falling Short	No additional distribution-connected capacity is added to the baseline before 2050.	80 MW	80 MW
System Transformation	The Pentland Firth Floating Offshore Wind demonstrator is projected to connect in **2027** and disconnect again in 2028 after decommissioning, in advance of a larger transmission-connected Pentland Floating Offshore Wind Farm in future.	80 MW	80 MW
Consumer Transformation	The Pentland Firth Floating Offshore Wind demonstrator is projected to connect in **2026** and disconnect in 2027.	80 MW	80 MW
Leading the Way	The Pentland Firth Floating Offshore Wind demonstrator is projected to connect in **2025** and disconnect in 2026.	80 MW	80 MW

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The DFES 2022 baseline for offshore wind is aligned with the National Grid FES 2022 baseline for the licence area.

Pipeline	Both FES 2022 and DFES 2022 pipelines include the 10 MW Pentland Floating Offshore Wind demonstration site under the three net zero scenarios. Still, the two analyses differ as FES 2022 assumes that the increased capacity is maintained out to 2050, whereas DFES 2022 assumes this site decommissions and capacity returns to the baseline level. This has been confirmed through direct engagement with the site developer.
Projections	Neither FES 2022 nor DFES 2022 projections assume any further post-pipeline distribution network connections for offshore wind.
Overarching Trend	The DFES and FES match well.

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.

Relevant assumptions from National Grid FES 2022

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 awareness of the EMEC Floating Wind Demonstrator project.

[xii] Principle Power n.d., *Kincardine Offshore Wind Farm.* https://www.principlepower.com/projects/kincardine-offshore-wind-farm
[xiii] Equinor n.d., *Hywind Scotland.* https://www.equinor.com/energy/hywind-scotland
[xiv] Scottish Government 2023, *Draft Energy Strategy and Just Transition Plan.* https://www.gov.scot/publications/draft-energy-strategy-transition-plan/pages/5/
[xv] 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

Large-scale solar PV

Summary of modelling assumptions and results

Technology specification

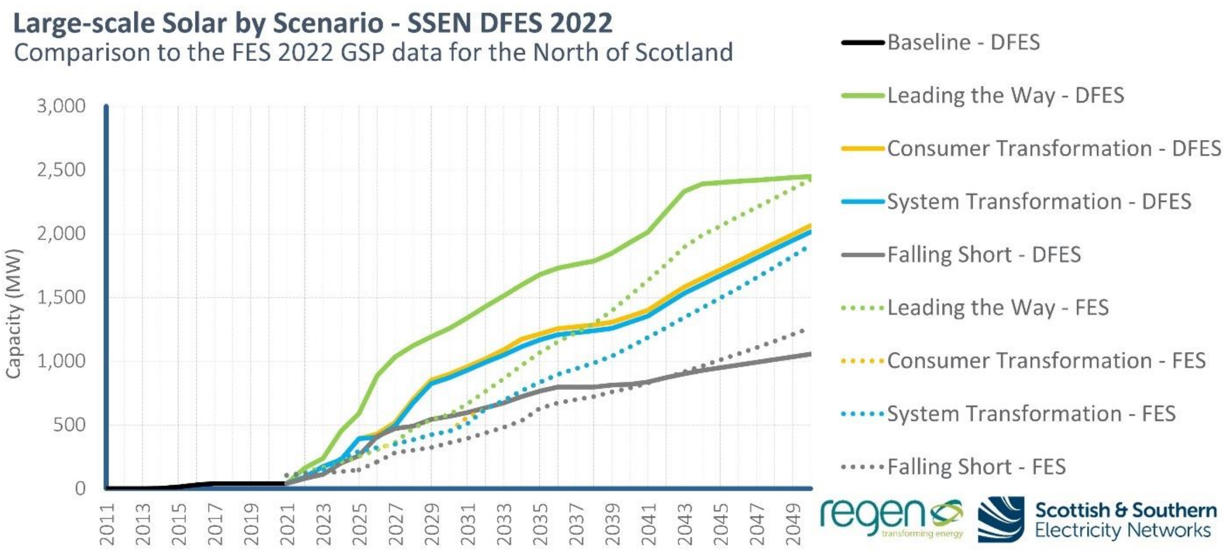
The analysis covers solar generation sites of installed capacity of 1 MW and above connecting to the distribution network in the North of Scotland licence area.

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

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

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	41	258	567	764	818	949	1,057
System Transformation		393	872	1,167	1,306	1,671	2,015
Consumer Transformation		393	899	1,214	1,352	1,717	2,062
Leading the Way		589	1,258	1,679	1,931	2,400	2,450

Figure 15: Large-scale solar PV projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections

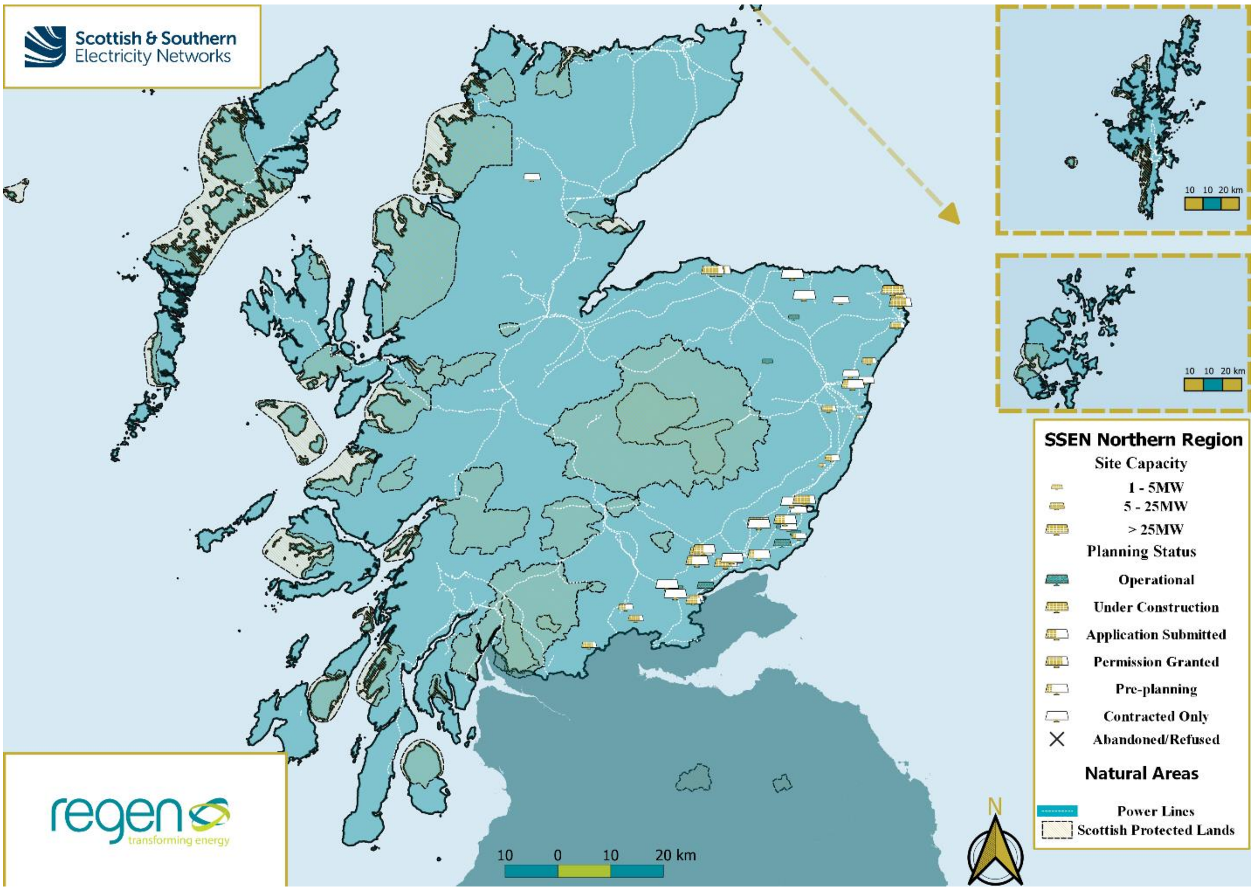


Summary

- The North of Scotland licence area has seen historically low levels of large-scale solar deployment, with 41 MW of installed capacity as of the end of 2021. This is a 14% relative increase in installed capacity compared to the previous year, reflecting that some development is actively happening.
- Despite low historic levels of installed capacity, there is a strong pipeline of projects with granted planning applications, including some currently under construction, making up 352 MW (29%) of the total 1.2 GW pipeline.
- Solar PV remains one of the cheapest forms of renewable energy, with further equipment cost reductions helping the technology to realise economies of scale. Ongoing reductions in capital costs[xvi], improvements in solar panel efficiency[xvii] and the development of more dynamic and lucrative power purchase agreements[xviii] are driving new interest to deploy potentially significantly more capacity of large-scale solar PV nationally.

- Current business models are based around larger-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.
- Historic planning friendliness towards solar installations is very high, with c. 96% of projects being accepted. In addition, 45% of local authorities responding to Regen's DFES local energy strategy survey have set ambitious renewables targets, indicating high medium-term growth in the licence area. Several Scottish businesses have also committed to increasing solar capacity and reducing on-site emissions[xix].
- Engagement with the Scottish Solar Trade Association (STA) in 2021 highlighted an ambition to rapidly accelerate the deployment of solar in Scotland, with the STA targeting 3.5 GW of large ground-mount solar PV by 2030[xx]. Whilst the irradiance zone and developable land space in the North of Scotland licence area are less favourable than the South of Scotland, the DFES has sought to reflect an increase in large-scale solar capacity across all scenarios by 2030 and by 2050 in the licence area.
- The highest resource areas in the North of Scotland are south of the licence area and across the east coast. This is the area where the majority of baseline sites and prospective new projects have been located.
- The British Energy Security Strategy[xxi] has set an ambitious goal of 70 GW of solar capacity by 2030, a five-fold increase from the 14 GW of installed domestic and large-scale solar when the strategy was released.
- The Scottish Government's draft Energy Strategy and Just Transition Plan[xxii] targets 20 GW of additional renewable electricity capacity and mentions a forthcoming strategy on solar energy in Scotland, currently being consulted upon. Proposed solar targets of 4-6 GW by 2030, in a response from MSPs to a letter from Solar Energy Scotland, indicate a shift away from a wind-dominant renewables sector in Scotland[xxiii].
- Under the most ambitious scenario, **Leading the Way**, solar reaches c. 1.3 GW by 2030, and continues to c. 2.5 GW by 2050. Under **Consumer Transformation**, c. 0.9 GW is reached by 2030 and c. 2.1 GW by 2050.
- Across the UK, a main barrier for solar sites connecting to the network is the large connections queue at both transmission and distribution level voltages. Due to the Statement of Works, many developers have been given connection dates in the late 2020s and, in some cases, into the 2030s. These delays have been reflected solely in the **Falling Short** scenario since delays will need to be alleviated to meet net-zero goals.

Figure 16: Large-scale solar PV baseline and pipeline sites by planning status in the North of Scotland



Modelling and assumptions

Baseline (2021)		
Number of Sites	**Total Capacity**	**Description**
8	41 MW	There has been a 5 MW increase in baseline capacity compared to DFES 2021 due to the reclassification of some existing connections previously considered wind. In addition, two solar sites added capacity at an existing wind site at Cairnmore Farm in Aberdeenshire, near Rhynie. The two sites with increased capacity were commissioned in 2014 and 2015; no new solar sites were commissioned in 2021 in the licence area.

Pipeline (2022-2030)

	Total	Contracted	Grid connection offered	In planning only
Number of sites	53	39	7	7
Total Capacity (MW)	1,205	897	242	67

For each new DFES analysis, the solar pipeline has consistently grown. The number and capacity of pipeline sites have increased this year to 53 sites (1,205 MW), of which 24 are new sites recorded in DFES 2022, equating to 674 MW. This represents an increase of pipeline capacity by more than 50% compared to DFES 2021, which included 414 MW of accepted sites and 262 MW of sites with grid connection offers that have now yet been accepted. In addition to sites from the SSEN connections data, the DFES 2022 analysis has also included sites identified in the Renewable Energy Planning Database[xxiv] that have not yet applied for a distribution network connection; this accounts for an additional 67 MW of pipeline capacity. Around 130 MW have been awarded a Contract for Difference (CfD).

Another reason for the larger amount of pipeline sites included in the analysis is the decision to include those that have not yet accepted a grid connection offer. These represent 242 MW from 7 sites. The volume of grid connection offers that SSEN process is significant, and not all are accepted. This data represents a snapshot of sites with outstanding connection offers; it is understood that some of these sites may have changed since the data was received in mid/late 2022. As such, offered but not accepted sites are only modelled to come online in **Consumer Transformation**, **System Transformation** and **Leading the Way** if found to have granted planning permission. In some cases, they are modelled to come online under **Falling Short**, where planning and pre-planning evidence was found. Where sites have been affected by Statement of Works delays for transmission network reinforcement, they have been delayed to the expected year of works completed under **Falling Short**.

Pipeline analysis

Status	Description	Sites	Capacity
Under Construction	One site was found to be under construction, Bilbo Farm[xxv] and was due to be commissioned in 2022, but there has been no public announcement of its commissioning as of Q1 2023.	1	25 MW
Planning Permission Granted	377 MW from 20 solar sites have been granted planning permission in the licence area, of which 323 MW have also been offered a grid connection. Two projects are 50 MW in size: Milltown PV and Grange of Berryhill.	19	327 MW
Planning Application Submitted	Seven sites have submitted planning applications, of which two sites, with a combined capacity of 12 MW, have not yet applied for a grid connection. The largest site is at Keithick Estate (56 MW) in Perthshire, which has a parallel application for a 56 MW co-located battery storage asset. This is also modelled to connect in the same year as the solar array in the DFES analysis.	7	230 MW

Pre-planning	Four sites, totalling 130 MW, are in pre-planning stages, including the Collace Solar farm[xxvi] in Perthshire (50 MW), which submitted an EIA screening request in June 2022. In addition, at least two pre-screening applications have been identified.	4	130 MW
No information/Other	22 sites in SSEN's connection data had no online planning information, indicating early project planning stages.	22	493 MW

Planning Logic and Assumptions (percentage of projects modelled to come online)

The 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 Renewable Energy Planning Database.

Scenario	Planning Granted or Under Construction	Planning Application Submitted	Pre-planning	No Information	Years from Planning Submitted to completion
Falling Short	100%	50%	Removed from analysis	Removed from analysis	2-9 years
System Transformation	100%	75%	25%	Removed from analysis	1-9 years
Consumer Transformation	100%	75%	25%	Removed from analysis	1-9 years
Leading the Way	100%	90%	50%	40%	1-7 years

Repowering

Description

From the mid-2030s onwards, existing baseline sites begin to repower their site capacity. The modelling accounts for the possibility of new upgraded solar panels and the extension of existing sites. Several legacy solar farms have been modelled to repower in the early-2040s, resulting in a late surge of increased capacity at existing sites.

By 2050, 20 MW of capacity could be 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 do not repower. Future repowering of pipeline sites could play a role In later projection years but has not been modelled in the DFES 2022 due to significant uncertainty of repowering rates for future sites.

	Falling Short	System Transformation	Consumer Transformation	Leading the Way
Year delay	--	25		
Repowering	--	+25%		+50%
Added capacity (MW)	--	10		20

<table>
<tr><th colspan="4">Scenario projections (2030 to 2050)</th></tr>
<tr><th>Scenario</th><th>Description</th><th>Capacity by 2035</th><th>Capacity by 2050</th></tr>
<tr><td>Falling Short</td><td>Whilst still representing a significant increase from the baseline with 1 GW of capacity by 2050, slower progress towards the Scottish Government and Scottish STA targets is made under this scenario. Solar PV business models remain limited as developers focus on regions with higher solar irradiance. There are fewer opportunities for co-location, leading to less investment in new solar projects.</td><td>764 MW</td><td>1,057 MW</td></tr>
<tr><td>System Transformation</td><td rowspan="2">There is significant growth in both scenarios, seeing a similar amount of uptake reaching as much as 1.7 GW by 2035 – a near doubling of projections by this same year compared to DFES 2021. This increase is justified by a larger development pipeline, which sees post-pipeline projections out to 2050 starting from a higher position. This effect is shifting projections to earlier years to meet decarbonisation targets faster, while less growth is seen in later years. With few legacy sites, repowering plays a small role in the 2040s.</td><td>1,167 MW</td><td>2,015 MW</td></tr>
<tr><td>Consumer Transformation</td><td>1,214 MW</td><td>2,062 MW</td></tr>
<tr><td>Leading the Way</td><td>As with other net zero scenarios, projections are increased in the medium term, considering that most sites with planning evidence are built, regardless of current local planning regimes. In the late-2030s, this scenario also sees a continued ambitious deployment of large-scale solar farms, exploiting higher-performance solar technology and the potential for new business models from co-location with electricity storage and hydrogen electrolysis. With few legacy sites, repowering plays a small role in the 2040s. As targets are reached in the early 2040s, annual solar PV deployment slows in the licence area.</td><td>1,679 MW</td><td>2,450 MW</td></tr>
</table>

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The FES 2022 baseline is 104 MW compared to the DFES 2022 baseline of 41 MW. The reason for this is unclear, but DFES has had sight of up-to-date SSEN connections data, which could be more accurate for energised sites in the licence area than FES sources.
Pipeline	The DFES 2022 pipeline deviates from the FES 2022 immediately under **Leading the Way** and from 2024 onwards in **System Transformation** and **Consumer Transformation** and **Falling Short**. This is justified by the significant connection pipeline seen in the DFES data and the analysis method applied to identify sites that will likely be commissioned in the near term out to the late 2020s.
Projections	**Falling Short** closely aligns with the FES 2050 figure compared to DFES 2021, reflecting a slightly more optimistic view in the lowest ambition scenario, likely reflecting the significant pipeline in the licence area. The post-pipeline solar buildout under Consumer Transformation and System Transformation in the DFES 2022 falls in line with the FES; both projections closely align from the late 2030s onwards. Projections by 2050 deviate by c. 100 MW under these two scenarios. Under **Leading the Way**, overall projection trends align with the FES 2022 until the late 2030s, where the DFES sees an acceleration as projections meet the Scottish Government's ambitions by 2045.
Overarching Trend	The main trend in the DFES followed a more stepped approach, simulating a near-term uptick in growth with periods of flattening out, based on evidence of known projects seeking to connect in the near term and considerations around network capacity saturation. This contrasts with the FES, which sees a more steady, linear growth to 2050.

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[xxvii]	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 2022

Scenario		4.2.15 - 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 technologies that are low carbon. Supports production of hydrogen by electrolysis.

Incorporation of Stakeholder Feedback

Stakeholder feedback provided	How this has influenced our analysis
During the webinar events, stakeholders were asked how much of the solar pipeline would likely connect and under what timescale. Most responders responded that half of the pipeline would realistically connect. This was the case when views from renewable energy developers' responses were isolated. Stakeholders were also asked to provide views on the factors most important for driving a high deployment of large-scale solar PV in Scotland. The highest response was for sustained electricity prices, followed by UK Government and Scottish solar targets, with corporate emissions targets ranked third.	To reflect the spread of views around how much of the pipeline is likely to connect, we have included a range of pipeline projects connecting across the scenarios, with most connecting in **Leading the Way** and a much smaller proportion connecting under **Falling Short**. The feedback that sustained electricity prices is an important factor in future large-scale solar development is considered under the three net zero scenarios. Under **Falling Short**, electricity prices are assumed to be much more volatile, impacting the future rollout of solar projects from smaller developers that are more risk averse.
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.

[xvi] 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/
[xvii] NREL n.d., *Best Research-Cell Efficiency Chart* https://www.nrel.gov/pv/cell-efficiency.html
[xviii] 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
[xix] See Scottish Enterprise net zero framework, published June 2021: https://www.scottishenterprise.com/media/4044/net-zero-framework-for-action.pdf
[xx] 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
[xxi] UK Government 2022, *British Energy Security Strategy.* https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy#renewables
[xxii] Scottish Government 2023, *Draft Energy Strategy and Just Transition Plan*. https://www.gov.scot/publications/draft-energy-strategy-transition-plan/pages/5/
[xxiii] Solar Energy UK 2022, *Cross-party MSPs jointly call for solar target.* https://solarenergyuk.org/news/cross-party-msps-jointly-call-for-solar-target/
[xxiv] Renewable Energy Planning Database https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract
[xxv] Power Technology 2022, https://www.power-technology.com/marketdata/bilbo-farm-solar-pv-park-uk/
[xxvi] Solar 2 n.d., *Collace Solar Farm.* https://collacesolarfarm.co.uk/
[xxvii] Council Climate Plan Scorecards 2022, https://councilclimatescorecards.uk/

Small-scale solar PV

Summary of modelling assumptions and results

Technology specification

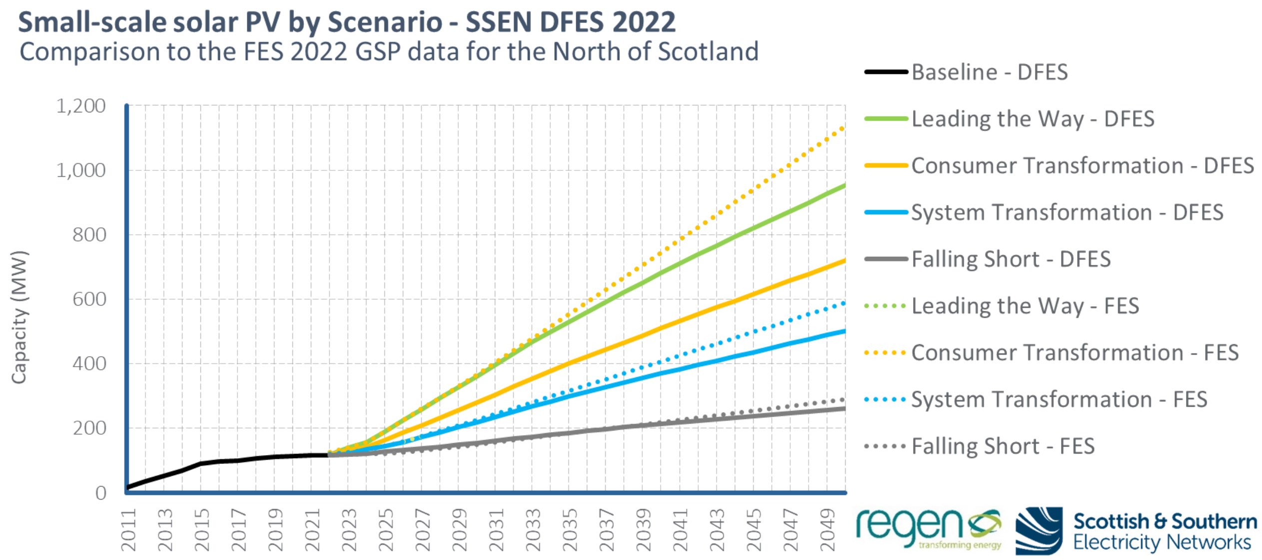
The analysis covers any solar generation sites of installed capacity less than 1 MW connecting to the distribution network in the North of Scotland licence area.

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

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

	Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Domestic (<10 kW)	Falling Short	75	80	101	126	149	169	187
	System Transformation		90	151	216	273	327	379
	Consumer Transformation		105	199	298	386	470	553
	Leading the Way		112	239	372	497	614	730
Commercial (10 kW – 1 MW)	Falling Short	41	49	54	60	65	70	75
	System Transformation		54	68	83	96	110	123
	Consumer Transformation		59	80	103	124	145	167
	Leading the Way		60	91	123	154	184	215

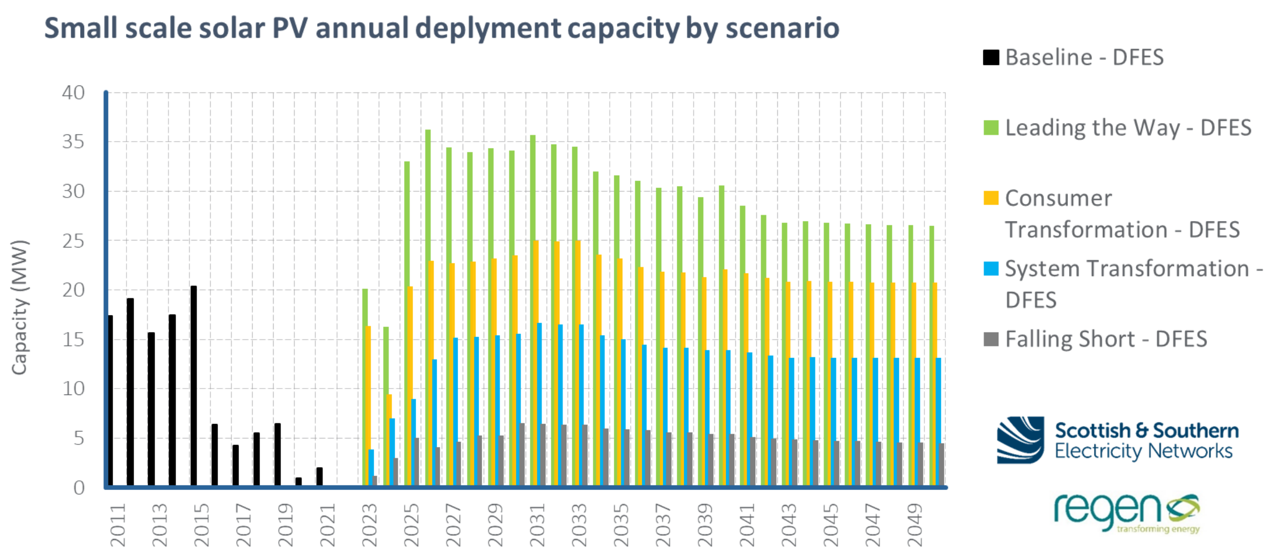
Figure 17: Small-scale solar PV projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections



Summary

- Domestic-scale solar PV has historically seen high uptake levels in the North of Scotland licence area, despite the lower irradiance levels than the rest of the country. Historical deployment is characterised by particularly high rates in the early years of the Feed-in Tariff and subsequently stalled following the scheme's closure.
- While the current baseline stands at 116 MW, whereas DFES 2021 had an estimated 91 MW, these figures are not directly comparable. Therefore, an updated method of considering connections data and Feed-in Tariff data at the ESA level has been included in this year's baseline analysis.
- The trajectory for small-scale solar in the near term may depend strongly on the uptake of the Smart Export Guarantee[xxviii] and the attractiveness of rooftop solar for homeowners regarding installation costs and savings from reduced wholesale electricity consumption.
- There is evidence that rooftop installations, especially on commercial premises, are undergoing a surge in demand, with developers highlighting a significant increase in demand for 0.05 – 0.15 MW commercial systems, retailers and trade bodies highlighting surging sales and installations.[xxix] This could relate to businesses seeking to reduce their electricity imports and reduce exposure to very high electricity costs.
- 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**, 762 MW of domestic and 190 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 five 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 since the end of the Feed in Tariff and 2050 deployment reaching 262 MW.

Figure 18: Annual small-scale solar PV projections for the North of Scotland licence area scenarios relative to the baseline annual deployment rate



Modelling and assumptions

Baseline (2021)		
Scale	**Total Capacity**	**Description**
Domestic (<10 kW)	75 MW	There are 75 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%. This represents a small increase from the 69 MW recorded in DFES 2021. Around 85% of these installations occurred between 2010 and 2015, supported by the Feed-in Tariff (FiT). The installation rate for rooftop solar in the licence area peaked at 18 MW installed in 2012. Deployment slowed notably as the FiT reduced and came to an end. To date, the Smart Export Guarantee has not significantly increased small-scale solar PV deployment beyond the levels seen after the closure of the FiT in 2015.
Commercial (10 kW – 1 MW)	41 MW	There are 41 MW of commercial rooftop PV baseline capacity in the North of Scotland licence area. As per domestic-scale installations, the FiT supported this deployment, and development has equivalently tailed off since 2016. This baseline is significantly higher than the 22 MW recorded in DFES 2021. While SSEN's connection data identifies approximately 2 MW of capacity connected post-January 2021, the reason for this increase is an updated means of considering connections data alongside FiT data. Where previously, FiT data was used to evidence pre-2015 deployment only, after which connections data was considered, DFES 2022 now uses a layered method, considering both datasets through the entire baseline period. A resultant maximum annual deployment on each ESA is taken forward into the baseline summation.

Pipeline (2022-2030)	
There are 69 sites totalling 11 MW with accepted or quoted connection offers in the licence area. These are **all commercial scale (10 kW – 1 MW) solar arrays**.	
Contracted	47 sites, totalling 8 MW of capacity, have accepted connection agreements in the North of Scotland licence area. All sites with accepted connection offers are modelled to connect in all scenarios. This is assumed to happen by 2023 under **Leading the Way** and **Consumer Transformation**, by 2024 under **System Transformation**, and by 2025 under **Falling Short**.
Quote Issued	22 sites, totalling 3 MW, have a connection quote issued, which have not yet been accepted. These sites are modelled to connect by 2024 under **Leading the Way**, **Consumer Transformation** and **System Transformation**. None of these sites are modelled to connect under **Falling Short.**

Rooftop solar PV on new homes

Rooftop PV on new build homes is modelled using the outputs of the DFES projections for new housing developments. Currently, around 10% of recently built homes in England have been built with rooftop solar PV installed[xxx]. This is used as a baseline metric for the North of Scotland licence area for all scenarios other than **Leading the Way**, which considers evidence suggesting that this could be significantly higher[xxxi] - at least 60% currently.

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[xxxii]. Scotland's recently approved National Planning Framework 4[xxxiii] has removed planning barriers to warehouse PV installations, which will affect commercial rooftop solar uptake.

Scenario	The proportion of new-build homes with rooftop solar PV		
	2025	2030	2050
Falling Short	6%	8%	20%
System Transformation	10%	20%	30%
Consumer Transformation	15%	30%	50%
Leading the Way	60%	70%	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.

In line with the FES 2022, the overall scenario trends established in the medium term continue to 2050, with annual deployment rates remaining relatively constant between 2026 and 2050.

There is a reduction in 2050 projections relative to DFES 2021, resulting from the updated method to determine new housing developments. This updated method has produced scenario-specific projections for new homes that are universally lower than the DFES 2021 new build projections. The resultant loss of projected domestic PV capacity is more significant in **Leading the Way** and **Consumer Transformation** – scenarios which assume higher percentages of new builds with solar PV. Small-scale solar capacity reaches just under 1 GW under **Leading the Way** and c. 260 MW under **Falling Short**.

Scenario	Description	Capacity by 2035	Capacity by 2050
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. The DFES 2022 projection is marginally higher in 2050 than in DFES 2021.	186 MW	262 MW

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 2022 projection is marginally lower in 2050 than in DFES 2021.	299 MW	502 MW
Consumer Transformation	Under Consumer Transformation and Leading the Way, high consumer ambition and engagement, 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 952 MW under Leading the Way. These projections are approximately 40 MW lower than the DFES 2021 analysis.	401 MW	720 MW
Leading the Way		495 MW	945 MW

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The updated DFES 2022 baseline aligns closely with the FES 2022 baseline.
Projections	As small-scale solar PV is more strongly driven by national considerations, support, policy and public adoption, the DFES 2022 aligns with the FES 2022 regional data regarding the spread between scenario projections. However, most DFES 2022 scenario projections are consistently lower that the FES 2022 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 2022 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 2022 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 2022.

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 83,000 new homes are projected to be built in the licence area between now and 2050. In Consumer Transformation (the highest deployment scenario), 50% of these new build homes could have a total of 78 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 2022

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	High	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
The DFES team engaged Dundee City Council, Aberdeenshire Council and AbSolar on their commercial-scale solar sites, enabling the analysis to reflect their build-out estimates in the scenarios.	AbSolar identified the G99 process as their main source of delay in bringing their sites through to connection; this has been considered a broader influencing factor for delayed uptake under **Falling Short**. AbSolar also stressed the high demand they were experiencing for 0.05 – 0.15 MW systems for commercial rooftops, which indicates the current appetite for commercial solar deployment, reflecting the cost of living crisis and very high electricity prices businesses are being affected by.
DFES 2022 continued to assume a high level of future ambition for solar PV in the licence area based on engagement with the Scottish STA in a previous DFES round.	The Scottish STA highlighted a high-ambition target for solar in Scotland that surpasses historic trends. The STA considered 6 GW 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

[xxviii] Ofgem 2022, *Smart Export Guarantee.* https://www.ofgem.gov.uk/environmental-and-socialschemes/smart-export-guarantee-seg
[xxix] Business Green 2023, *Solar industry celebrates 'spectacular' surge in rooftop installations.* https://www.businessgreen.com/news/4076504/solar-industry-celebrates-spectacular-surge-rooftop-installations
[xxx] Solar Energy UK 2021, *Future homes are solar homes.* https://solarenergyuk.org/future-homes-are-solar-homes/
[xxxi] Solar Energy UK 2021, Scottish Building Regulations. https://solarenergyuk.org/wp-content/uploads/2021/11/SEUK-response-Scottish_Building-Regulation.pdf
[xxxii] 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.
[xxxiii] 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.

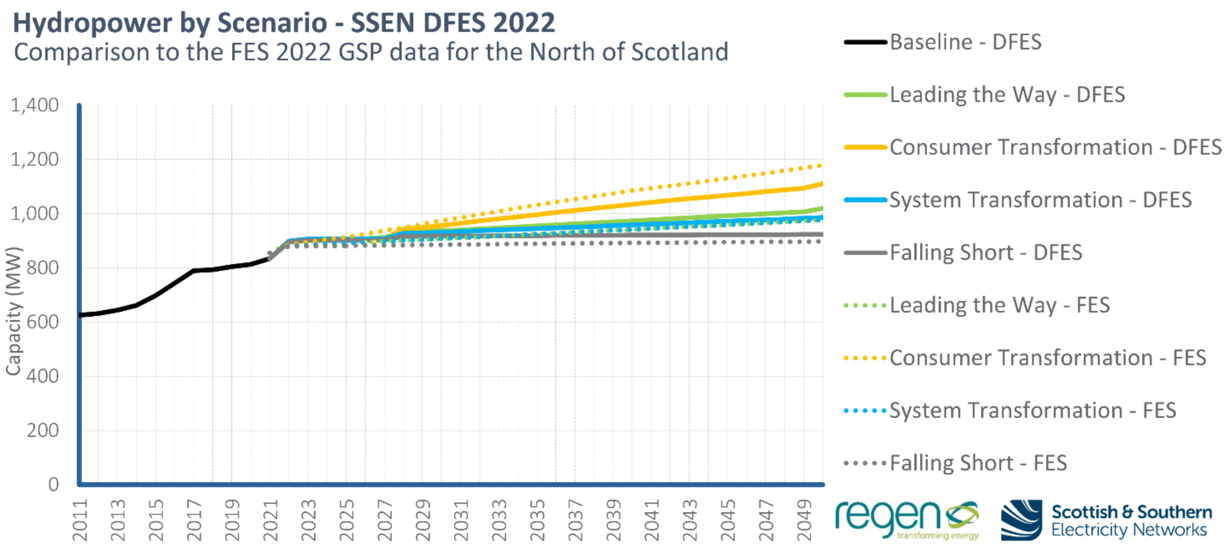
The analysis does not include pumped hydropower, which is considered an energy storage technology.

Network technology data 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	835	901	917	919	921	922	924
System Transformation		908	932	945	958	972	986
Consumer Transformation		908	957	996	1,034	1,068	1,110
Leading the Way		908	937	955	974	992	1,020

Figure 19: Hydropower projections for the North of Scotland licence area, compared to National Grid FES 2022 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 835 MW, across 608 sites.
- The pipeline for the North of Scotland comprises 32 sites. All of these sites, except for a 52 MW capacity addition, are less than 3 MW. The average size, excluding the large capacity site, is 0.85 MW.
- 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[xxxiv]. Geospatial mapping of catchment area resources in the licence area suggests a high ambition 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 (with the closure of the feed-in tariff), discount rates and abstraction licence costs.
- The UK Hydropower Resource Assessment 2022[xxxv] report confirms that hydropower deployment is highly dependent on the site's economic viability and market forces within the Scottish Government and the UK government's control.
- Small-scale sites are seeing continued improvements as technology increases efficiency, and the possibility of co-located batteries can increase their economic viability[xxxv].
- The analysis has reflected a more ambitious uptake of new hydro projects in the **Consumer Transformation** and **Leading the Way** scenarios, showing an increase of c. 180-280 MW by 2050 across these scenarios.

Modelling and assumptions

Baseline (2022)			
Scale	**Number of Sites**	**Total Capacity**	**Description**
Total	608	835 MW	18 sites, totalling 470 MW (57% of baseline capacity), were installed before 2002.
1 MW and above	109	706 MW	Since 2002, 63 projects with a capacity of greater than 1 MW have been developed. However, only 3 of these sites were larger than 5 MW, with an average capacity being c. 2.4 MW.
Below 1 MW	499	129 MW	The majority of the 499 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 (69 sites) has been connected since 2017.

Pipeline (2022-2030)	
Number of pipeline sites	**Total capacity**
32	78.31 MW

Pipeline analysis			
Status	**Description**	**Sites**	**Capacity**
Operational in 2022	The majority of the capacity for sites that became operational in 2022 came from the 52 MW Lochaber project that began operation in early 2022.	3	53.15 MW
Under Construction	Four medium-scale hydropower sites totalling 5.8 MW were found to be currently under construction. All are within the Highland local authority area. Six other pipeline sites totalling c. 2.6 MW were also found to be currently under construction in the licence area.	10	8.45 MW

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. The lowest capacity site is in Highland and is an additional capacity (0.125 MW).	7	5.77 MW
Planning Application withdrawn	An application for a small 100 kW project located in Argyll and Bute was withdrawn.	1	0.1 MW
No information	No information could be found for the remaining ten pipeline sites. These are generally small-scale, with an average capacity of 0.45 MW. The largest of the projects is a 2.2 MW project in the Perth and Kinross licence area.	10	4.35 MW
Other notes	The Tummel Bridge project added 6.46 MW of additional capacity to their existing site, which did not require planning permission. A press release confirmed the site extension is expected to be completed in 2023.	1	6.46 MW *(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[xxxvi]. This methodology has been developed further from DFES 2021, and as a result, all scenarios have seen a slight but not significant increase in total capacity by 2050.

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

Scenario Projections (2030 to 2050)

Scenario	Description	Capacity by 2035	Capacity by 2050
Falling Short	Under this scenario, only pipeline projects currently under construction are modelled to come online, with a delay factor added. This projection is slightly higher than the DFES 2021 due to a larger contracted pipeline overall and a change in pipeline logic applied.	919 MW	924 MW
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.	945 MW	986 MW

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[xxxvii] and assumptions that economic policies will be developed to support small-scale renewable technologies such as hydropower.	996 MW	1,110 MW
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.	955 MW	1,020 MW

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The FES 2022 baseline for distributed hydropower in the North of Scotland is 856 MW, 29 MW higher than the identified baseline in the DFES 2022 analysis. A similar variance seen in DFES 2021, despite uplifts in connected capacity across FES and DFES in 2022. The reason for variance is unclear.
Pipeline	The DFES 2022 models a similar near-term growth in hydropower to the FES 2022 in all scenarios except for Consumer Transformation, which shows a slightly lower near-term deployment than in the FES. The DFES reflects a site-specific analysis of planning data.
Projections	The FES 2022 **Falling Short** scenario shows similarly limited growth to 2050, as reflected in the DFES. Under Leading the Way, the DFES projections deviate from System Transformation to account for an analysis of planning friendliness and untapped hydropower resources in the licence area under this scenario. The FES 2022 scenario with the most sustained growth is Consumer Transformation reaching more than 1.2 GW by 2050. This is ~75 MW higher than that projected in the DFES 2022 and is likely based on a more ambitious view of resource availability in the licence area.
Overarching Trend	DFES 2022 scenarios see new capacity added at a faster rate in the near term, but the projections out to 2050 are largely in line with FES 2022.

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 2022

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 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 from 2021.	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.

[xxxiv] 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

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

[xxxvi] 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

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

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 (EMEC) to identify potential pipeline projects that will likely connect to the distribution network out to 2050. If the technology proves successful at a commercial scale, additional marine generation capacity is very likely to connect to the transmission network.

The technologies included in the DFES marine energy analysis are:

• Wave energy – typically connected to the distribution network as small pre-commercial arrays and demonstration projects.

• Tidal stream energy – harnessing kinetic tidal flows around headlands and in channels.

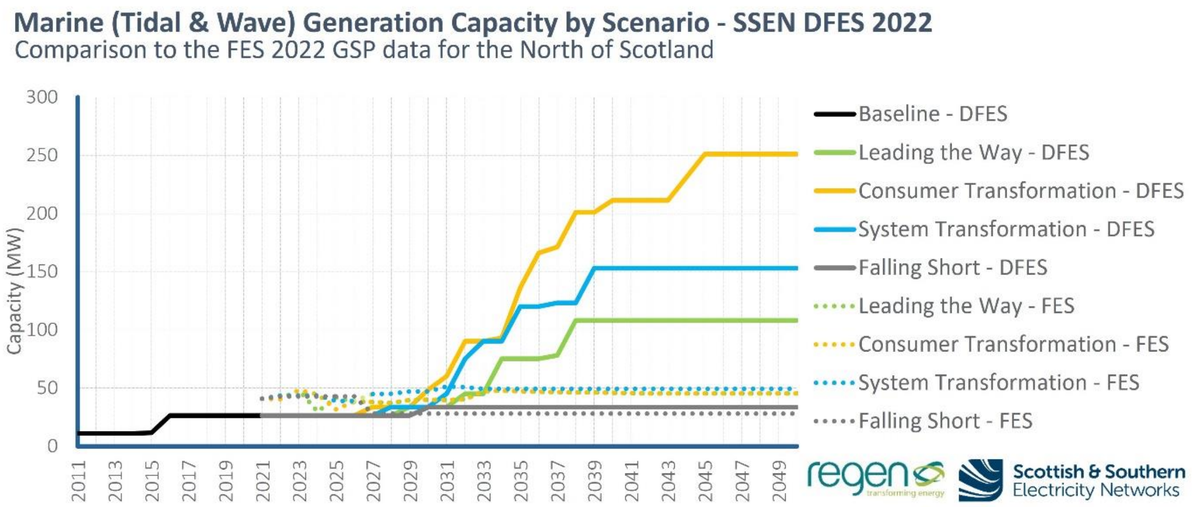
Note: there are no tidal lagoon projects in the licence area, but these would connect at transmission network level.

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	26	26	34	34	34	34	34
System Transformation		26	34	120	153	153	153
Consumer Transformation		26	49	136	211	251	251
Leading the Way		26	34	75	108	108	108

Figure 20: Marine generation projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections



Summary

- There are five connected marine generation projects in the North of Scotland licence area, totalling 26 MW. In addition, three tidal stream projects, totalling 13.5 MW, have secured connection agreements. The EMEC wave and tidal test sites have received quotations for expanding site capacity by 58 MW.
- In July 2022, the results of the Contracts for Difference (CfD) Allocation Round 4 were announced, which included a ring-fenced budget of £20m for tidal stream. Over 40 MW of projects succeeded in winning their first CfD at a strike price of £178.54/MWh (15% lower than the administrative strike price of £211/MWh). Over 35 MW of CfDs went to projects in the North of Scotland licence area – including SAE's MeyGen Phase 2 (28 MW, transmission-connected)[xxxviii] and Orbital Marine Power's Eday 1 & 2 (7.2 MW, distribution-connected)[xxxviii].
- These results have reignited activity within the marine generation industry, but further development will depend on continued policy support and the industry's ability to reduce technology costs.
- Beyond the known pipeline, additional capacity has been modelled at both commercial and test facilities. This projected future capacity is modelled at the most viable locations, reflecting further development of mature and viable tidal stream technologies.
- 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 (2021)

Technology	Number of Sites	Total Capacity	Description
Total	5	26 MW	The baseline is made up of
Wave	1	7 MW	A 7 MW installation is located at EMEC's wave energy test site at Billia Croo on the island of Orkney.
Tidal Stream	4	19 MW	There are three small pre-commercial tidal arrays: SAE's MeyGen site (14.9 MW), Nova Innovation's Cullivoe Tidal berth (45 kW) and larger Shetland Tidal Array (0.5 MW), and the EMEC Eday test site (4 MW).

Pipeline (2022-2030)

Number of pipeline sites	Total capacity
6	71 MW

Pipeline analysis

Status	Description	Sites	Capacity
Planning Permission Granted	4 sites have planning permission in the licence area: Sound of Islay (10 MW), MeyGen[xxxix] (0.3 MW additional capacity), EMEC Billia Croo[xl] wave test facility (30 MW) and the first expansion phase of EMEC Eday[xli] tidal test facility (3.2 MW).	4	43.5 MW

No information	No development or planning information could be found for phases 2 and 3 of EMEC's Eday tidal test facility (4.8MW and 22.8MW) beyond the previously mentioned 3.2 MW pipeline site with planning permission granted.	2	27.6 MW

Scenario Projections (2030 to 2050)			
Scenario	**Description**	**Capacity by 2035**	**Capacity by 2050**
Falling Short	Low support for tidal stream means that ring-fenced budgets for tidal stream in future CfD Allocation Rounds are dropped under this scenario. Only existing CfD-winning, distribution network-connected projects are completed, while others struggle to get off the ground without further subsidy support. As a result, capacity only moderately grows to 34 MW by 2050.	34 MW	34 MW
System Transformation	Under this scenario, support for larger-scale technologies and projects, likely via future CfD rounds, leads to further expansion in the 2030s at several prospective sites around the Scottish coast, ranging from 3 MW to 30 MW: • EMEC - Fall of Warness, • Westray South/Duncansby Head (Phase 1) • Nova - Yell Sound site • Nova - Oran na Mara whiskey distillery site • EMEC - Billia Croo wave test facility • West Islay Tidal Marine Energy Park.	120 MW	153 MW
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 considered in **System Transformation**, further expansion at Westray South and development of projects at the Sound of Islay, Lashy Sound, Mull of Kintyre and Churchill Barriers (25 MW). Total capacity reaches 251 MW by 2050, which equates to c. 67% of the FES GB projection for distributed marine generation in 2050.	136 MW	251 MW
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 in the late 2030s at Orbital Marine Power's Eday and Westray South deployments, EMEC's tidal and wave test facilities and Nova Innovation's Oran na Mara site.	75 MW	108 MW

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The FES 2022 baseline (41 MW) is 15 MW higher than the DFES 2022 baseline (26 MW). 5 MW of the FES 2022 baseline is connected to the Lairg GSP, which likely relates to the Shin Hydro scheme. The remaining difference is due to different capacity levels connected to Thurso GSP. This could be explained by the recent section 36 consent awarded to EMEC that will increase the capacity of the Billia Croo wave energy test site from 7 MW to 20 MW.
Pipeline	Based on the most recent connection data and stakeholder engagement, we have identified and modelled several specific pipeline projects that are not reflected in national FES 2022 projections. As a result, marine generation capacity in the DFES 2022 starts at a lower baseline than the FES 2022 but reaches 75-136 MW in 2030 (scenario dependent, excluding **Falling Short**) in the DFES 2022, compared to 47-49 MW in the FES 2022.
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 2022. Under **Consumer Transformation**, the FES 2022 remains at 45 MW by 2050, accounting for only 12% of all GB distribution network-connected marine energy capacity in 2050 (according to FES 2022 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.
Overarching Trend	The DFES models marine generation capacity based on knowledge of the site and company-specific activity and where increased capacity is most likely to occur. Whereas the FES 2022 projects a more constant distribution-connected capacity, the DFES 2022 considers the potential for marine energy to expand through CfD support, 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
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 2022

Scenario	4.1.2 - Other renewables including marine and hydro generation	
Falling Short	Low	Low support and therefore other renewables cannot complete 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 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] Low Carbon Contracts n.d., *CfD Register*. https://www.lowcarboncontracts.uk/cfd-register/
[xxxix] SAE Renewables n.d., *Meygen.* https://saerenewables.com/tidal-stream/meygen/
[xl] European Marine Energy Centre Ltd. (EMEC) 2023, *EMEC Streamline Wave Energy Consenting At Billia Croo.* https://www.emec.org.uk/emec-streamline-wave-energy-consenting-at-billia-croo/
[xli] 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

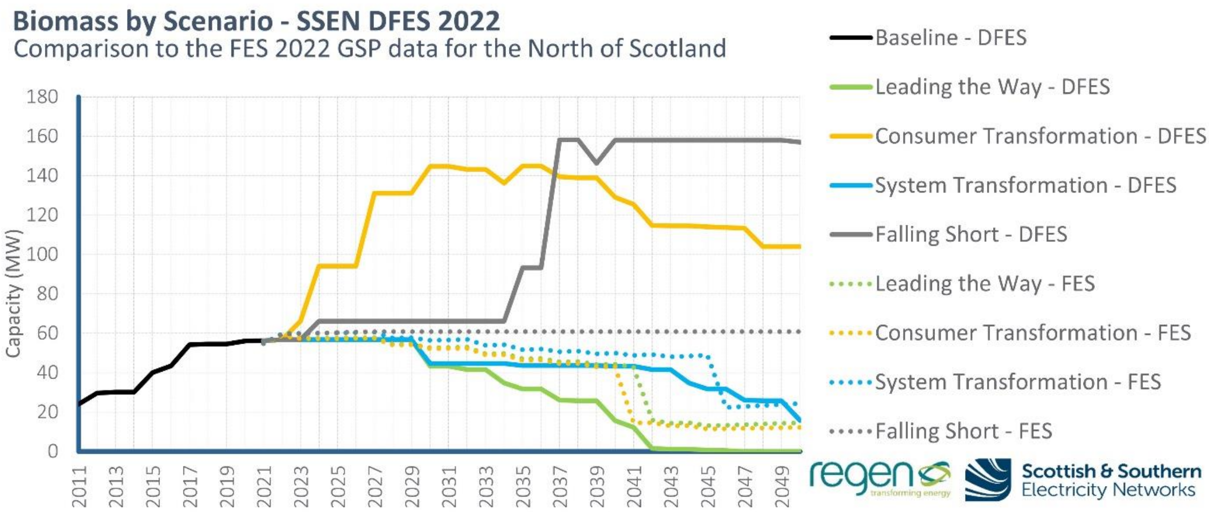
The analysis covers biomass-fuelled generation connecting to the distribution network in the North of Scotland licence area. This includes both biomass for power generation and biomass CHP. However, the analysis does not include biomass used solely for heat or bioenergy generation with carbon capture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

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

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

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	56	66	66	93	158	158	157
System Transformation		57	45	44	43	32	16
Consumer Transformation		94	145	145	129	114	104
Leading the Way		57	43	32	16	1	0

Figure 21: Biomass generation projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections



Summary

- The North of Scotland licence area has significant local biomass resource as a by-product of the forestry industry across the region. As a result, the licence area has a large 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, or larger-scale commercial plants developed for power generation.
- 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[xlii].

- Under **Consumer Transformation** and **Falling Short**, some Scottish Island diesel backup generators are modelled to be replaced with biomass engines, making up the majority of growth in this scenario from 2025 onwards.
- Under the UK Biomass Policy Statement[xliii], 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 sites.
- In 2021, the UK Government issued a call for evidence to consult on the removal of the 300 MW threshold for Carbon Capture Readiness requirements. If this removal goes through, small-scale distributed biomass as a business model will become increasingly challenging without further subsidy support.
- **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 2046. Only 16 MW remains connected by 2050 under **System Transformation**.
- **Consumer Transformation** and **Falling Short** see some sites connecting where positive planning evidence was found. Only one site decommissions in **Falling Short**, combined with replaced diesel island backup generators, bringing capacity to 157 MW by 2050, whereas several decommission in the longer term under **Consumer Transformation**. The conversion of diesel backup sites also outweighs the loss of decommissioned sites, bringing capacity to 104 MW by 2050 under this scenario.

Modelling and assumptions

<table>
<tr><th colspan="4">Baseline (2021)</th></tr>
<tr><th>Number of Sites</th><th>Total Capacity</th><th colspan="2">Description</th></tr>
<tr><td>20</td><td>56 MW</td><td colspan="2">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.</td></tr>
<tr><th colspan="4">Pipeline (2022-2030)</th></tr>
<tr><th colspan="2">Number of pipeline sites</th><th colspan="2">Total capacity</th></tr>
<tr><td colspan="2">3</td><td colspan="2">9.9 MW</td></tr>
<tr><td colspan="4">There are three pipeline sites included in the analysis totalling 9.9 MW. The majority of this pipeline capacity stems from the 9.4 MW Arjowiggins New Energy Centre at the Stoneywood Papermill in Aberdeen[xliv]. This site has already secured a connection agreement with SSEN and has been modelled to connect under Consumer Transformation. The other two sites (totalling c. 500 kW) were identified in planning but have not yet secured connection agreements with SSEN. However, as both have been granted planning permission, they have been modelled to connect in 2022 in all scenarios.</td></tr>
<tr><th colspan="4">Decommissioning Logic</th></tr>
<tr><td colspan="4">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.</td></tr>
<tr><th>Falling Short</th><th>System Transformation</th><th>Consumer Transformation</th><th>Leading the Way</th></tr>
<tr><td>50 years</td><td>35 years</td><td>25 years</td><td>25 years</td></tr>
</table>

Scenario Projections (2030 to 2050)			
Scenario	**Description**	**Capacity by 2035**	**Capacity by 2050**
Falling Short	Biomass capacity remains relatively stable out to 2050, assuming that existing plants are replaced or refurbished as frequently as they are decommissioned.	93 MW	157 MW
System Transformation	Baseline biomass sites decommission in line with net zero targets out to 2025. In **Consumer Transformation**, 104 MW of biomass generation is installed on Scottish Islands to replace existing unabated diesel engine assets. 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.	44 MW	16 MW
Consumer Transformation		145 MW	104 MW
Leading the Way	Under **Leading the Way,** there is no operational biomass electricity fuelled generation in the licence area by 2050.	32 MW	0 MW

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The DFES 2022 baseline aligns with FES 2022 at 56 MW.
Pipeline	The DFES captures some small pipeline sites that FES 2022 potentially does not have sight of. This results in a. increase in capacity in DFES 2022 under **Consumer Transformation** and **Falling Short**.
Projections	Under DFES 2022, **Leading the Way** fully decommissions all biomass capacity by 2042, whereas FES models at least 12 MW of capacity remaining online by 2050 under all scenarios. **System Transformation** projections largely align between FES and DFES; in both, a similar amount of capacity decommissions, but in slightly different years. The largest variance in long-term projections is seen under **Consumer Transformation** and **Falling Short**, which may relate due to the DFES approach to modelling the transition of Scottish Island diesel engines to biomass.

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 2022

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 2022.	

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

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**	35	36	35	18	16	15	13
	System Transformation		35	20	19	19	17	17
	Consumer Transformation		33	21	21	22	23	24
	Leading the Way		35	35	36	38	40	41

Figure 22: Renewable Engines projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections

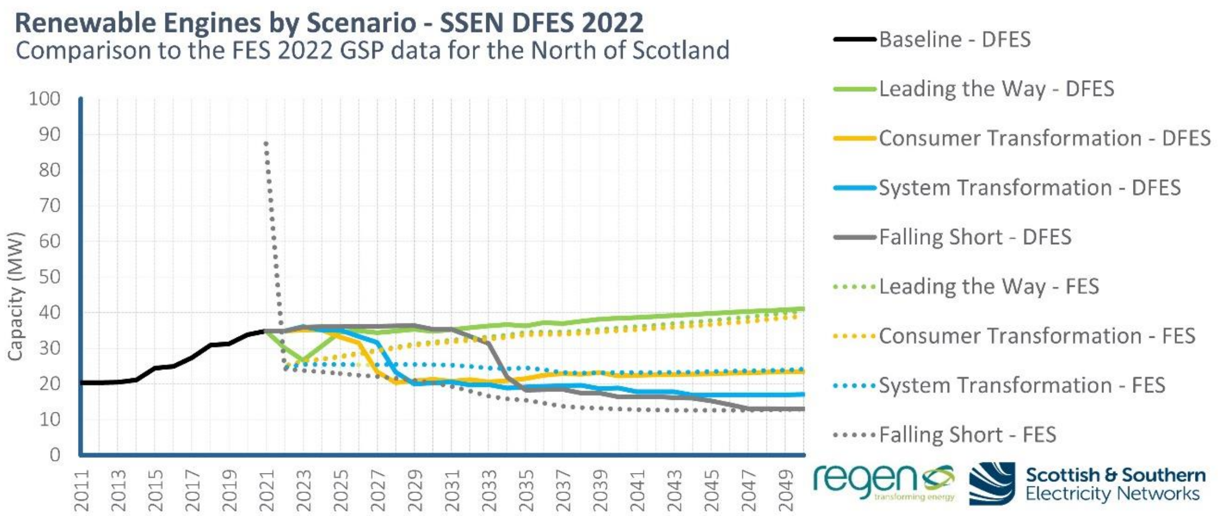
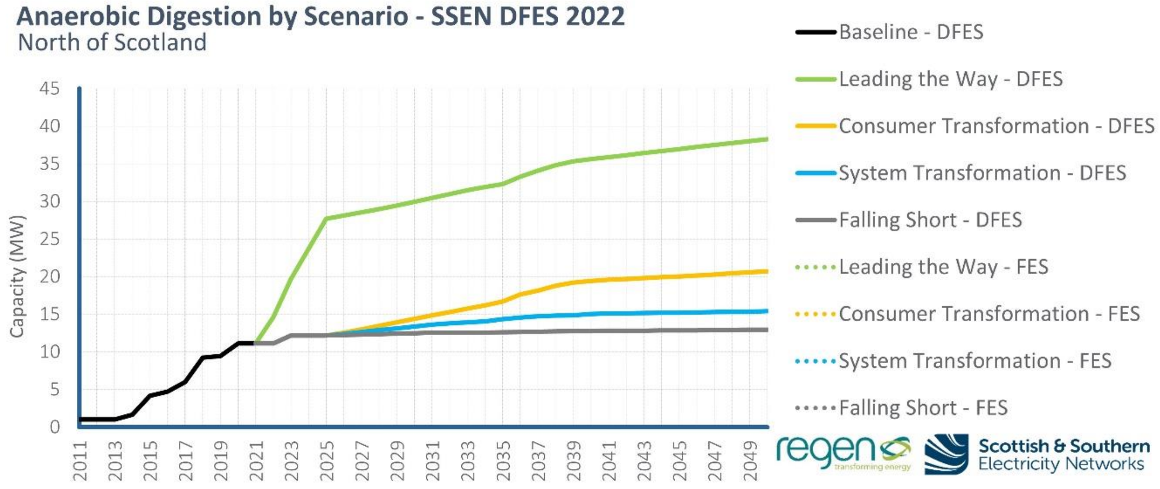
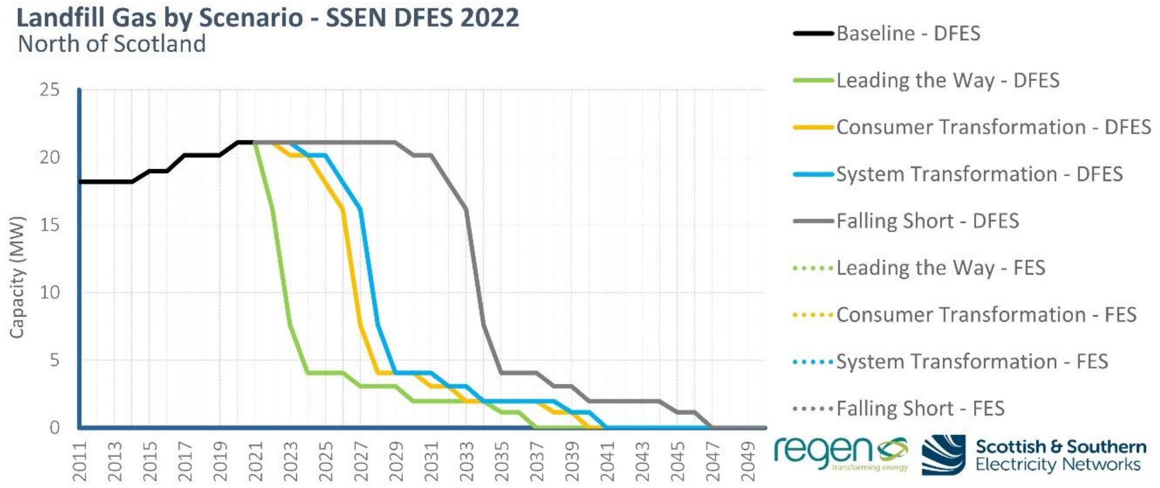
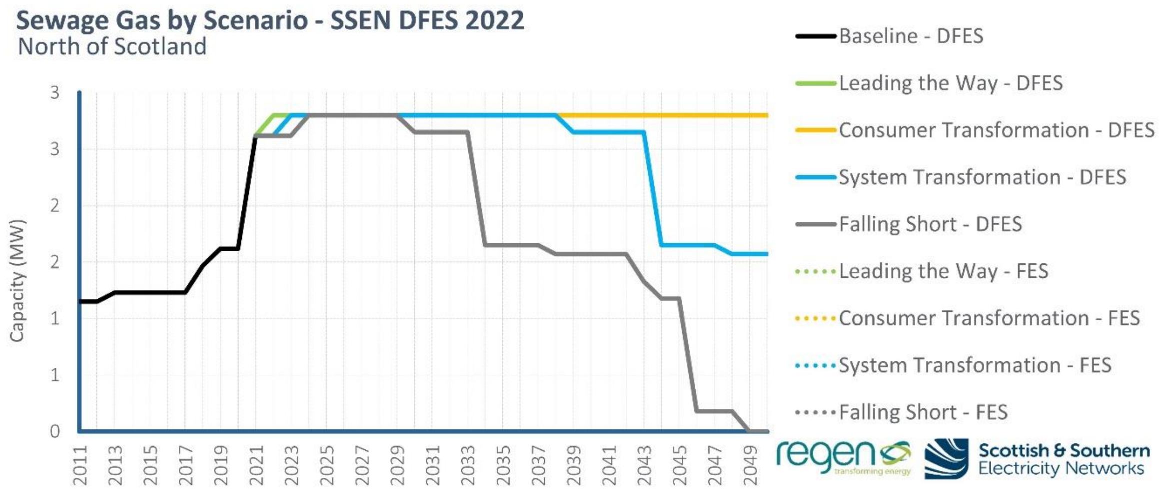


Figure 23: Renewable Engines projections for the North of Scotland licence area, by sub technology



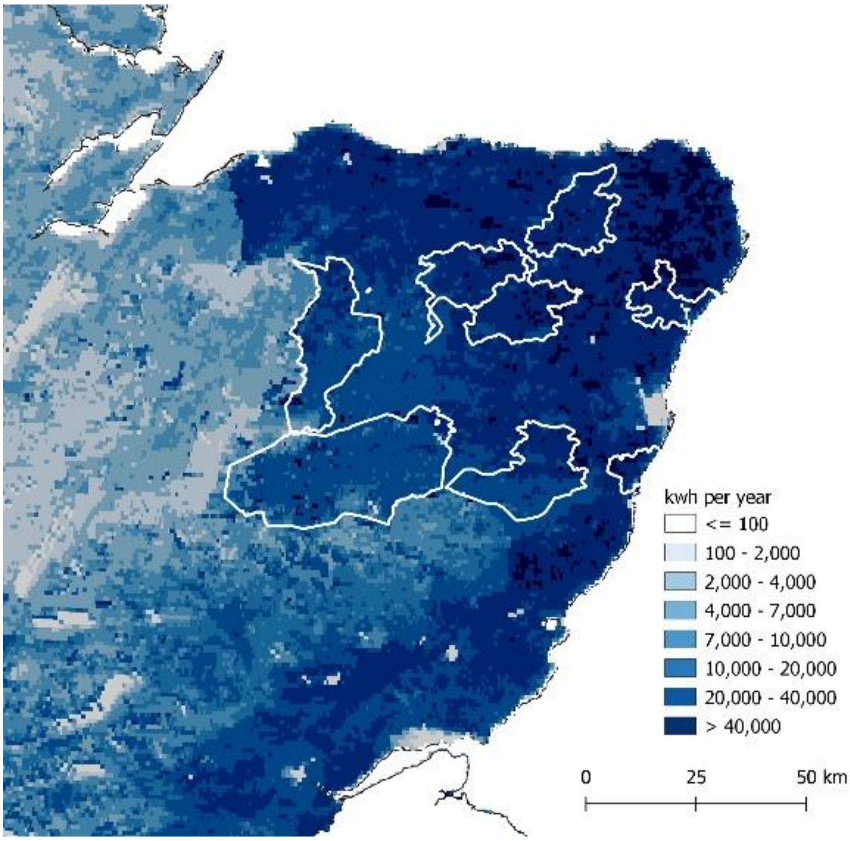




Summary

- As of the end of 2021, there was 35 MW of installed renewable engine capacity in the licence area, of which 11 MW was anaerobic digestion (AD), 21 MW was landfill gas, and 3 MW was sewage gas.
- 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 4% of all viable land in GB.
- According to Regen's manure resource assessment analysis, there is a high concentration of resource in Aberdeenshire, Moray and Angus.
- Landfill gas is expected to decrease over time due to the ban on landfills in Scotland[xlv], leading to a gradual decommissioning by 2047 of all landfill sites under all scenarios.
- Sewage gas remains at similar levels under net zero scenarios to today but is modelled to decommission over time under **Falling Short**.
- 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[xlvi], funded through payments made by licenced gas suppliers under the Green Gas Levy. This may limit the amount of future electricity distribution connected sites.
- Under **Leading the Way**, overall renewable engine capacity gradually increases, reaching 41 MW by 2050.
- All other scenarios see some decommissioning of landfill gas, without the replacement of this capacity with new AD sites, decreasing to 24 MW, 17 MW and 13 MW by 2050 under **Consumer Transformation**, **System Transformation** and **Falling Short** respectively.

Figure 24: Anaerobic Digestion potential from animal manure in Aberdeenshire.



Note: ESAs with the highest concentration of energy generation capacity from animal manure have been outlined in white.

Modelling and assumptions

Baseline (2021)		
Number of Sites	**Total Capacity**	**Description**
42	35 MW	The baseline consists of 35 MW from 42 sites, 11 MW of which is AD, 21 MW from landfill gas, and 3 MW from sewage gas. The majority of anaerobic digestion 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 (2022-2030)	
Number of pipeline sites	**Total capacity**
8	17 MW
There are eight pipeline sites in various planning stages; all sites are AD facilities, except for one sewage gas site of 180 kW. Two sites come from the SSEN connections data, whereas the remaining six were identified by analysing the Renewable Energy Planning Database (REPD). It remains uncertain how likely it will be that the six sites without SSEN connections offers will connect to the distribution network or operate as off-grid sites for either on-site electricity generation or as biofuel production facilities.	

Pipeline sites			
Status	**Description**	**Sites**	**Capacity**
Under Construction	Two anaerobic sites are currently under construction, one at Portgordon Maltings in Moray (1 MW)[xlvii] and another at a Brewdog property at Balmcassie Commercial Park in Ellon, Aberdeenshire (3.5 MW). The latter became operational in June 2022[xlviii] and will deliver fuel for delivery vehicles on-site and export the remaining to the grid. As this site was not visible in SSEN connection data, it has only been modelled to connect in 2022 under **Leading the Way**.	2	4.5 MW
Planning Permission Granted	Four sites have been identified with granted planning permissions in the REPD but are yet to secure connection agreements. As a result, they have only been modelled to come online under **Leading the Way**, whereas, under other scenarios, they are assumed to commission as off-grid sites. One such site is a 2 MW extension to the Portgordon Maltings site currently under construction in Moray. The largest site is Academy Road Energy Centre & Anaerobic Digestion Facility in Invergordon (4 MW).	4	10 MW
Planning Application Submitted	One site submitted a planning application in Dalcross, Inverness, in 2022 (2 MW). It is unclear If it will apply for an electricity grid connection, and thus only modelled under **Leading the Way**.	1	2 MW
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 due to its small size and limited impact on the network.	1	180 kW

Decommissioning Logic				
Landfill gas and sewage gas are modelled to disconnect in some scenarios. AD is modelled to stay online in all scenarios out to 2050. Landfill gas sites are modelled to decommission rapidly in response to the Scottish ban on landfill sites[xlix], as waste management shifts to incineration and Advanced Combustion Technologies (ACT).				
	Falling Short	System Transformation	Consumer Transformation	Leading the Way
Landfill gas	30 years	24 years	23 years	20 years
Sewage gas	25 years	35 years	--	--

Scenario Projections (2030 to 2050)

AD is 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 sites with high concentrations of animal husbandry and agricultural land that could produce manure and 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 38 MW under **Leading the Way**. Sewage gas sites are expected to remain at current levels under **Leading the Way** and **Consumer Transformation** but decommission at the end of their current operational lifespans under **System Transformation** and more quickly under **Falling Short**.

Scenario	Anaerobic digestion capacity by		Landfill gas capacity by		Sewage gas capacity by	
	2035	2050	2035	2050	2035	2050
Falling Short	13	13	4	0	2	0
System Transformation	14	15	2	0	3	2
Consumer Transformation	17	21	2	0	3	3
Leading the Way	32	38	1	0	3	3

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The FES 2022 baseline (87 MW) is significantly different to both the FES 2021 baseline (36 MW) and the DFES 2022 baseline (35 MW). This, plus the sharp decommissioning to 25 MW in 2022 after the baseline year, cannot be accounted for in the SSEN connection data. Therefore, the reason for this significant variance is unclear.
Pipeline	Not including the significant baseline variance, projections across the 2020s are partially in line. However, some variance is seen 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. 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.
Regen manure feedstock resource assessment	The Regen in-house manure feedstock resource assessment uses a rasterised geospatial dataset[l] to estimate the density of livestock and manure produced in the licence area. Conversion factors[li] are then used to estimate the theoretical potential energy produced in kWh.
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 2022

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 Transformation	Medium	Bigger push for renewable gas as required to meet longer-term 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
As part of the DFES analysis of new property developments, 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.

[xlv] Resource 2019, *Scottish Government to Delay Scottish Landfill Ban to 2025*. https://resource.co/article/scottish-government-delay-scottish-landfill-ban-2025
[xlvi] 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
[xlvii] Planning Alerts 2021, *Planning Application: 21/01695/APP*. https://planning.org.uk/app/217/R0NARWBGIPZ00
[xlviii] Edie 2022, *BrewDog unveils £12m anaerobic digestor to create green gas for its Ellon brewery*. https://www.edie.net/brewdog-unveils-12m-anaerobic-digestor-to-create-green-gas-for-its-ellon-brewery/
[xlix] Scottish Environment Protection Agency 2012, *Biodegradable municipal waste landfill ban.* https://www.sepa.org.uk/regulations/waste/landfill/biodegradable-municipal-waste-landfill-ban/
[l] Harvard Dataverse 2010, *Gridded Livestock of the World database (GLW 3).* https://dataverse.harvard.edu/dataverse/glw
[li] Scarlat et al 2018, *A spatial analysis of biogas potential from manure in Europe.* https://www.sciencedirect.com/science/article/pii/S1364032118304714

Waste-fuelled generation

Summary of modelling assumptions and results

Technology specification

The analysis covers all forms of electricity generation from waste, including both incinerators and Advanced Conversion Technologies 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

Technology	Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
Incineration	Falling Short	19	82	73	73	73	73	63
	System Transformation		82	73	73	63	63	--
	Consumer Transformation		75	73	73	63	--	--
	Leading the Way		75	66	56	56	--	--
Advanced Conversion Technologies (ACT)	Falling Short	--	--	9	9	9	9	19
	System Transformation		--	9	9	19	19	35
	Consumer Transformation		--	9	9	19	35	35
	Leading the Way		--	9	19	19	35	35

Figure 25: Waste-fuelled generation projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections

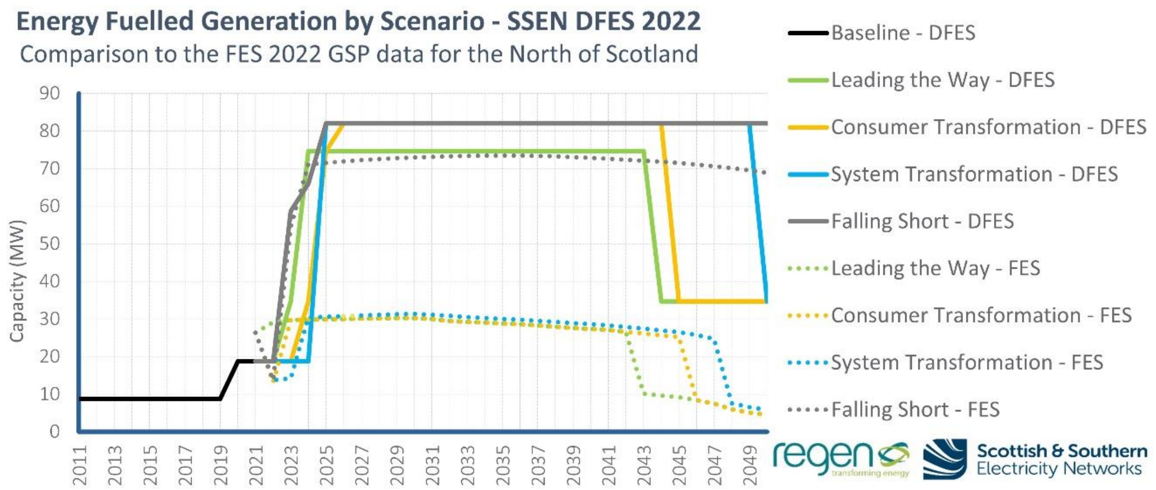
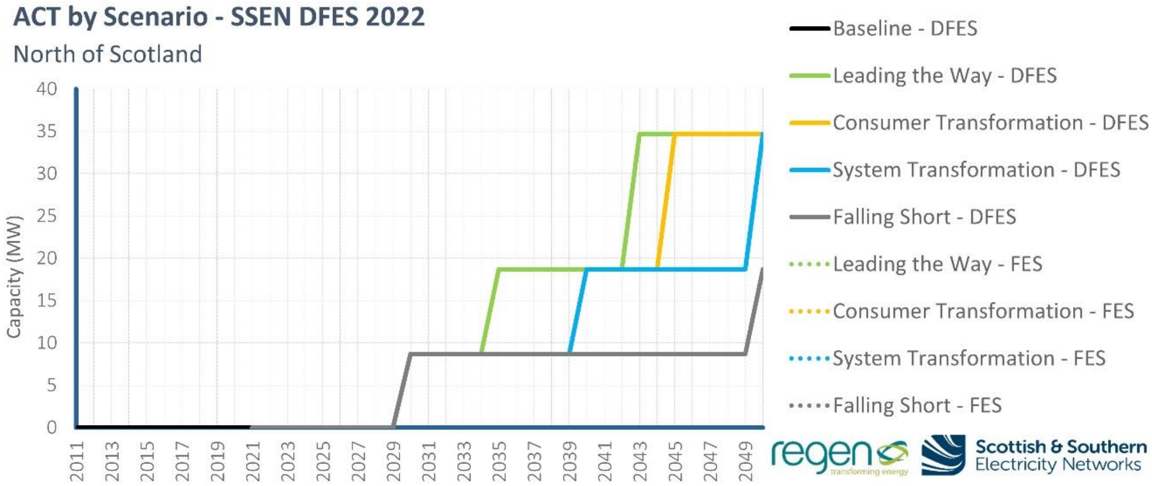
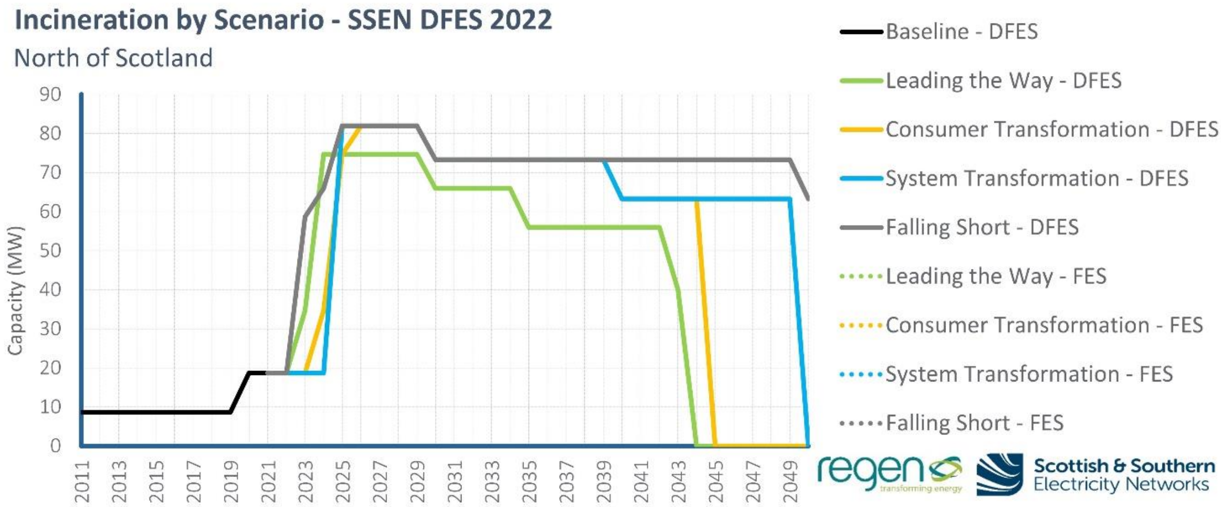


Figure 26: Waste-fuelled generation projections for the North of Scotland licence area, by subtechnology





Summary

- There is currently 19 MW of waste fuelled generation operating in the licence area, all from incineration plants. There is a pipeline of 63 MW of potential additional waste incineration plants with accepted connection offers in the licence area, some of which have secured planning approval.
- The carbon emissions from older unabated waste incineration plants are not consistent with net zero emissions targets. As a result, in the DFES 2021 scenarios that meet net zero targets, it is assumed that connected incineration plant capacity reduces after 2030 as older facilities reach the end of their lifetime. Some of these sites were considered to be replaced with new, lower-carbon ACT installations.
- Baseline incineration sites are modelled to decommission between 25 and 30 years after commissioning, depending on the scenario. The planned commissioning of new incineration sites in the pipeline means some sites decommission quite late into the 2040s. Only new incineration sites with positive planning evidence are modelled to connect.
- 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[31], which breaks down organic waste material using bacteria to produce biogas
    - Gasification, which uses high temperatures to convert solid waste into a gas

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

    - 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 related to waste technology include the extent to which they are considered consistent with decarbonisation objectives, planning issues related to air quality and the volume of waste that could be reduced or recycled, limiting resources for future ACT sites. There is an additional uncertainty as to how much capacity will be distribution-network connected.
- By 2050, all three net zero scenarios see waste fuelled generation levelling out at 35 MW of installed capacity remaining operational, with less demand for waste treatment needed overall in a waste-conscious society. Under **Falling Short**, waste-fuelled generation capacity continues to grow, reaching 82 MW by 2050, most of which is incineration.

Modelling and assumptions

Baseline (2021)		
Number of Sites	**Total Capacity**	**Description**
1	19	There are two baseline entries in the licence area, both incineration capacities 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.

Pipeline (2022-2030)	
Number of pipeline sites	**Total capacity**
3	63.3 MW
All three pipeline sites identified are waste incineration facilities. This increase in active incineration pipeline projects in the licence area may be linked to the ban on waste landfills, expected to be implemented in 2025[lii]. There were no known ACT sites in the pipeline in the North of Scotland licence area as of mid-2022, and any sites identified in the Renewable Energy Planning Database were expired.	

Pipeline sites			
Name	**Description**	**Planning status**	**Capacity**
Thainstone Energy Park	Due to being located in Inverurie in Aberdeenshire, this site is the largest in the waste generation pipeline and is modelled to connect between 2023 and 2025 in all scenarios.	Granted	40 MW
Greenbank Crescent[liii]	Greenbank Crescent (aka NESS Energy Project) in Aberdeen is now under construction after several years of delay and securing planning permission in 2016. It is modelled to go forward in all scenarios, commissioning in 2023 at the earliest.	Under Construction	16 MW
Binn Farm	This site is one of multiple planning applications at the same Binn Eco Park, which has existing installed capacity of several technologies. The waste incinerator is modelled to connect between 2024 and 2026 in all scenarios but **Leading the Way**.	Granted	7.3 MW

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 associated carbon emissions, making it at odds with net zero targets. Therefore, the DFES 2022 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)[liv], the operational life of an incineration facility is typically between 20 and 30 years. This has been incorporated into the decommissioning modelling assumptions for each scenario.				
	Falling Short	System Transformation	Consumer Transformation	Leading the Way
Baseline	30 years	20 years	20 years	15 years
Pipeline	30 years	25 years	25 years	20 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[lv], which will ultimately decrease the need for waste treatment overall. In addition, landfills are set to be banned from 2025[lii], meaning that any remaining waste will require treatment by other means.

IEA Bioenergy, in its paper entitled 'Waste Incineration for the Future'[lvi], 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 proven contenders for low carbon replacements to traditional combustion plants and could replace legacy and new sites in years to come. The DFES models additional post-pipeline ACT cites to replace existing incineration sites once they decommission at the same location as the previous site.

Scenario	Description	Incineration capacity by		ACT capacity by	
		2035	2050	2035	2050
Falling Short	Under this scenario, waste incineration sites are assumed to operate for 30 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.	73 MW	63 MW	9 MW	19 MW

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**.	73 MW	--	9 MW	35 MW
Consumer Transformation		73 MW	--	9 MW	35 MW
Leading the Way		56 MW	--	19 MW	35 MW

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The baseline for waste fuelled generation is 7 MW higher according to FES 2022 at 26 MW compared to 19 MW identified from SSEN's connections data. The reason for this is unclear but could be related to the technology classification of some connected sites.
Pipeline	In the near term, DFES 2022 deviates from FES 2022 in all scenarios but **Falling Short**, with 75 MW connecting under **Leading the Way** and 82 MW connecting under the other scenarios. In contrast, FES only sees 30 MW connecting in the net zero scenarios. This variance is due to the DFES pipeline evidence and assessment methodology, 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 due to a strong likelihood for sites to build out.
Projections	In the 2030s, projections are aligned in the DFES and FES, 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. Incineration sites connect only with positive planning information. ACT sites are modelled to connect either at their proposed location in planning or at decommissioned incineration sites.

Relevant assumptions from National Grid FES 2022

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. The valuation of food waste in separate waste streams suggests that a reduction of waste to incinerators is likely to come from non-biogenic waste reduction in the future. This has been taken into consideration in the analysis and has limited the reduction in waste-to-energy capacity out until 2050, assuming that some sites will need to remain online or convert to cleaner technologies.

[lii] Resource 2019, *Scottish Government to Delay Scottish Landfill Ban to 2025*. https://resource.co/article/scottish-government-delay-scottish-landfill-ban-2025
[liii] Aberdeen City Council n.d., *NESS Energy Project*. https://www.aberdeencity.gov.uk/ness-energy-project
[liv] 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
[lv] Scottish Government *Scotland Zero Waste Plan*. https://www.gov.scot/publications/scotlands-zero-waste-plan/pages/4/
[lvi] 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

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.

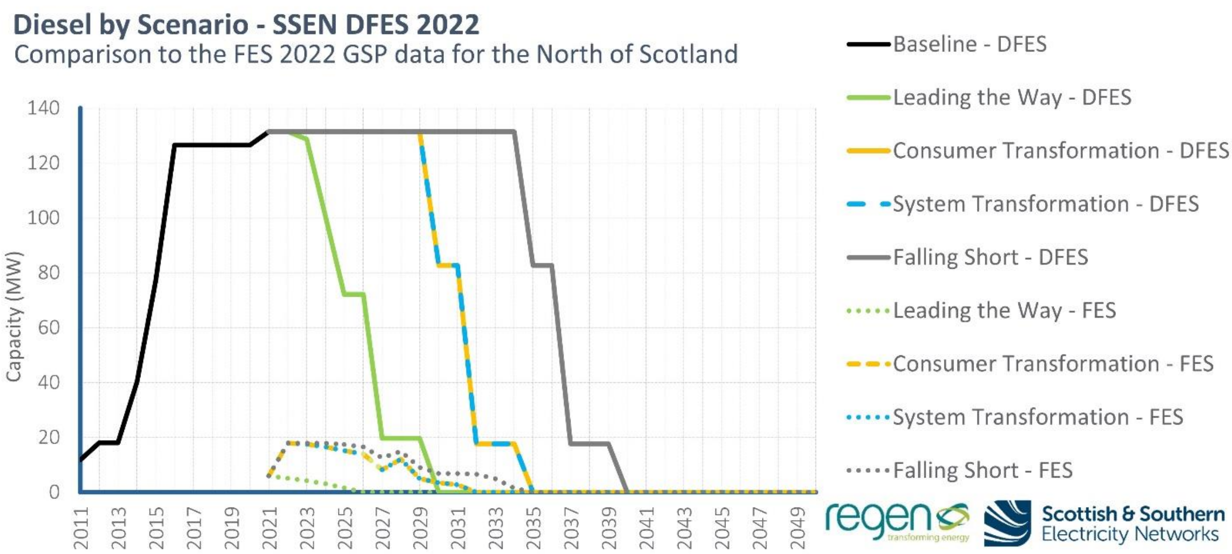
The analysis does not include dedicated backup diesel engines located on some commercial and industrial premises that are only operated when mains supply failure occurs and cannot export to the network.

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	131	131	83	0	0	0
System Transformation		131	83	0	0	0	0
Consumer Transformation		131	83	0	0	0	0
Leading the Way		72	0	0	0	0	0

Figure 27: Diesel generation projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections



Summary

- Diesel generation within the scope of the DFES study entirely comprises support generators sited on the Scottish Islands, which are used for backup supply when the subsea cables or the main network supply to the island are offline.
- As of the end of 2021, the North of Scotland has nine operational diesel generation plants, totalling 131 MW. The age of diesel plants ranges, with some commissioned as early as the 1940s and the latest commissioned in 2021. There is 0 MW of contracted diesel sites in the North of Scotland licence area.
- These are all standalone support diesel power plants, located on Kirkwall on the Orkney Islands, Lerwick on the Shetland Islands, Bowmore, Stornoway, Tiree, Barra and at Loch Carnan on South Uist. There are no new diesel backup or standalone generation sites in the future pipeline for the North of Scotland.
- The continued use of unabated diesel generation is expected to be time-limited due to net zero carbon emissions targets and the implementation of stringent emission limits required by environmental permitting regulations. Regulations restricting the use of diesel generators, such as the Medium Combustion Plant Directive (MCPD)[lvii], have already been implemented into UK law. This requires combustion plants to adhere to stringent air quality limits by securing environmental permits unless a plant only operates for a few hours per year (i.e. backup generators).
- Unabated commercial diesel generation connected to the distribution network falls within this regulation and will, therefore, no longer be allowed to operate from 2025[lviii] without exhaust abatement technologies (such as catalytic reduction technology). This type of companion technology is unlikely to be financially viable in the near term.
- The eventual phase of out of diesel generation was confirmed during engagement sessions with representatives from the Scottish islands and Scottish Governments. All island diesel capacity has been modelled to decommission from the network in all scenarios, albeit under different time frames.
- Under **Consumer Transformation** and **Falling Short**, some sites are modelled to transition to biomass-fuelled generation. Under **System Transformation** and **Leading the Way**, these sites adopt hydrogen fuelled generation. This modelling decision resulted from stakeholder feedback that island generators would need to stay online for energy security reasons and thus would need to transition to lower carbon sources to meet the broader net zero 2045 target set by the Scottish Government.

Modelling Stages

Baseline (2021)		
Number of Sites	**Total Capacity**	**Description**
9	131 MW	The diesel baseline is made up entirely of standalone sites located on remote Scottish islands. Capacity was recently added to Lerwick Power Station compared to DFES 2021, bringing the baseline from 126 MW to 131 MW.
Planning Logic and Assumptions		
Under **Leading the Way, Consumer Transformation** and **System Transformation**, no new unabated diesel generation sites become operational. **Falling Short** assumes that any site with an accepted connection capacity after 2017 will become operational. 28.5 MW of diesel from three pipeline sites have since had their connection offers cancelled since DFES 2021, leaving 0 MW of pipeline capacity currently contracted to the network.		
Decommissioning Logic		
DFES analysis for diesel generation focuses entirely on decommissioning existing known baseline and pipeline sites. Between now and the mid-2030s, depending on the scenario, the model's decommissioning logic considers: • The type of diesel site (standalone or backup) • The year it 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.

Scenario Projections (2022 to 2050)			
Scenario	**Description**	**Capacity by 2035**	**Capacity by 2050**
Falling Short	All diesel generation is decommissioned in the licence area by 2040, aligning with Scotland's 2045 net zero target. Biomass is modelled to replace decommissioned sites.	83 MW	--
System Transformation	All diesel generation decommissions under these scenarios by 2035, being replaced by hydrogen-fuelled generation under **System Transformation** and biomass under **Consumer Transformation**.	--	--
Consumer Transformation		--	--
Leading the Way	All diesel sites decommission by 2030 under this scenario. Decommissioned sites are replaced by hydrogen fuelled generation.	--	--

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The FES 2022 baseline (20 MW) is lower than the DFES (131 MW) in the North of Scotland. FES 2022 data shows that only one GSP sees any connected diesel capacity in the licence area, whereas the DFES has sight of several sites across a number of the Scottish Islands.
Pipeline	Neither FES 2022 nor DFES 2022 model any additional diesel generation sites to connect.
Projections	**Leading the Way** decommissions all its generation by 2025 in FES 2022 and by 2030 in DFES 2022. **Consumer Transformation** and **System Transformation** decommission all sites by the mid-2030s under DFES 2022 and FES 2022. The FES sees all diesel generation decommissioned in the licence area by 2035 under **Falling Short** and by 2040 in the DFES.
Overarching Trend	Diesel generation is expected to drop to zero in net zero scenarios by the end of the 2030s in both FES 2022 and DFES 2022. More capacity is decomissioned under the DFES than the FES, reflecting a potentially different classification of the Scottish Island generators.

Geographical Factors affecting deployment at a local level

Geographical Factors	Description
Baseline and pipeline locations	The DFES analysis for diesel generation focuses on decommissioning existing known baseline and pipeline sites. Spatial distribution references the locations of these sites.

[lvii] European Commission n.d., *The Medium Combustion Plant Directive*. https://ec.europa.eu/environment/industry/stationary/mcp.htm
[lviii] BEIS 2019, *MCPD guidance on permitting and compliance dates*. https://www.gov.uk/guidance/medium-combustion-plant-when-you-need-a-permit#permitting-and-compliance-dates

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.

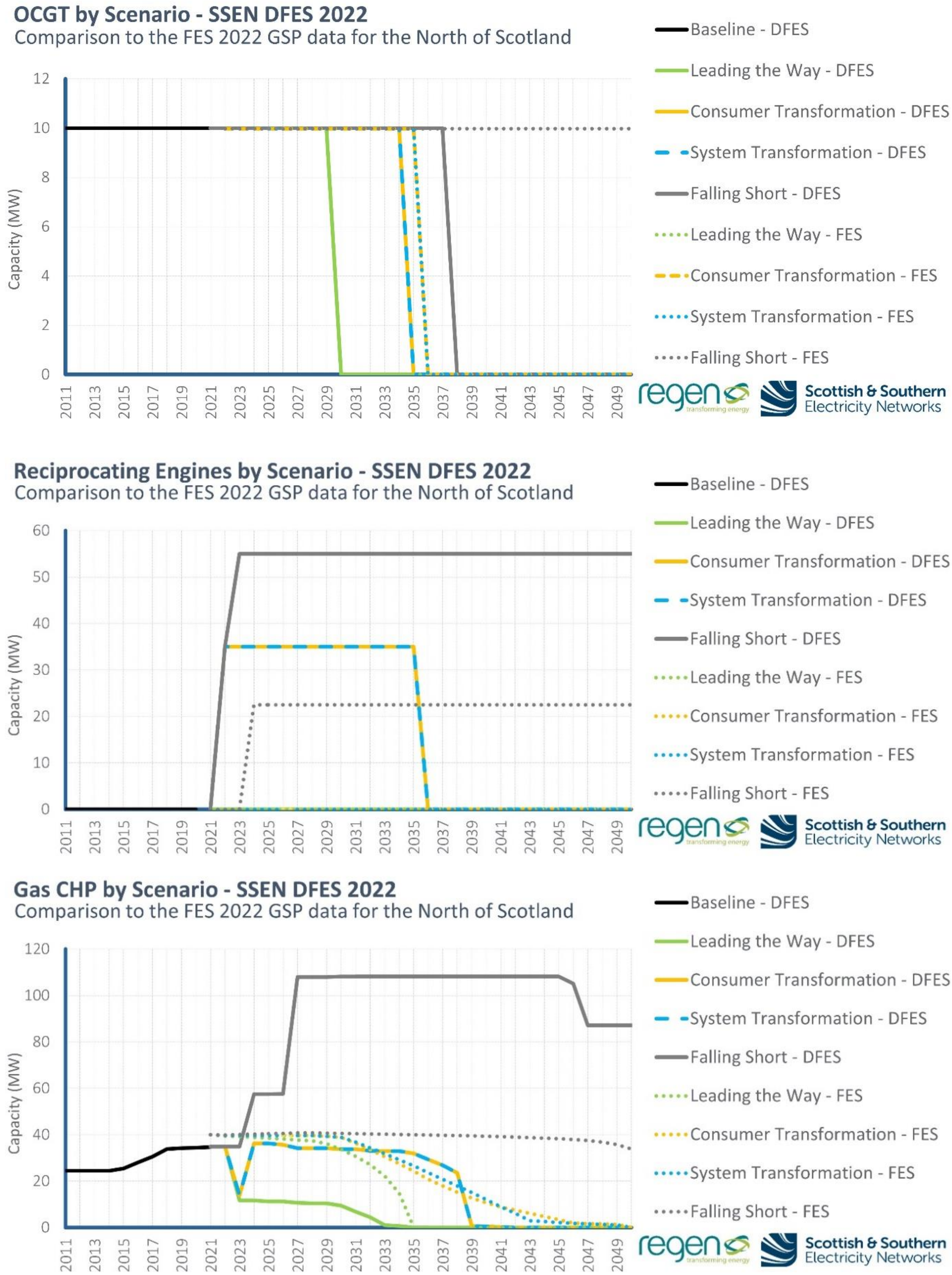
Network technology data building block: **Combined cycle gas turbines (CCGT) – Building block Gen_BB009**; **Open cycle gas turbines (OCGT) – Building block Gen_BB008**; **Gas reciprocating engines – Building block Gen_BB006**; **Gas combined heat and power plants (gas CHP) – Building block Gen_BB001**

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	55	55	55
	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	57	108	108	108	108	87
	System Transformation		36	34	32	0	0	0
	Consumer Transformation		36	34	32	0	0	0
	Leading the Way		11	9	0	0	0	0

Note: there is no CCGT baseline or pipeline and projections in the licence area.

Figure 28: Fossil gas projections for the North of Scotland licence area, compared to National Grid FES 2022 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 baseline is dominated by gas CHPs, accounting for 35 MW of the baseline capacity. The only non-CHP site is the 10 MW OCGT site 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 130 MW. Of this:
    - Three are reciprocating engine sites, totalling c. 56 MW
    - The remaining 7 are gas CHP sites, totalling c. 74 MW.
- Sites with planning approval or contracted in recent Capacity Market auctions[lix] 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, all fossil gas generators see a decline in the near and medium term, and all generators are modelled to come offline by the late 2030s.
- The conflict in Ukraine and significant increases in UK gas prices[lx] could 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.
- However, the Energy Security Strategy[lxi] has renewed the possibility for extraction of natural gas in the north sea, reflecting a world in which gas supply is maintained via new domestic extraction.
- 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 to provide flexibility services throughout the scenario timeframe. Total fossil gas generation capacity in this scenario reaches 152 MW by 2050.

Modelling and assumptions

Baseline (2021)			
Sub technology	**Number of Sites**	**Total Capacity**	**Description**
Total	45	45 MW	There has been an increase in baseline capacity since DFES 2021, which is entirely made up of new CHP sites.
OCGT	1	10 MW	The small 10 MW OCGT asset located onsite at the Flotta Oil Terminal on Orkney was commissioned in 1988.
Gas CHPs	44	35 MW	The rest of the baseline of fossil gas generation in the licence area comprises gas CHPs. Most of these are small <1MW assets located onsite at schools, swimming pools, hotels, farms and or university campuses. There are also a small number of larger CHPs located in Aberdeen and Dundee. DFES 2021 had 38 CHP sites with a total of 31 MW. Two sites, totalling 400 kW, have since been commissioned. Three additional CHP baseline sites were previously modelled under different technologies and have since been reclassified as gas CHP.

Pipeline (2022-2030)	
Number of pipeline sites	**Total capacity**
10	130 MW

Pipeline analysis			
Sub-technology	**Description**	**Sites**	**Capacity**

CCGT & OCGT	As with previous years of analysis, there are no OCGT or CCGT sites in the pipeline. This indicates a move towards smaller-scale assets and reciprocating engines as the norm for future gas sites, operating as peaking plants to perform flexibility services.	--	--
Reciprocating Engines	The fossil gas pipeline in the licence area is smaller than that seen in DFES 2021. This is mainly due to the removal of a 20 MW site, Rautomead PPG in Dundee, which is no longer in the SSEN connections data as its connection has been cancelled. Beyond this, there are thee reciprocating engines with accepted connection offers totalling 56 MW.	3	56 MW
Gas CHP	The number of gas CHP sites in the pipeline has notably increased since DFES 2021. The increase comprises four new sites with a total of 52 MW, bringing up the total capacity of pipeline sites to 74 MW.	7	74 MW

Planning Logic and Assumptions

The assumptions around the proportion of pipeline sites and capacity that are modelled to connect under each scenario are based on an analysis of planning applications and activity in 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 the **Falling Short** scenario.

Decommissioning Logic

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
- How each scenario reflects policies such as the Industrial Emissions Directive, how flexibility is treated in the scenarios, and wider progress towards net zero targets.

The following table summarises the years in which sites are modelled to decommission by sub-technology and scenario.

Sub-technology	Falling Short	System Transformation	Consumer Transformation	Leading the Way
OCGT	By 2038	By 2035	By 2035	By 2030
Reciprocating engines	2040 – post-2050	2023–2039	2023–2039	2023–2034
Gas CHPs	2048 – post-2050	2023–2047	2023–2047	2023–2035

Scenario Projections (2030 to 2050)

Sub-technology	Scenario	Description	Capacity by 2035	Capacity by 2050

OCGT	Falling Short	The Flotta OCGT site 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**, reflecting 50 years of operation.	10 MW	0 MW
	System Transformation		0 MW	0 MW
	Consumer Transformation		0 MW	0 MW
	Leading the Way		0 MW	0 MW
Reciprocating engines	Falling Short	A significant proportion of the reciprocating engine site pipeline is modelled to build out under this scenario, reflecting a future in which rapid-response technology continues to secure balancing service and flexibility contracts. Capacity reaches 55 MW in the 2030s and remains at that capacity out to 2050.	55 MW	55 MW
	System Transformation	Several reciprocating engine sites with connection offers with SSEN 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 MW	0 MW
	Consumer Transformation		35 MW	0 MW
	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.	0 MW	0 MW
Gas CHP	Falling Short	Under this scenario, the baseline of gas CHP engines continue to operate in the medium term, in addition to a number of pipeline CHP sites that are modelled to connect. Only a few older sites are modelled to disconnect in the longer term, with 87 MW remaining online by 2050.	108 MW	87 MW
	System Transformation	A notable number of the gas CHP sites in the North of Scotland licence area are located onsite at businesses and commercial premises. These are therefore not modelled to disconnect in the near term, due to the onsite/backup services they are providing. In addition, whilst some pipeline sites with planning approval are also modelled to connect, there is little growth in gas CHP capacity modelled to come online. Capacity begins to decommission from the 2030s, resulting in all capacity being modelled to disconnect by 2040.	32 MW	0 MW
	Consumer Transformation		32 MW	0 MW
	Leading the Way	Some of the smaller onsite gas CHP pipeline sites are modelled to connect in the 2020s, but alongside this older baseline sites begin to decommission. All gas CHP capacity is modelled to disconnect by the mid-2030s.	0 MW	0 MW

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The FES 2022 and DFES 2022 baseline both reflect the 10 MW Flotta OCGT site. Both the DFES and FES show no reciprocating engine sites connected in the licence area. The FES Gas CHP baseline is closely aligned with the DFES, with only 5 MW more than the DFES.
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 under **Falling Short**, but the DFES has also modelled some of the sites with positive development evidence coming online under **Consumer Transformation** and **System Transformation**. In addition to this, the DFES models c. 30 MW more capacity coming online by the mid-2020s. The FES models a constant CHP capacity remaining online until the late 2040s. Based on the DFES pipeline modellnig, 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	The single OCGT baseline site is modelled to disconnect in all scenarios before 2040 under DFES 2022, whereas the FES 2022 models this site to remain online in **Falling Short** out to 2050. The DFES and FES both model the continued operation of gas reciprocating engines under **Falling Short**. Whilst the FES does not model any pipeline sites connecting under **Consumer Transformation** and **System Transformation** scenarios is reflected, both the DFES and the FES are aligned with no operational reciprocating engines in the licence area under the three net zero scenarios by 2050. Pipeline growth aside, the FES models no change at all in gas CHP capacity across the period to 2050 under **Falling Short**, whereas the DFES has modelled some older baseline sites decommissioning in the 2040s. Under the three net zero scenarios, the DFES and FES both model decommissioning of 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 2022

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[lxii], local stakeholders responded to a poll on how current gas price increases might affect the current pipeline of gas generation projects. The overwhelming majority of respondents (93%) highlighted that the increases would either delay development (23%) or drive a shift away from fossil gas peaking plants (70%).	This result has justified the net zero scenario projections, where only a select few of the known pipeline sites are modelled to build out and the long-term decommissioning of fossil gas generation that follows.

[lix] National Grid ESO n.d., *Capacity Market Registers.* https://www.emrdeliverybody.com/CM/Registers.aspx
[lx] Trading Economics 2022, *UK natural gas price 2022-23.* https://tradingeconomics.com/commodity/uk-natural-gas
[lxi] UK Government 2022, *British Energy Security Strategy.* https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy
[lxii] 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

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

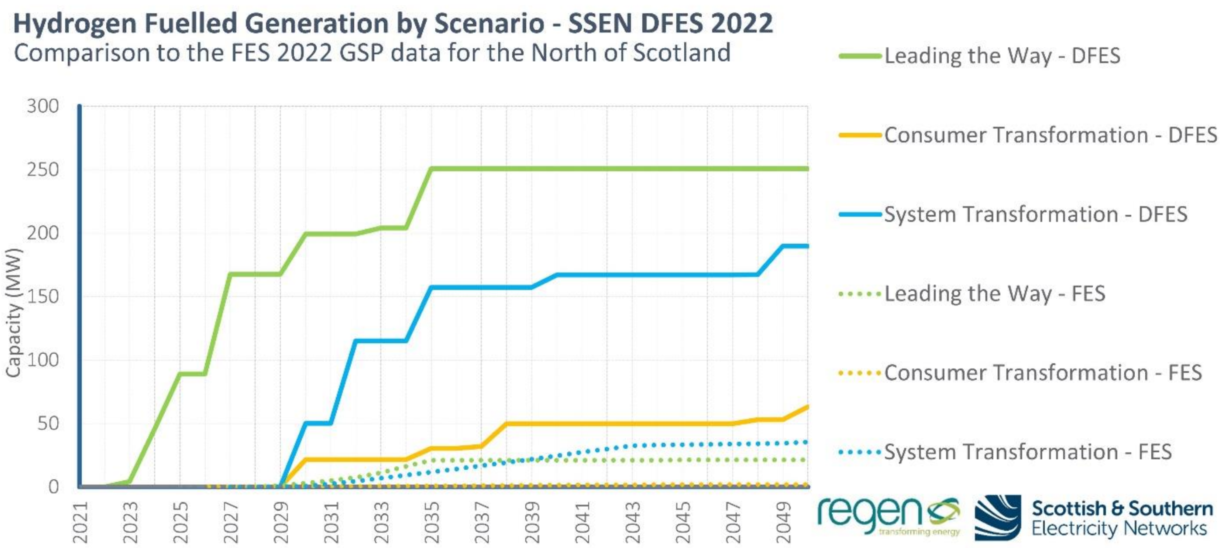
New large-scale hydrogen-fuelled power stations could also be developed. However, in the absence of any pipeline evidence and the lack of low carbon hydrogen supply infrastructure development to date, it has been assumed that these plants would more likely connect to the transmission network.

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	50	157	167	167	190
Consumer Transformation		0	22	31	50	50	63
Leading the Way		89	199	251	251	251	251

Figure 29: Hydrogen-fuelled electricity generation projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections



Summary

- A net zero electricity system will see significant levels of variable renewable energy generation, a major increase in electricity demand from low carbon technology adoption, and a diverse mix of flexible technologies to enable system operability and balancing demand and supply.
- Currently, many of these balancing services are provided by fossil gas generation plants, ramping up generation in response to system balancing price signals. In a net zero electricity system, unabated fossil fuel generation will be unable to provide flexibility services. Therefore technologies like battery storage, bioenergy generation and other dispatchable assets will need to meet the system flexibility needs. Low-carbon hydrogen-fuelled electricity generation (engines or turbines) could become one of these options.
- In the North of Scotland, some diesel backup sites are modelled to convert to hydrogen peaking generators as early as the mid-2020s. This is supported by the existence of a number of turbine manufacturers, including Siemens and GE[lxiii], that already offer hybrid hydrogen/methane turbines and have committed to providing 100% hydrogen plants in the near future.
- The DFES analysis for hydrogen-fuelled electricity generation predominantly considers the potential for existing fossil gas and diesel generation to repower or replace their generation assets to run on low-carbon hydrogen in the future when it becomes available.
- The Scottish Government Hydrogen Action Plan[lxiv], released in December 2022, announced a target to reach 5 GW of hydrogen production capacity by 2030 (and 25 GW by 2045). The UK is aiming to develop 10 GW of low-carbon hydrogen generation by 2030. However, it is not yet clear if, and when, hydrogen may begin to displace fossil fuel generation.
- Engagement with hydrogen sector stakeholders suggests that many projects will be targeting large-scale sites and conversion of fossil fuel generation facilities connected to the transmission network.
- As a result of this uncertainty, projected hydrogen generation capacity in the licence area by 2050 ranges significantly, from no capacity under **Falling Short** (due to fossil fuel generation remaining operational) to 251 MW under **Leading the Way**.

Modelling and assumptions

Baseline (2021)
There are no baseline 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 and 131 MW of diesel baseline 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 net zero scenarios.
Pipeline (2022-2030)
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 on low carbon hydrogen in the near term, although some pilot schemes have begun to appear, including large-scale gas power stations trialling the injection of hydrogen at existing sites[lxv] and turbine manufacturers already beginning to develop hydrogen generation technologies[lxvi]. As a result, only several island backup diesel sites are modelled to transition to hydrogen before the 2030 and only under **Leading the Way**, while all other scenarios see sites beginning to connect from 2030 onwards. There is 130 MW of fossil gas with accepted connections, and no diesel sites in the pipeline; some are modelled to come online in the near-term and could repower to be hydrogen fuelled generation in the long term.
Hydrogen repowering
The DFES analysis reflects the potential for a proportion of existing fossil gas and diesel plants repowering as hydrogen-fuelled generation assets in the future. This potential is based on a geographic assessment of potential hydrogen hubs in the licence area, including Orkney, Shetland, Aberdeen and Dundee. The scale of repowering as hydrogen generation varies by scenario, based on repowering factors and development phasing. 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)			
Scenario	**Description**	**Capacity by 2035**	**Capacity by 2050**
Falling Short	Due to unabated fossil fuel generation continuing to operate out to 2050, no sites are modelled to convert low carbon hydrogen.	0 MW	0 MW
System Transformation	Fossil fuel sites located in hydrogen development zones and some sites outside of these zones repower as hydrogen-fuelled generation in the 2030s and 2040s. This reflects a high availability of low-carbon hydrogen. A significant capacity of hydrogen-fuelled generation capacity also connects at transmission scale.	157 MW	190 MW
Consumer Transformation	Only fossil fuel sites located in hydrogen development zones repower as hydrogen-fuelled generation in the 2030s and 2040s. This reflects a lack of a national hydrogen network, requiring hydrogen to be produced close to sources of demand.	31 MW	63 MW
Leading the Way	There is an ambitious deployment of distributed hydrogen-fuelled generation. Medium-scale fossil gas and diesel sites (baseline and pipeline) are modelled to repower their thermal generation plant to be fuelled by hydrogen, with 50% more capacity. Both existing and pipeline sites in and outside of known hydrogen development zones are modelled to repower, reflecting the widespread availability of hydrogen through a national network. This scenario also reflects a higher proportion of hydrogen-fuelled generation sites connecting to the distribution network, with just over 250 operating in the network by 2050.	251 MW	251 MW

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline **Pipeline**	Both the DFES 2022 and FES 2022 are aligned. There are no existing operational hydrogen-fuelled generation sites, nor near-term developments before 2030 in the licence area. The only deviation is in the DFES 2022 **Leading the Way**, where some diesel sites are modelled to come offline and replaced by some of the first hydrogen-fuelled generation sites.
Projections	The DFES and FES are aligned on no hydrogen generation capacity being modelled to come online by 2050 under **Falling Short**. In the medium- and long-term, the DFES 2022 projections have a notably higher uptake of hydrogen-fuelled generation in the North of Scotland licence area than the FES 2022 GSP regional data The main rationale for a higher capacity of hydrogen-fuelled generation in the SSEN DFES 2022 is the occurrence of diesel and gas plants in the region, including critical support generators on the Scottish Islands, that would need to be decarbonised to meet Scottish and local net zero targets. It should be noted that, for both DFES and FES projections, there is a high degree of uncertainty regarding the potential role that hydrogen-fuelled generation could play.

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	Regen undertook a spatial analysis of potential hydrogen supply areas and hydrogen development hubs in the licence areas. This considers locations of existing hydrogen trials and initiatives, larger industrial areas, proximity to gas network infrastructure, proximity to major roads, ports and potential hydrogen storage facilities.

Relevant assumptions from National Grid FES 2022

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.[32]

[lxiii] General Electric n.d., *Hydrogen fuelled 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=EAIaIQobChMIh5amwIiq9QIV2Y1oCR2nHgqZEAAYAiAAEgLtXvD_BwE
[lxiv] Scottish Government 2022, *Hydrogen Action Plan.* https://www.gov.scot/publications/hydrogen-action-plan/
[lxv] 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
[lxvi] 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

[32] These assumptions represent dispatchable hydrogen-fuelled generation assets connecting at both distribution and transmission levels. By 2050, under Leading the Way, 11 GW of hydrogen-fuelled electricity generation connects to the distribution network and 5.5 GW to the transmission network. Therefore, the DFES analysis has reflected a moderately higher adoption of distributed hydrogen generation under this scenario than the above scenario assumption suggests.

Other generation

Summary of modelling assumptions and results

Technology specification

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

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

Installed capacity (MW)	Baseline	2025	2030	2035	2040	2045	2050
All Scenarios	1	1	1	1	1	1	1

Summary

- There are eight sites of unidentified generation technology in the North of Scotland Licence area, totalling 1 MW of installed capacity. This has increased since DFES 2021 (560 kW) due to investigative analysis of sites using satellite imagery, developer outreach, news articles and in-depth desk research to identify site technologies and ambiguity over certain sites previously allocated to other technology models.
- At an average capacity of 112 kW, these sites are predominantly micro CHP plants within schools, hotels, farms and recreational centres; however, the fuel type is uncertain. Hence these sites cannot be positively allocated a technology. The largest site is 210 kW.
- There are no pipeline sites for which the technology type could not be identified.
- 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.

Battery storage

Summary of modelling assumptions and results

Technology specification

Battery storage, comprising four 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.

These three business models combine to form "large scale" battery storage, which aligns with the FES building block: **Srg_BB001**

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

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	0	199	810	810	810	810	810
	System Transformation		299	860	903	946	989	1,032
	Consumer Transformation		508	1,555	1,787	1,839	1,891	1,943
	Leading the Way		870	1,735	1,874	1,995	2,169	2,290
	Storage Planning		1,873	3,488	3,488	3,488	3,488	3,488
Generation co-location	Falling Short	8	75	158	168	170	255	259
	System Transformation		52	194	208	237	288	295
	Consumer Transformation		91	281	301	377	403	411
	Leading the Way		91	304	335	368	397	401
	Storage Planning		158	304	335	368	397	401
Behind the meter - high energy user	Falling Short	0	13	18	20	22	22	22
	System Transformation		27	36	39	44	44	44
	Consumer Transformation		40	53	59	111	111	111
	Leading the Way		53	89	98	111	111	111
	Storage Planning		117	242	251	264	264	264
Domestic batteries	Falling Short	0	1	1	4	4	12	27
	System Transformation		1	11	15	20	47	54
	Consumer Transformation		3	28	51	83	134	237
	Leading the Way		9	40	72	117	187	327

Figure 30: Large-scale battery storage projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections – including DFES 'Storage Planning' high growth scenario

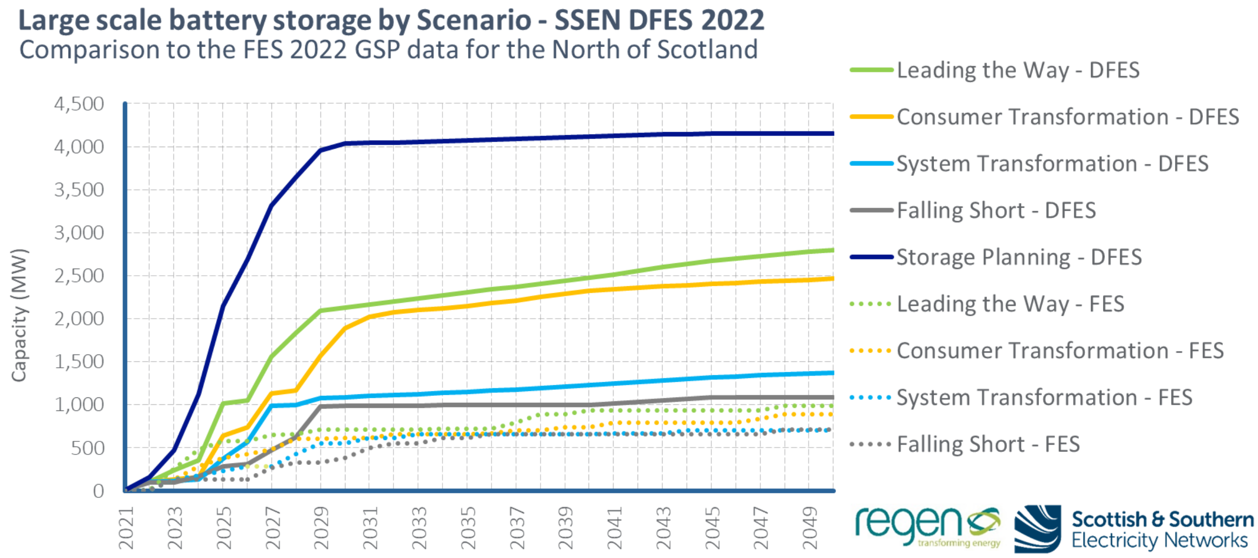
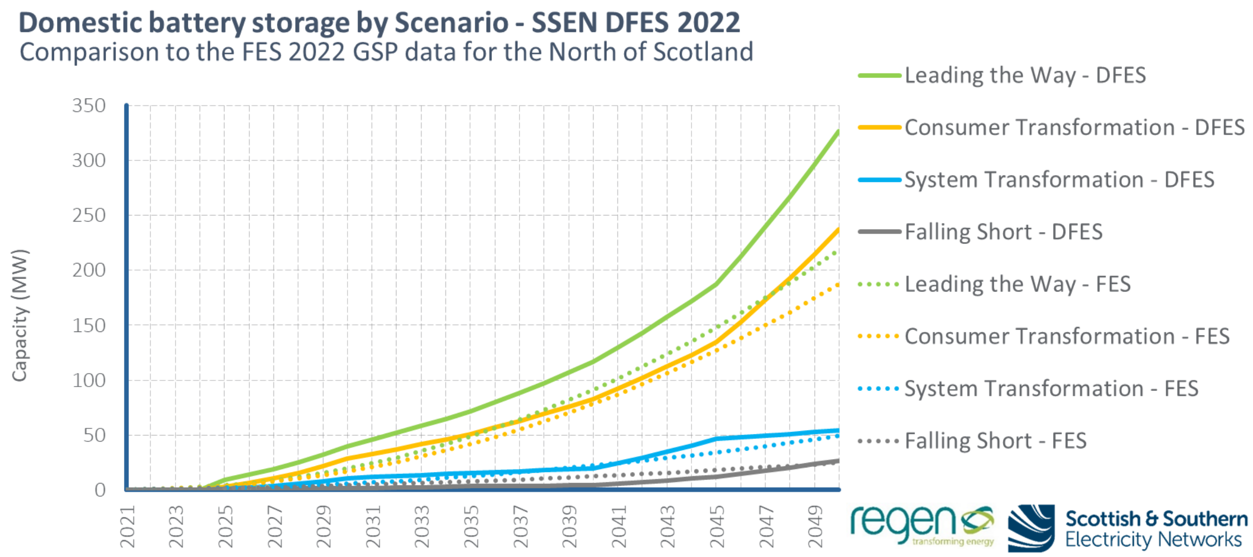


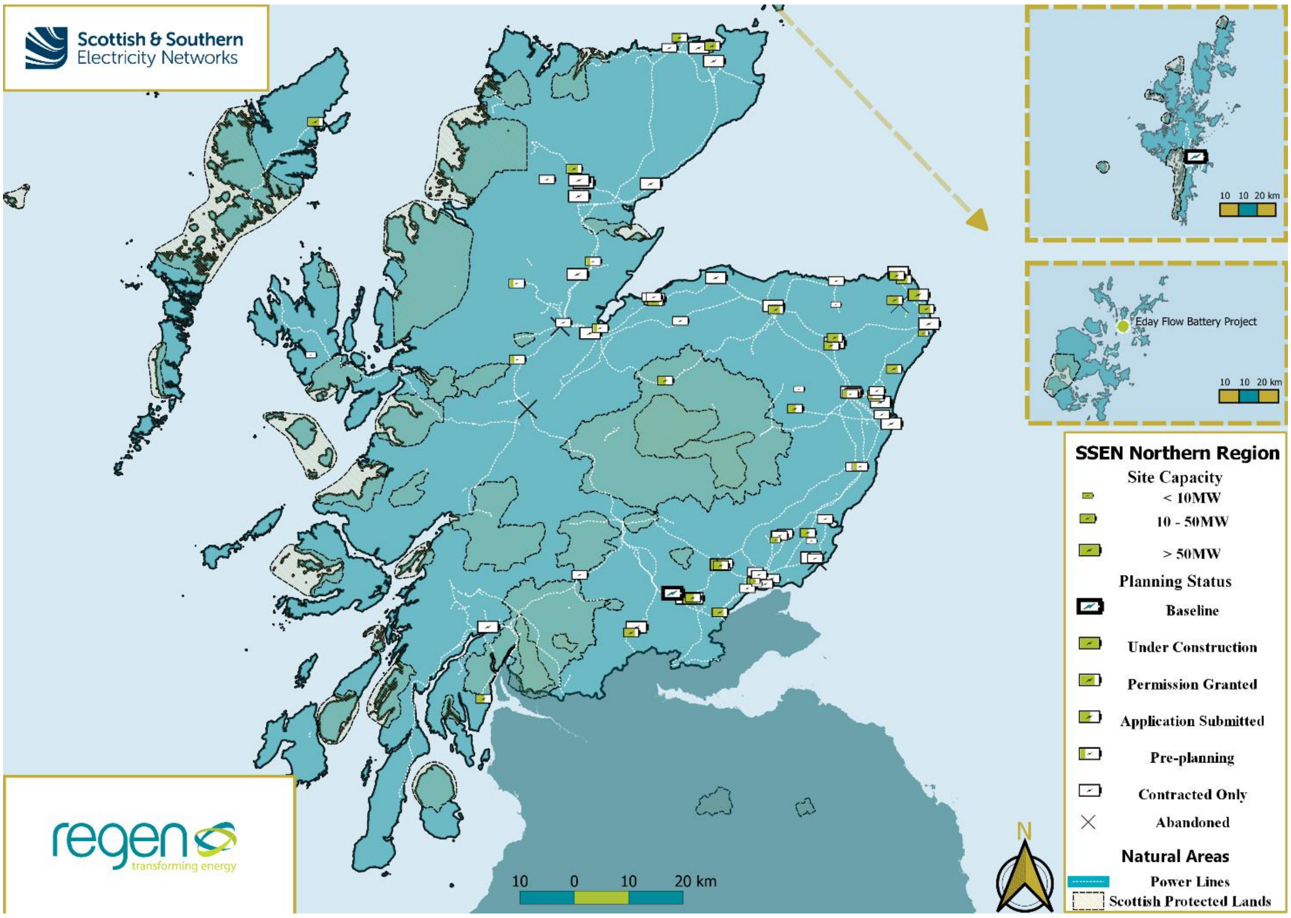
Figure 31: Domestic battery storage projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections



Summary

- As a sector that saw its first commercial-scale projects in 2016, battery storage has rapidly developed into an active and significant technology sector across the UK electricity network.
- The North of Scotland licence area currently has two operational battery storage sites, totalling 8 MW. These two sites, Lerwick Power Station (8 MW) and Comrie Croft (0.015 MW), are both co-located with renewable energy sites.
- Of all technologies included in the DFES analysis, battery storage has the largest pipeline of projects with a quote issued or accepted connection offer - totalling some 9.6 GW across the two SSEN licence areas. Of this, 104 sites totalling 4.2 GW fall within the North of Scotland licence area.
- Putting this into context, currently, SSEN manages a portfolio of c. 6.5 GW of operational fossil fuel and renewable generation assets.
- Many organisations have raised concern over the scale of the national connection pipeline, the number of potentially speculative applications[lxvii] , how they contribute to lengthy connection queues and potential grid constraints.
- The North of Scotland licence area does have significant potential for long-term growth in connected storage capacity. This is due to the following:
    - The Northern licence area has amongst the best onshore wind resource in the UK and, thus, strong potential for significant battery storage co-location.
    - Targeted network services, such as phase two of National Grid ESO's stability pathfinder tender, awarded tenders to large battery projects adjacent to network substations in Scotland.[lxviii]
    - The spread of price arbitrage as a source of revenue and balancing services business models.
    - Several 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.
- Overall battery storage capacity in 2050 in the North of Scotland licence area ranges from 1.1 GW in **Falling Short** to 3.1 GW in **Leading the Way**.
- Upstream constraints (and associated Statement of Works processes) on the transmission network can impact the deployment timescale of distribution network projects. These have been reflected in the **Falling Short** scenario only, based on the completion year of the transmission upgrade works. This allows the scenarios to represent a realistic range of potential near-term connections to the distribution network.
- This year, 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 currently visible contracted/quoted connection pipeline.
- Under the **Storage Planning** scenario, 4.2 GW of large-scale storage is modelled to connect in the North of Scotland licence area by 2050.
- Alongside battery storage, Long Duration Energy Storage (LDES) is a subsector seeing growing government interest and policy support, including the LDES demonstration competition[lxix]. This could give rise to several 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 32: Baseline and pipeline battery storage sites in the North of Scotland licence area.



Note: The Eday FLOW battery project on Orkney[lxx] is a contracted test site that looks to store tidal energy in a hydrogen electrolyser.

Modelling and assumptions

Baseline (2021)			
Business Model	**Number of Sites**	**Total Capacity**	**Description**
Generation co-location	2	8	The baseline comprises the 8 MW Lerwick Power Station battery, recently installed to supplement the 72.8 MW diesel backup engine on Shetland[lxxi]. In addition, the 0.015 MW Comrie Croft site in Perth and Kinross is co-located with solar PV and connected in 2017.

Pipeline (2022-2030)	
Number of pipeline sites	**Total capacity**
104	4.2 GW
Every site in the pipeline was assessed for its current development status and timeline through online research in local planning portals EMR Delivery Body Capacity Market T-4 and T-1 registers, online project webpage summaries, and direct engagement with project developers.	

Pipeline analysis			
Planning status	**Description**	**Sites**	**Capacity**
Planning Permission Granted	Over half of the capacity of the 21 sites with planning approval (c.450 MW) comes from nine 50 MW standalone battery projects. Under **Consumer Transformation**, **Leading the Way** and **Storage Planning**, these sites are assumed to build out in the near term, while **System Transformation** and **Falling Short** see development delayed to the mid-to-late 2020s. Six of these 21 sites have secured Capacity Market agreements and are modelled to meet their contracted delivery year(s) under all scenarios.	21	730 MW
Planning Application Submitted	With an average capacity of 44 MW, sites with planning applications submitted totals over 600 MW. This includes the 80 MW Shalmstry Farm site in the Highlands and the 67MW 'Bilbo & Frodo' co-located solar and battery site in Aberdeenshire. No evidence of any of these 14 sites having secured Capacity Market agreements exists. Under the **Consumer Transformation**, **Leading the Way**, and **Storage Planning** scenarios, these sites are modelled to build out between 2024 and 2030. Under **System Transformation** and **Falling Short**, only two co-located sites are assumed to connect, as there is a strong potential for both the solar PV and battery assets to be developed at these sites in these scenarios.	14	618 MW
Pre-planning	All but one of the 11 sites that are pre-planning are standalone 50 MW batteries, which have all recently accepted connection agreements. Under **Consumer Transformation**, **Leading the Way**, and **Storage Planning**, these sites are modelled to build out between 2028 and 2031. They do not connect under **System Transformation** and **Falling Short**.	11	530 MW
No information / Other	Due to the rapidly growing pipeline of new prospective battery projects, there remains a significant volume (2.4 GW) with no evidence of activity in planning or the Capacity Market auctions. This is a significant group of sites (55% of the total pipeline capacity) with a high degree of uncertainty in their potential future development, despite having a connection agreement with SSEN. As a result, they are not modelled to build out under any of the standard DFES scenarios. The new **Storage Planning** scenario included in DFES 2022 seeks to demonstrate the scale of potential deployment in the licence area if all contracted or quote-issued sites were to eventually connect. Therefore all sites are modelled to come online based on a fixed delay after the developer accepts their connection offers. Where no SSEN anticipated connection date was available, sites have been modelled to connect in randomly assigned years between 2024 and 2030. Some sites were identified as duplicate connection enquiries, projects that have been abandoned or have had their planning applications refused. These cases have been removed from the analysis.	58	2,358 MW

Planning Logic and Assumptions					
Sites with no Capacity Market information, co-located site information, or developer feedback were subject to scenario logic reflecting the varying likelihood of delays to connection time. 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	**Under Construction**	**Planning Application Granted**	**Planning Application Submitted**	**Pre-planning** *(e.g. proposal of application submitted)*	**No information**
Falling Short	2023	Granted year +7	-	-	-
System Transformation	2023	Granted year +5	-	-	-
Consumer Transformation	2023	Granted year +5	Submitted year + 7	Submitted year + 9	-
Leading the Way	2023	Granted year +3	Submitted year + 5	Submitted year + 7	-
Storage Planning	2023	Granted year +3	Submitted year + 5	Submitted year + 7	Random year 2024-2030

Scenario Projections (2030 to 2050)

The four business models for battery storage are modelled separately, and different factors drive potential deployment in the licence area under these business models:

The significant development of standalone sites projected in the near term may lessen over time as the grid and balancing markets are saturated with flexible assets. As a result, low growth is projected for standalone batteries following the modelled connection of the visible pipeline. This reflects developers looking at other business models for storage assets.

It is assumed that the business case for behind-the-meter batteries co-located at high-energy user sites may increase, under some scenarios, as businesses look to manage their on-site energy consumption, reduce energy costs, maximise their self-use of on-site renewable generation and move from being consumers to prosumers.

In addition to this, there is the potential for an increased uptake of home batteries under some scenarios, with more homeowners deploying rooftop solar PV and seeking to increase self-consumption, as well as a proliferation of domestic-level flexibility, time-of-use-tariffs and community-level demand side response.

In the long term, the biggest increase in projected battery storage capacity in the licence area is seen under the **Leading the Way** scenario, totalling 3.1 GW by 2050, reflecting a strong potential deployment landscape of batteries across all four business models.

Falling Short sees the lowest overall storage deployment in the licence area, reaching 1.1 GW by 2050. This reflects a lesser need for electricity system flexibility, a lower renewable energy adoption and ongoing use of fossil fuel generation as a source of flexibility. This reduced development outlook for battery storage is reflected in the longer term, out to 2050, across all four business models.

The **Storage Planning** scenario demonstrates the size of the contracted or quote-issued pipeline. Beyond the modelled connection of the full pipeline, additional co-located storage and 'behind the meter – high energy user' capacity was modelled out to 2050, mirroring the assumptions seen in a **Leading the Way** scenario. As a result, large-scale battery storage capacity under this scenario reaches 4.2 GW by 2050

Business model	Description	Scenario	Capacity by 2035	Capacity by 2050
Standalone network services	Standalone storage sites in the currently visible pipeline dominate growth by 2035. The capacity growth reduces beyond the late 2030s to 2050, reflecting a saturation of distribution network capacity and flexibility markets, reducing the number of large-scale standalone projects seeking to connect in the longer term.	**Falling Short**	810	810
		System Transformation	903	1,032
		Consumer Transformation	1,787	1,943
		Leading the Way	1,874	2,290
		Storage Planning	3,488	3,488
Generation co-location	Battery storage co-locating with renewable generation is likely to be located in areas with high levels of solar and wind generation and potentially in areas with grid constraints, such as Scottish Islands. There is currently 2.1 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 6.7 GW modelled to connect by 2050 and significant potential for large-scale solar PV. The potential for co-located battery storage under this scenario is projected to reach 411 MW by 2050.	**Falling Short**	168	259
		System Transformation	208	295
		Consumer Transformation	301	411
		Leading the Way	335	401
		Storage Planning	335	401
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. As a result, by 2035, high energy user battery capacity ranges from 22 MW **Falling Short** to 111 MW under **Leading the Way**. The **Storage Planning** scenario, in this case, assumes that three behind-the-meter sites associated with commercial properties in Aberdeen and Dundee connect in the mid-2020s. With no evidence of these sites progressing through planning, they are not modelled to connect in any other scenario.	**Falling Short**	20	22
		System Transformation	39	44
		Consumer Transformation	59	111
		Leading the Way	98	111
		Storage Planning	251	264
Domestic batteries		**Falling Short**	4	27
		System Transformation	15	54

	The licence area also has c.740,000 domestic properties, and whilst solar irradiance is relatively low in the licence area compared to other parts of the UK, 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 327 MW (equivalent to c. 62,000 homes) under Leading the Way. This is an increase in the DFES 2021 projections due to some updated assumptions around the average capacity of rooftop solar and domestic battery units and an updated method of projecting future new developments.	Consumer Transformation	51	237
		Leading the Way	72	327

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation – Large-scale batteries
Baseline	The 8 MW of co-located storage capacity identified in the DFES 2022 baseline is not shown in FES 2022, which shows zero current installed capacity. The reason for this is unclear.
Pipeline	The DFES 2022 projections significantly exceed the FES 2022 near-term projections in all scenarios, reflecting the near-term pipeline of known projects. This is due to the constantly increasing pipeline of accepted connection offers evidenced in SSEN's connection data. This variance between FES and DFES becomes significant in the medium term in the more ambitious scenarios, reaching 1.4 GW 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	The variance between DFES and FES continues in all scenarios but does not increase significantly post-2030 due to lower levels of deployment projected out to 2050. The DFES 2022 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 2022 projects significantly higher installed capacity in the licence area than the FES 2022. The difference is larger in the increasingly ambitious scenarios, with Leading the Way and Consumer Transformation projecting more than double the equivalent FES projections by 2050. This results from the scale of the contracted pipeline and a site-specific pre-2030 pipeline assessment. Post-2030 growth is higher under FES 2022 than under DFES 2022.

Modelling Stage	Reconciliation – Domestic Batteries
The DFES 2022 projections for domestic batteries align well with FES 2022 across the analysis period in all scenarios. The DFES projects slightly more capacity by 2050. This reflects strong targets for solar PV deployment (across all scales)[lxxii] 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 2022.

Relevant assumptions from National Grid FES 2022

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 compared to other scenarios due to the 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 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 mean this technology does not come forward at the volumes 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 the 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[lxxiii], local stakeholders responded to a poll on the scale of deployment of battery storage in the licence area. When asked how much of the 4.2 GW pipeline of large-scale batteries were likely to connect in the North of Scotland, the 29 respondents gave a wide range of responses. The most popular response was to suggest that 50% of the pipeline would build-out. However, a larger combined group felt that 80-100% of the pipeline would potentially connect. This group was formed primarily of energy project developers or sector consultants. On the expected speed of deployment of the project pipeline, the respondents were more evenly distributed, with 80% believing the pipeline would connect by the early 2030s.	The uncertainty around the current pipeline is reflected in the spread of scenario outcomes modelled. The Storge Planning scenario demonstrates the connection of the licence area's entire 4.2 GW project pipeline. Feedback around the speed of deployment outcome is reflected in all scenarios, with known pipeline sites modelled to connect by 2032 at the latest.
SSEN engagement on Shetland backup power supply plans. With the transmission link to Shetland under construction, SSEN is currently planning the future of the Lerwick diesel power station as a backup site[lxxiv]. The DFES team were informed that a 75 MW BESS site would support the operation of the site in this new function.	This site is modelled to come online in 2025 under **Leading the Way** and **Consumer Transformation** and subsequent years in less ambitious scenarios.

[lxvii]Energy Storage News 2021, *Large-scale battery storage in the UK.* https://www.energy-storage.news/large-scale-battery-storage-in-the-uk-analysing-the-16gw-of-projects-in-development/
[lxviii] National Grid ESO 2022, *NOA Stability Pathfinder – Phase 2 updates.* https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-2
[lxix] UK Government, 2021, *Long Duration Energy Storage Competition.* https://www.gov.uk/government/collections/longer-duration-energy-storage-demonstration-lodes-competition
[lxx] Current 2020, *Tidal, flow batteries and green hydrogen combined in world first £1.8m Orkney project.* https://www.current-news.co.uk/tidal-flow-batteries-and-green-hydrogen-combined-in-world-first-1-8m-orkney-project/#:~:text=The%20project%20will%20be%20located,help%20%E2%80%9Csmooth%E2%80%9D%20tidal%20generation.
[lxxi] SSEN, 2022, *Shetland Energy*. https://www.ssen.co.uk/about-ssen/our-works/shetland-energy/
[lxxii]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
[lxxiii]Regen, 2022, *SSEN DFES stakeholder consultation webinars*. https://www.regen.co.uk/event/ssen-distribution-future-energy-scenarios-2022-stakeholder-consultation-webinars/
[lxxiv] SSEN, 2022, *Final ED2 Business Plan, page 92 on transition if Lerwick Power Station to backup role.* https://ssenfuture.co.uk/wp-content/uploads/2021/12/24645-SSEN-ED2-Final-Business-Plan-Website.pdf

Liquid air energy storage

Summary of modelling assumptions and results

Technology specification

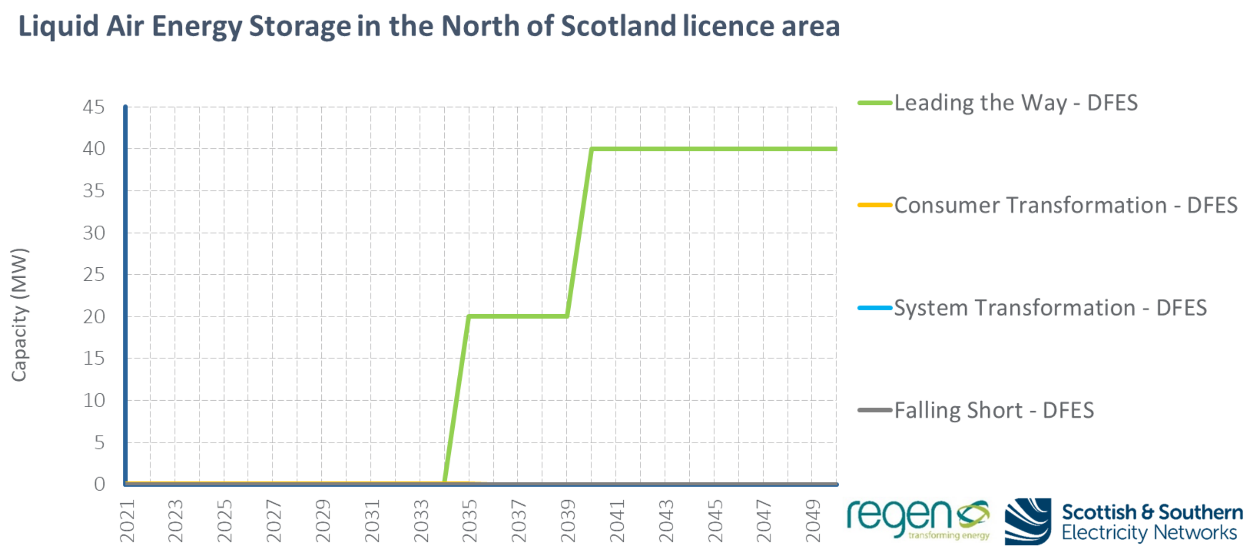
The analysis covers liquid air energy storage (LAES), sometimes referred to as cryogenic electricity storage, connected to the distribution network in the North of Scotland licence area.

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



Summary

- Battery storage technologies dominate the UK storage pipeline (see the Battery Storage chapter of this report). Liquid air energy storage (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 required, the liquid air is exposed to ambient temperature air (or waste heat from industrial processes) to convert it back to a gaseous state. This resultant expanded gas is used to turn a turbine to generate electricity.

- This technology could be supported by future UK grant and innovation funding schemes, following on from the Long Duration Storage Competition[lxxv] fund, delivered and managed by (then) BEIS.
- One of the leading LAES developers in the UK, Highview Power, are developing trial and pre-commercial plants in Greater Manchester[lxxvi].
- 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[lxxvii].
- 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), the DFES 2022 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. 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 trail 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[lxxviii]. 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.

[lxxv] 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
[lxxvi] Highview Power, 2023. https://highviewpower.com/plants/
[lxxvii] National Grid ESO 2023. *Stability Pathfinder.* https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability
[lxxviii] Invinity 2022. *EMEC Flow battery installation*. https://invinity.com/invinity-battery-system-successfully-energised-emec-orkney-isles/

Electric vehicles and EV chargers

Summary of modelling assumptions and results

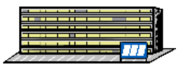
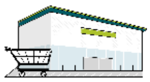
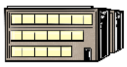
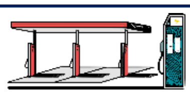
Technology specification

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).**

No 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 2022 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	6.7	26	101	282	582	844	929
	System Transformation		30	136	430	790	904	856
	Consumer Transformation		76	279	622	823	837	805
	Leading the Way		65	276	714	888	849	701
Plug-in hybrid EVs (Total, numbers, thousands)	Falling Short	4	11	30	57	85	58	22
	System Transformation		11	27	47	35	15	-
	Consumer Transformation		10	20	30	20	8	-
	Leading the Way		12	26	25	13	-	-

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	4	17	65	171	328	426	427
	System Transformation		19	85	247	423	426	427
	Consumer Transformation		33	154	372	429	440	450
	Leading the Way		42	175	415	435	439	439
Non-domestic EV chargers[33] (Total, MW)	Falling Short	48	68	139	294	554	782	930
	System Transformation		75	188	479	806	872	886
	Consumer Transformation		122	337	594	738	752	757
	Leading the Way		108	306	692	846	868	920

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

Figure 34: EV projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections

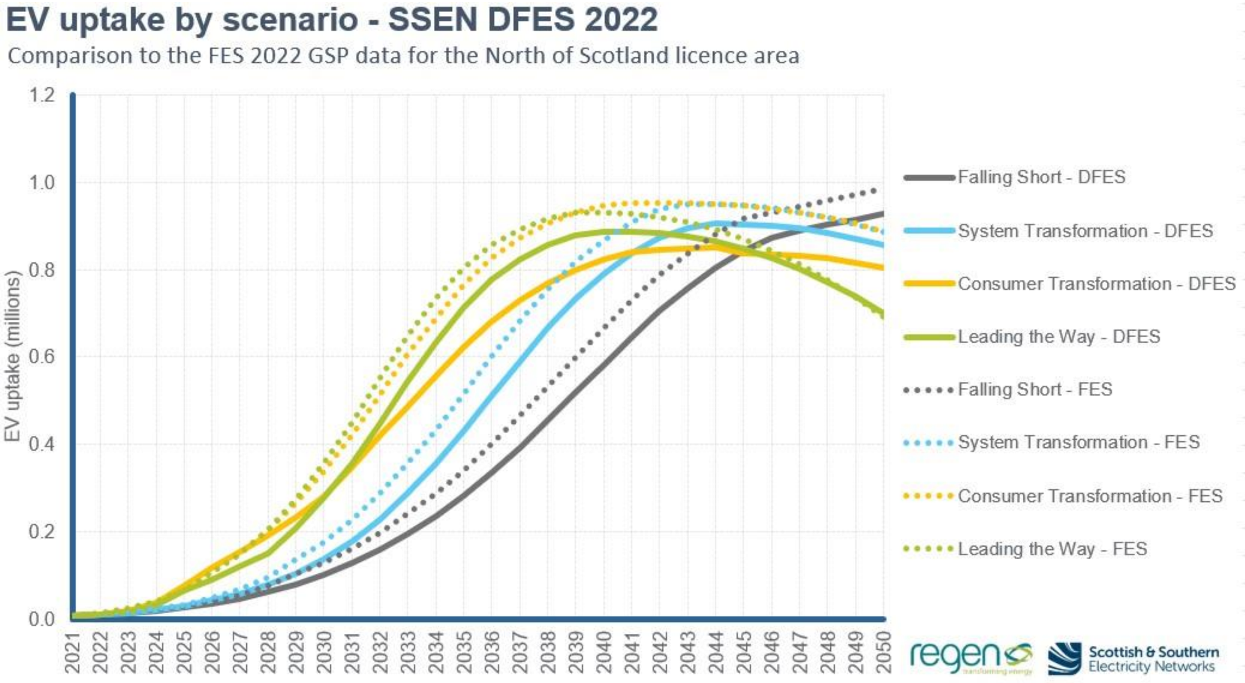
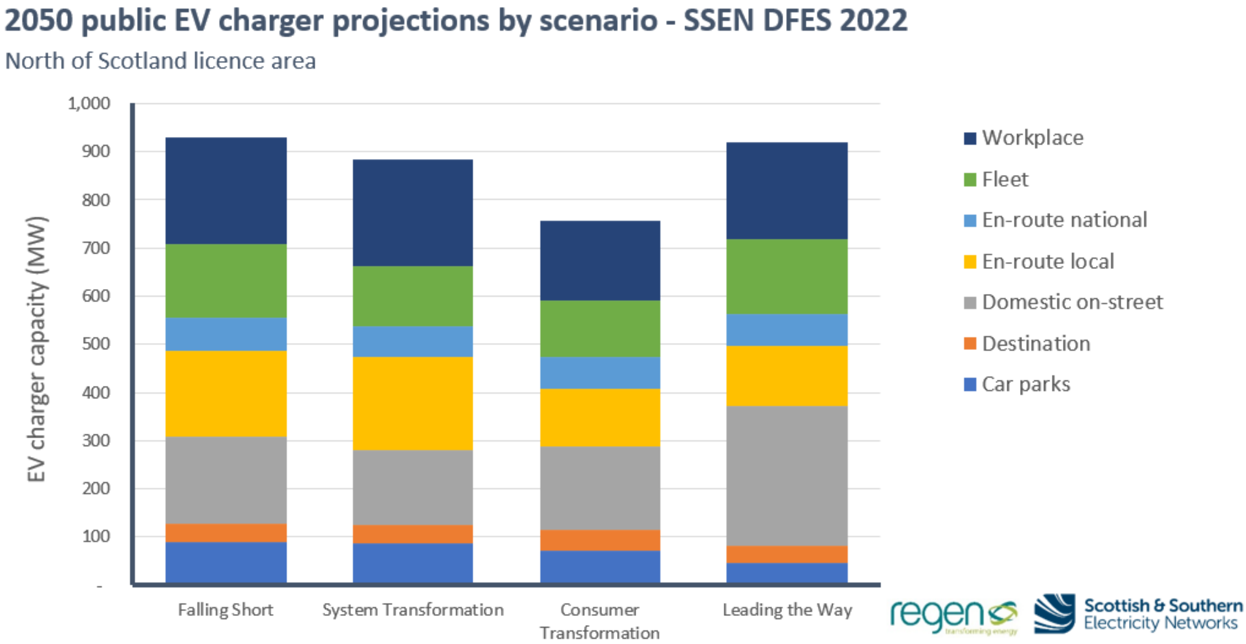


Figure 35: Non-domestic EV charger projections for the North of Scotland licence area

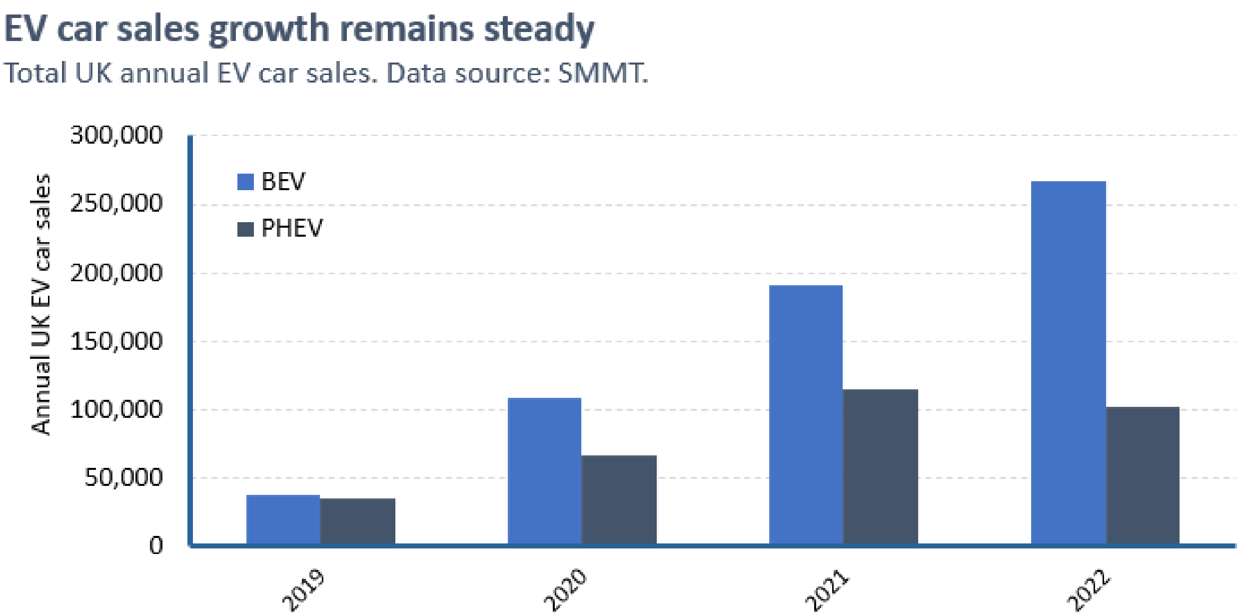


No comparison to the FES 2022 is made for EV charger projections, as FES 2022 data does not provide sufficient regional or GSP level information to reconcile DFES EV charger projections with.

Summary

- 1% of cars in the North of Scotland licence area are currently battery EVs, while 0.6% are plug-in hybrids; both are below the national uptake rate for these vehicles of 1.5% and 1%, respectively. EV uptake rate is anticipated to increase substantially in the licence area and across the UK under every scenario as the UK looks to decarbonise the transport sector.
- In all net zero scenarios, petrol and diesel vehicles are replaced by low emissions vehicles between now and 2050 to align with the UK Transport Decarbonisation Plan, which sets out to ban the sale of new petrol and diesel cars by 2030, which was announced in November 2020[lxxix]. In all scenarios, over 90% of petrol and diesel vehicles are replaced with battery EVs, with all plug-in hybrid EVs being phased out in all scenarios but **Falling Short**.
- 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[34] and broader support from the Scottish Government. This trend is expected to continue in the near term until demand for charging increases.
- The uptake of EV chargers is projected to increase substantially under 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; the split between off-street home charging versus public charging, 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.

Figure 36: Over 260,000 EV car sales in the UK in 2022, up 40% in 2021. However, these sales are not as high as the uptake in most net zero FES 2021 scenarios.

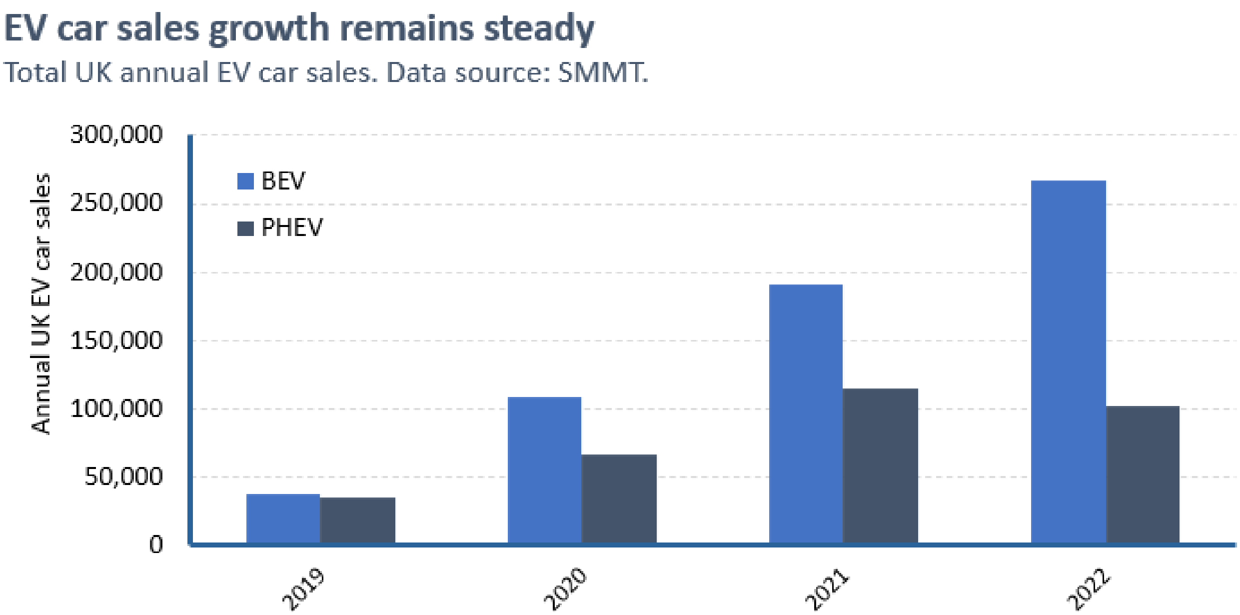


- The **Consumer Transformation** has been modelled to adopt the Scottish Government's ambition for the decarbonisation of road transport vehicles and consequently diverges from the FES 2022 **Consumer Transformation** scenario.

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

- Compared to the DFES 2021 report and FES 2021, the long-term projected uptake of EVs in DFES 2022 is slightly higher in all scenarios due to revisions to DfT's registered vehicle data for the area[35]. Furthermore, in all scenarios but **Consumer Transformation**, the proportion of HGVs, LGVs, buses, and coaches that are battery electric rather than other low-carbon fuels in the long term has increased. Consequently, there is an increase in EV charger capacity to accommodate the increased electricity demand from additional EVs, though this is less pronounced in **Consumer Transformation**.
- Compared to the DFES 2021 report and FES 2021, the short-term projected uptake of EVs in DFES 2022 is slightly lower than previously projected due to the passage of a further year since the last study in which EV uptake has not aligned with the ambitious net zero scenarios.

Figure 37: Over 260,000 EV car sales in the UK in 2022, up 40% in 2021. However, these sales are not as high as the uptake in most net zero FES 2021 scenarios.



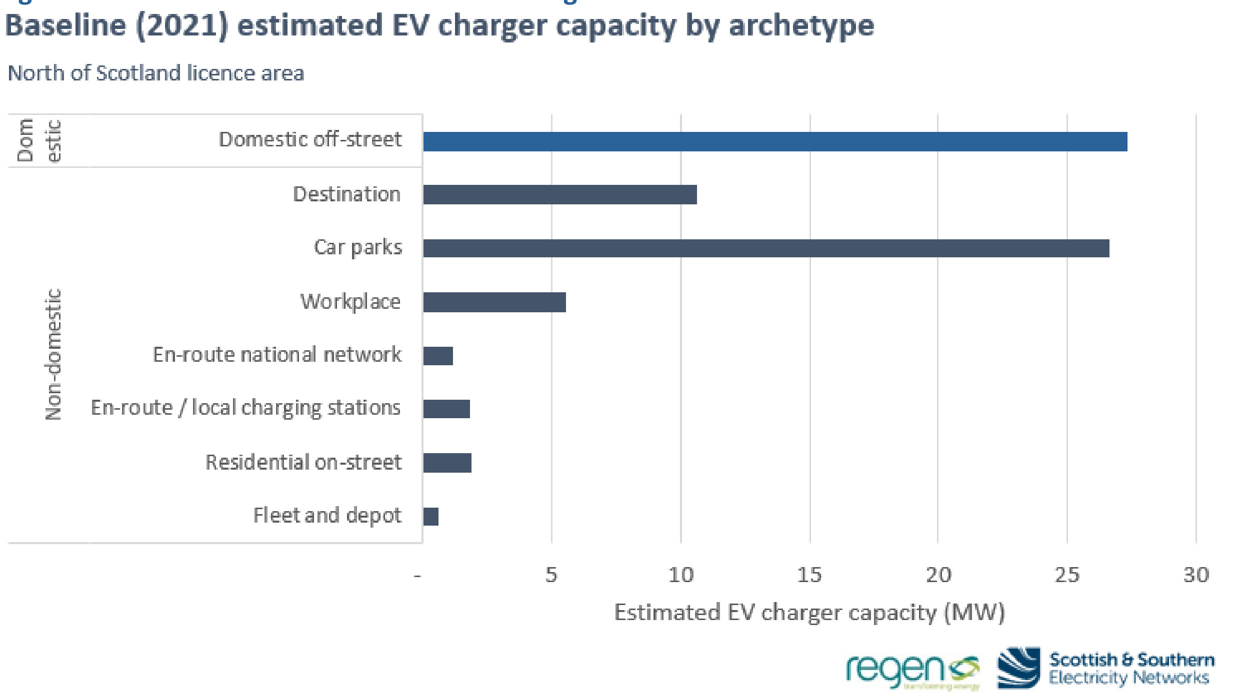
Modelling and assumptions

Baseline (2021)		
Archetype	**Thousands of vehicles**	**Description**
Pure electric car	6.2	Although EV uptake in the North of Scotland licence area is behind the national average, EV uptake has steadily increased across GB, particularly for battery EVs in recent years. This has been due to several factors, including: • Favourable tax benefits and grant support for ultra-low emissions vehicles • Increasing consumer confidence and awareness of EVs • Electrification of commercial vehicle fleets • Financial benefits of high mileage vehicles compared to petrol or diesel vehicles.
Plug-in hybrid car	4.0	
Pure electric LGV	0.4	

[35] DfT data (VEH0105) for Q3 2022 reported an approximate 5% increase in total vehicle numbers in the North of Scotland licence area compared to when the DFES 2021 study was undertaken.

Plug-in hybrid LGV	0.0	While most EV uptake has centred on cars, other vehicles, such as LGVs and buses, are 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.
Other electric vehicles	0.1	
EV charger baseline (2021)		
Archetype	**Capacity or numbers**	**Description**
Non-domestic EV chargers	48 MW	EV charger capacity increases have until recently occurred at a faster rate than EVs; however, EV charger deployment has slowed in Scotland in recent years, possibly due to there presently being a higher number of chargers compared to EVs relative to the GB average. In addition, most domestic EV owners are assumed to be associated with houses with off-street parking availability, and, therefore, most are assumed to have a home charger[lxxx].
Domestic EV chargers	3,910 chargers	

Figure 38: Domestic and non-domestic EV charger baseline



EV Scenario Projections
Under the three net zero scenarios, EV car adoption approaches saturation, and new EV uptake slows in most areas in the early 2040s. However, harder-to-electrify vehicles that saw lower uptake in the near term, such as HGVs, see a higher uptake out to 2050.

EV uptake slows and then reduces in all net zero scenarios but most prominently in **Leading the Way** in the long term, reflecting a lower level of car ownership and higher use of public transport. It is assumed that while EV numbers may reduce in the 2040s under all net zero scenarios, installed EV chargers will remain in place but may see different use trends as the overall number of vehicles on the road decreases and behaviours change.

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. While by 2050, the vast majority of vehicles are still electrified, a high proportion of this electrification will occur in the 2040s, and there are still petrol and diesel vehicles on the road in 2050 under this scenario.	282	929
System Transformation	The electrification of vehicles is slightly slower under this scenario, with the ban on sales of new petrol and diesel cars being pushed back until 2032. Nevertheless, the licence area will reach half a million registered EVs three years later than the most ambitious scenarios by 2036. Plug-in hybrid vehicles see moderate uptake, but battery electric vehicles are the dominant EV technology across all vehicle classes. The higher availability of low-carbon hydrogen in this scenario results in fewer passenger and non-passenger vehicles converting to hydrogen. Around half of the HGVs are also electrified under this scenario, with the remainder fuelled by low-carbon hydrogen.	430	856
Consumer Transformation	The Scottish Government's ambition to have no petrol and diesel vehicles of any archetype by 2045 is adopted. This scenario also adopts the Scottish Government's ambition for rapid uptake of electric buses, coaches and LGVs, in addition to its ambition for hydrogen vehicles.	622	805
Leading the Way	Passenger vehicles such as cars and LGVs are rapidly electrified, bolstered by a ban on sales of new petrol and diesel vehicles from 2030. Non-passenger vehicles, such as HGVs and buses, follow suit over a longer timeframe. By 2050, almost all road vehicles will be electrified in these scenarios. 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.	714	701

EV charger Scenario Projections					
Regen's EV charger DFES model determines the capacity required to charge the number of vehicles projected under 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 in the projections and assumptions around how EVs may be charged under each FES scenario and mileage driven. Where possible, the National Grid ESO FES data drives these charging behaviour assumptions. Domestic EV charger uptake is modelled based on EV uptake in households with off-street parking. It is assumed most households with an EV install an 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, will continue increasing until 2050. By this point, almost all road vehicles are electrified. EV charger uptake is relatively highest in car parks, public land, and en-route locations, facilitated by government and local authority leadership; however, uptake across all EV charger archetypes is the slowest compared to other scenarios.	171	427	294 MW	930 MW
System Transformation	Both EV adoption and associated EV charger capacity peak in the 2040s. 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.	247	427	479 MW	886 MW
Consumer Transformation	**Consumer Transformation** has adopted the Scottish Government's ambition for the high uptake of electric and hydrogen vehicles. Relative to the FES 2022 scenarios, hydrogen vehicles are more numerous in the Scottish Government's transport ambitions, particularly for HGVs, buses and coaches, and LGVs. Consequently, in the long-term, **Consumer Transformation** has a lower total EV charger capacity than other DFES 2022 scenarios due to a lower electricity demand associated with EV charging.	372	450	594 MW	757 MW

Leading the Way	Both EV adoption and associated EV charger capacity peak in the early 2040s. By this point, almost all road transport is electrified. In **Leading the Way**, the uptake of EV cars slows and then reduces significantly as consumers adopt new transport methods, including public transport, shared vehicles and autonomous vehicles (AVs). However, while the number of EV cars may reduce, utilisation and milage per AV increases significantly. The reduction in overall energy demand is, therefore, less significant.	415	439	692 MW	920 MW

EVs reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	Baseline EV numbers in the DFES 2022 are sourced from DfT vehicle licencing data and are slightly different to the FES 2022 baseline figures, most likely due to the time of data extraction.
Projections	The SSEN DFES 2022 projections are broadly in line with the FES 2022 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 **Consumer Transformation** aligns with the Scottish Government's ambition and is not directly aligned with FES 2022. It is assumed the small variations in projections between SSEN DFES 2022 and FES 2022 projections are due to similar variations found in the baseline, associated with varying accounting of the total number of vehicles in the licence area.

EV charger reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline and projections	The ESO FES 2022 data does not provide sufficient regional or GSP-level information to reconcile DFES EV charger projections. However, factors that will affect EV charging infrastructure which are available in the FES 2022 assumptions and data workbooks, are used where it is possible to do so, including: • Projections of vehicle numbers • Projections of EV average annual mileage trends • Projections of EV and EV charger efficiencies. Other FES assumptions related to EV chargers can be seen in the FES 2022 assumption tables below.
Other assumptions	Although there have been several trial projects and new data becoming available, there is still a lack of evidence of future consumer charging behaviour, charger utilisation rates and vehicle ownership trends. This results in some uncertainty in the assumptions that must be made to project future EV charging requirements. Assumptions that have been made include: • What proportion of annual EV energy requirements will be delivered at different locations (and thus by which EV charger archetypes) • EV charger utilisation rates at different locations. These assumptions have been made using industry input and Regen analysis. As more behavioural data and other evidence become available, these assumptions will be further refined for future DFES analysis. Some assumptions have been made as to the behaviour of AV cars, including:

	• The proportion of AVs that are private or shared in the absence of further information. • AV charging behaviour is similar to EV cars, the key difference being increased fleet/depot charging.

Geographical Factors affecting deployment at a local level

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

Scottish Government policy context

- The Scottish Government's Second National Transport Strategy[lxxxi] was published in 2022, setting out the actions to deliver Scotland's vision and priorities for transport. Aiming to reduce inequalities, take climate action and other economic and health benefits for Scotland, the report highlights the need to consider the transport system holistically and equitably to enable the transition to electric vehicles and other sustainable transport means.
- It is estimated that Chargeplace Scotland operates 85% of all public EV chargers, a national network of EV chargers funded by the Scottish Government. This has resulted in a baseline with more chargers in public locations such as car parks, public estates, and local charging infrastructure relative to other licence areas. However, the proportion of chargers that are estimated to be operated by Chargeplace Scotland has reduced slightly from last year, potentially indicating an increasing number of private EV chargers in the area.
- Chargeplace Scotland's dominant market position and strategy of chargers in predominantly public and centralised locations is expected to continue in the short term. However, as demand for EV charging increases, charging infrastructure is expected to become increasingly distributed, particularly as the number of privately operated chargers increases.

Relevant assumptions from National Grid FES 2022

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. Therefore, growth is limited by the growth in Robotaxis for urban transport in this scenario.
3.3.2 - Autonomy	
Falling Short	Uptake is limited by technology readiness and consumer trust. Does not affect 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 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 many urban households to become one-car families with a corresponding mile increase. Cars do further increase 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 will be ULEV, and by 2040, 100% of van sales will be 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. However, there's a 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. In addition, there's a 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 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 limit 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. A 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's a lack of solutions to residential charging for those without off-street parking, which consumers are willing to adopt. These consumers charge at destinations such as work
System Transformation	There's a lack of solutions to residential charging for those without off-street parking, which consumers are willing to adopt. Emphasis on the 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 the public rollout of fast chargers also allows near-home rapid charging.
Leading the Way	Widespread innovation & behaviour change allows the majority of those with on-street parking to charge overnight. This limits the market for near-home rapid charging

Incorporation of Stakeholder Feedback

Stakeholder feedback provided	How this has influenced our analysis
When 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), stakeholders were split but leant towards (40%) publicly owned charging infrastructure, compared to 32% neighbourhood charging and 28% a shift towards distributed on-street charging.	Stakeholder feedback highlighted the uncertainty of the shape and size of a future EV charger network and future consumer behaviour. Therefore, to reflect this feedback, the scenarios model variability in the proportion of EV charging undertaken at dispersed locations and more centralised locations and the proportion undertaken near and far away from home.
The North of Scotland stakeholders viewed several factors as barriers to the widespread EV uptake in the licence area. However, no standout factor was viewed as significantly more impactful than other barriers.	Stakeholder feedback highlighted several factors affecting the uptake of EVs in the area. However, this validated existing modelling assumptions, so no further action was taken based on this feedback.

References

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

[lxxix] Department for Transport 2020, *Government takes historic step towards net-zero with end of sale of new petrol and diesel cars by 2030.* https://www.gov.uk/government/news/government-takes-historic-step-towards-net-zero-with-end-of-sale-of-new-petrol-and-diesel-cars-by-2030

[lxxx] 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

[lxxxi] Scottish Government 2022. *Scottish Government National Transport Strategy Delivery Plan (2022-2023).* https://www.transport.gov.scot/media/51675/national-transport-strategy-nts2-second-delivery-plan-2022-2023.pdf

Heat pumps and resistive electric heating

Summary of modelling assumptions and results

Technology specification

The analysis covers all variants of electrically fuelled heating technologies within the scope of the SSEN DFES 2022. 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	18	35	76	129	206	265	329
		System Transformation		40	76	105	144	184	244
		Consumer Transformation		50	216	333	406	486	517
		Leading the Way		87	255	341	394	422	425
	Hybrid heat pumps	Falling Short	--	--	2	6	12	16	20
		System Transformation		2	6	17	56	95	123
		Consumer Transformation		1	6	6	6	8	10
		Leading the Way		2	9	19	31	41	45
		Number of properties (thousands)	**Baseline**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Non-domestic	Non-hybrid heat pumps	Falling Short	3	5	7	9	11	13	14
		System Transformation		5	9	13	17	20	22
		Consumer Transformation		6	18	23	24	24	25
		Leading the Way		5	14	18	20	20	21
	Hybrid heat pumps	Falling Short	--	--	--	--	1	2	2
		System Transformation		1	2	4	7	8	9
		Consumer Transformation		1	3	5	5	6	6
		Leading the Way		1	3	5	6	7	8

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	113	105	89	73	60	51	48
	System Transformation		103	87	72	47	27	16
	Consumer Transformation		108	94	75	69	63	53
	Leading the Way		101	88	72	63	56	56

Figure 39: Domestic heat pumps (non-hybrid and hybrid[36]) projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections

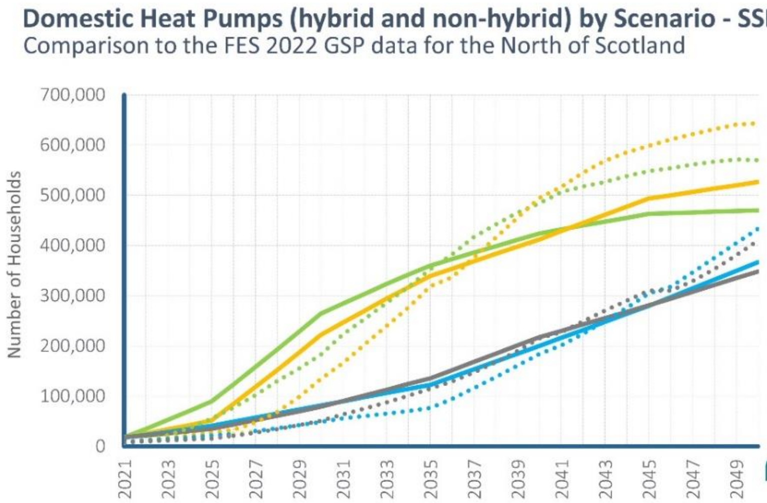
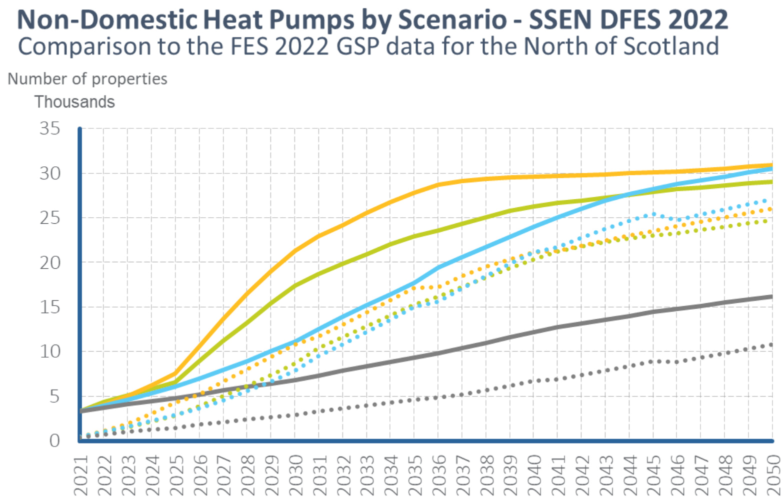
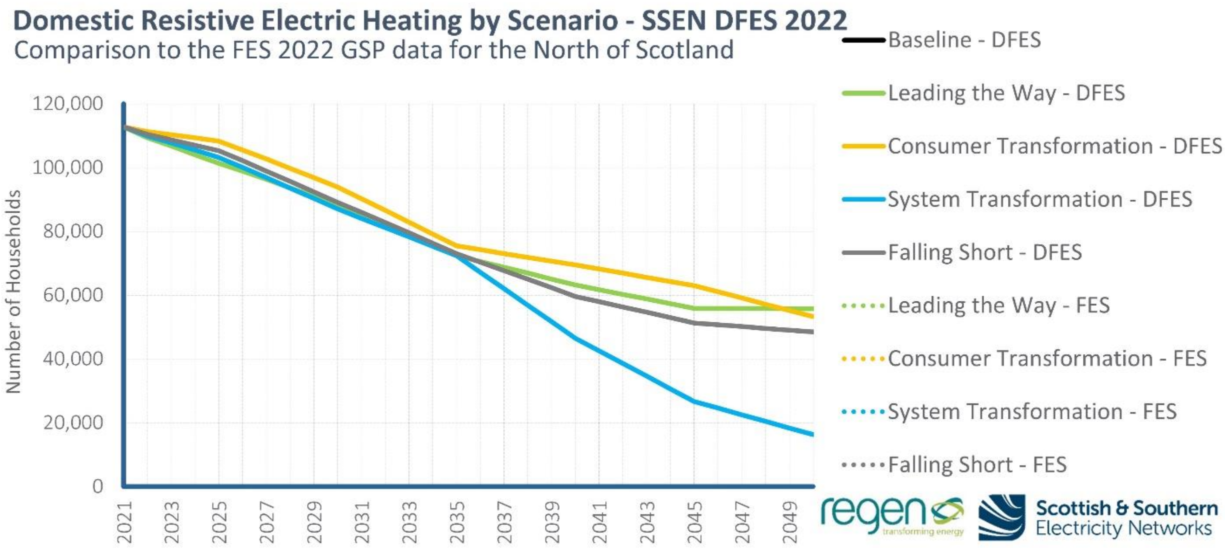


Figure 40: Non-domestic heat pumps (non-hybrid and hybrid) projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections



[36] The Building Block data provided in the FES 2022 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 2022 results has been undertaken using combined figures for both non-hybrid and hybrid heat pumps together.

Figure 41: Domestic resistive electric heating projections for the North of Scotland licence area



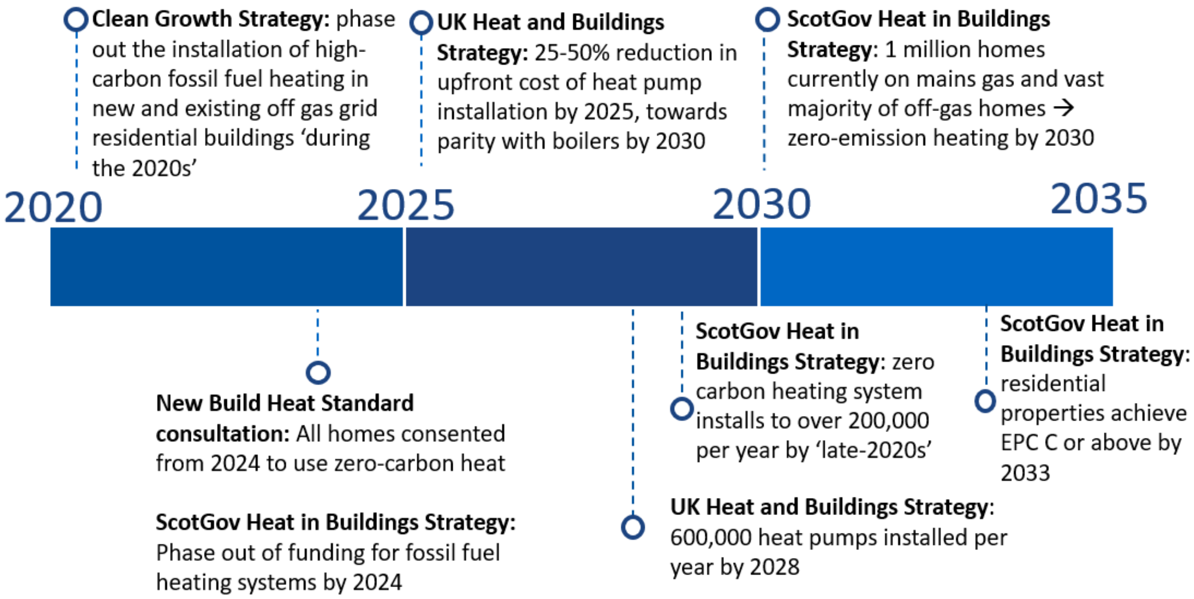
Summary

- 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[lxxxii] if Scotland and the UK are to meet their carbon reduction targets. Scotland's Heat in Buildings Strategy (2021) also targets an installation rate of zero emissions heat that peaks at over 200,000 new systems per annum in the late-2020s. Scottish Government also recently amended the Home Energy Scotland Scheme[lxxxiii] to make it easier for households to access funding for heat and energy efficiency measures in their homes and to target support for those in rural areas.
- The North of Scotland licence area has diverse 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 in the near future, especially in areas where off-gas buildings are prevalent.
- Under **Consumer Transformation** and **Leading the Way**, heat pumps are the primary driver in the decarbonisation of heat in the North of Scotland licence area and at a national level. The initial adoption of heat pumps is projected to occur mostly in off-gas, well-insulated buildings, with a subsequent wider-scale rollout of heat pumps across the majority of buildings modelled out to 2050. For the North of Scotland licence area, this results in c. 527,000 homes and c. 31,000 non-domestic buildings operating a heat pump by 2050 under **Consumer Transformation**.
- Under **System Transformation**, the primary driver for the decarbonisation of heat is low-carbon hydrogen, which is utilised through a mixture of standalone hydrogen boilers and hybrid heat pumps. However, due to a higher proportion of off-gas buildings in the North of Scotland, non-hybrid heat pumps are expected to be more prevalent, as the availability of hydrogen for domestic and non-domestic heating is assumed to be similar to that of current fossil gas heating.
- Under **Falling Short**, slow progress is made towards heat decarbonisation. Despite some adoption of heat pumps in the late 2030s and the 2040s, a significant number of buildings still rely on fossil gas boilers for heating in 2050, reflecting a failure to achieve the UK's carbon emissions reduction targets.
- In all scenarios, there is a decline in the number of buildings using resistive electric heating, including direct electric heating and night storage heaters, which is replaced by heat pumps and district heating. Direct electric heating, being the most expensive heating method, serves as a financial incentive for consumers to transition to alternative technologies in all four scenarios. Additionally, there is 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 properties with very low energy efficiency levels.

Implementation of Scottish Government Policies in the DFES 2022 analysis

The **Consumer Transformation** and **Leading the Way** scenarios have been 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[lxxxiv].

Figure 42: Heat Policies in Scotland and the UK



In addition, the Hydrogen Policy Statement[lxxxv] outlines policies that may have implications for heat decarbonisation in the longer term. At a local level, Scottish local authorities are taking the lead on heat decarbonisation and the rollout of Local Heat and Energy Efficiency Strategies (LHEES) [lxxxvi].

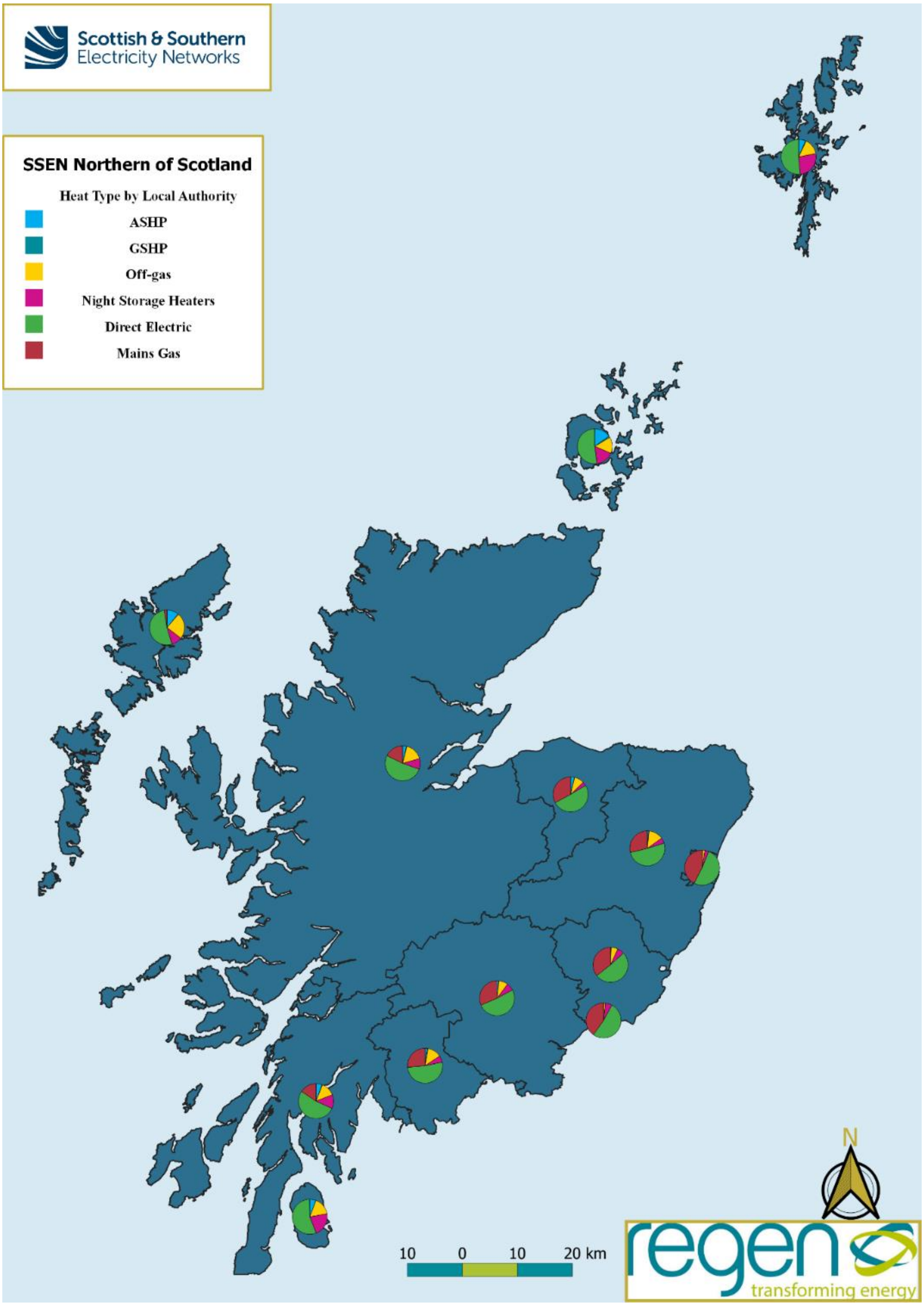
A combination of low carbon technologies will be necessary to achieve zero emissions heating in Scotland. The most cost-effective pathway will require a strategic response using multiple technology solutions. While heat pumps are the key low-carbon heating solution available today and necessary to meet 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[lxxxvii], which identified actions to address drivers of fuel poverty and address fuel poverty for those at the highest risk. In 2021, Scotland introduced the Heat Networks (Scotland) Bill[lxxxviii] to introduce regulation and a district and communal heating licensing system to accelerate the use of the networks across Scotland.

Modelling Stages

Baseline (2021)			
Domestic heat pumps			
Sub-technology	**Number of homes (thousands)**	**Proportion of homes**	**Description**
Non-hybrid ASHP	15	2.2%	The Renewable Heat Incentive (RHI) scheme, which operated from 2014 to 2022, provided significant support for the installation of heat pumps in existing homes. The RHI has been succeeded by the Boiler Upgrade Scheme[lxxxix], which offers upfront grant payments aimed at reducing the capital costs associated with heat pump installations. The RHI was particularly popular in Scotland, with around 16% of all heat pumps accredited by the RHI being in the North of Scotland licence area. As a result, 2.7% of homes in the North of Scotland licence area currently have a heat pump, which is above the national average. As of the end of 2021, an estimated 18,000 homes were heated by domestic heat pumps, compared to c. 22,000 in 2020. This change in baseline data is due to far greater availability of EPC data, giving more confidence in the characterisation of the area compared to the more probabilistic assessment of key parameters used for DFES 2021 at a more granular low-voltage feeder level.
Non-hybrid GSHP	3	0.4%	
Hybrid heat pump	--	--	
Domestic resistive electric heating			
Night storage heaters	85	12.4%	As of the end of 2021, approximately 113,000 homes were heated by resistive electric heaters, compared to c. 138,000 in the previous DFES analysis. This decrease in the baseline figure is due to the use of the updated EPC dataset for this year's analysis, which holds a greater availability of data and therefore gives more confidence in this year's baseline figures. Resistive electric heating is much more common in the North of Scotland licence area compared to the national average, heating over 16% of homes in the licence area compared to 8% nationally, according to FES 2022. This is mainly due to the high proportion of off-gas homes across the licence area and the cost of non-electric off-gas fuels such as oil and LPG in the more remote areas of the licence area, such as the Highlands and Islands (see Figure 43).
Direct electric heaters	28	4.1%	

Non-domestic heat pumps			
Non-hybrid heat pump	3	--	An estimated 3,300 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.

Figure 43: Heat Type by Local Authority for the SSEN North of Scotland Licence Area



<table>
<tr><th colspan="4">Near-term projections (2022-2025)</th></tr>
<tr><td colspan="4">The future uptake of different types of electric heating in the licence area is modelled based on several key factors, including housing types and sociodemographic factors. Under the three net zero scenarios, the uptake of heat pumps in the licence area is projected to increase significantly by 2025, particularly in off-gas homes heated by oil and LPG. Conversely, the number of homes heated by resistive electric heating is projected to slowly decrease under every scenario in the near term.</td></tr>
<tr><th colspan="4">Domestic heat pumps</th></tr>
<tr><th rowspan="2">Scenario</th><th rowspan="2">Description</th><th colspan="2">Proportion of homes in 2025</th></tr>
<tr><th>North of Scotland</th><th>GB (FES)</th></tr>
<tr><td>Falling Short</td><td rowspan="2">Under these scenarios, near-term decarbonisation and electrification of heat is low. 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. 35,000-41,000 homes (as well as c. 5,000-6,000 non-domestic buildings) 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.</td><td>5%</td><td>2%</td></tr>
<tr><td>System Transformation</td><td>6%</td><td>2%</td></tr>
<tr><td>Consumer Transformation</td><td rowspan="2">The uptake of ASHP and GSHP heat pumps is highest in these scenarios, as Scotland and UK progress towards their 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-emissions 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 system 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 North of Scotland licence area, areas of off-gas and well-insulated homes are modelled to see particularly high levels of heat pump deployment. In addition, some on-gas houses and flats also convert to heat pumps due to regional adoption of the Boiler Upgrade Scheme[lxxxix]. As a result of this and Scotland's ambitious zero emissions heat system installation targets, the North of Scotland licence area sees high near-term uptake of heat pumps relative to GB overall.</td><td>7%</td><td>3%</td></tr>
<tr><td>Leading the Way</td><td>13%</td><td>7%</td></tr>
</table>

Domestic resistive electric heating			
Falling Short	Under 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 high, 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.	15%	8%
System Transformation		15%	8%
Consumer Transformation	Under these two 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.	15%	8%
Leading the Way		14%	8%

Non-domestic heat pumps			
Scenario	Description	Installations in 2025	
		non-hybrid	hybrid
Falling Short	Non-domestic heat pump varies slightly by scenario in the near-term, with the highest uptake occurring under **Consumer Transformation**, where small-scale businesses are expected to accelerate uptake, to decarbonise heating at a faster rate as conscious commercial consumers.	4,573	173
System Transformation		5,282	826
Consumer Transformation		6,306	1,200
Leading the Way		5,486	1,100

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. Under **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. Under every scenario, this includes both heat pumps and connections to district heat networks. There are 78,000-88,000 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[xc].

Domestic heat pumps					
Scenario	Description	Proportion of homes			
		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.	18%	11%	46%	41%
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, a quarter of all heat pumps modelled under 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 sees heat pump uptake that is significantly ahead of the GB trend. The remaining homes are heated by hydrogen boilers.	16%	7%	48%	44%

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 on-gas homes convert to a heat pump by 2035 (45-48%); 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 under 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. 470,000-530,000 properties are operating a heat pump by 2050 under these scenarios.	45%	35%	69%	73%
Leading the Way		48%	42%	61%	64%
Domestic resistive electric heating					
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 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.	10%	6%	6%	5%
System Transformation		10%	6%	2%	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. 53,000 homes (7%) could operate a resistive electric heater by 2050 under these scenarios.	10%	7%	7%	5%
Leading the Way		10%	6%	7%	5%

Non-domestic heat pumps					
Scenario	Description	Installations in 2035		Installations in 2050	
		non-hybrid	hybrid	non-hybrid	hybrid
Falling Short	The majority of 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. Under **Consumer Transformation**, c.31,000 non-domestic premises install a type of heat pump by 2050, reflecting more businesses focusing on electrification to meet their net zero plans.	8,934	384	13,872	2,336
System Transformation		13,269	4,483	21,547	8,992
Consumer Transformation		23,127	4,725	24,832	6,046
Leading the Way		17,912	5,044	20,730	8,323

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	**Domestic heat pumps:** The DFES baseline is approximately double that of the FES but is supported by EPC data. **Non-domestic heat pumps:** The DFES baseline is markedly larger than the FES, supported by 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 licence area is above the national average in several attributes, resulting in 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 slightly lower under every scenario. Licence area attributes lead to a higher *proportion* of homes with heat pumps in the DFES compared to the FES. Still, the lower *absolute values* indicate a difference between DFES and FES in the total housing stock modelled out to 2050. **Non-domestic heat pumps:** All scenarios become broadly similar to the FES, differing by the magnitude of the baseline difference.
Overarching trend	The DFES outcomes for heat pumps under each scenario show a higher uptake than the FES in the near-medium term. By 2050, DFES projections for domestic heat pumps fall below FES projections (likely due to differences in housing stock modelling). The DFES non-domestic heat pump projections are higher in all scenarios than the FES 2022. This is likely due to small differences in the total number of heated non-domestic buildings considered in each analysis. The DFES building stock is modelled based on BEIS NEED data, Ordnance Survey Addressbase data, Non-Domestic EPC, and Display Energy Certificate data.

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[xci], 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 levels of energy efficiency categorised into well-insulated homes (EPC B and above) and less well-insulated homes	EPC data

Relevant assumptions from National Grid FES 2022

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.

[lxxxii] Scottish Government 2021, *Heat in Buildings Strategy.* https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/pages/3/
[lxxxiii] 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/
[lxxxiv] Scottish Government 2021, *Heat in Buildings Strategy.* https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/
[lxxxv] Scottish Government 2020, *Hydrogen Policy Statement*. https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/
[lxxxvi] Scottish Government 2020, *Local Heat and Energy Efficiency Strategies (LHEES): phase 2 pilots evaluation.* https://www.gov.scot/publications/local-heat-energy-efficiency-strategies-lhees-phase-2-pilotsevaluation/
[lxxxvii] Scottish Government 2021, *Tackling fuel poverty in Scotland: a strategic approach.* https://www.gov.scot/publications/tackling-fuel-poverty-scotland-strategic-approach/
[lxxxviii] Scottish Government 2020, *News: Heat Networks Bill.* https://www.gov.scot/news/heat-networks-bill/
[lxxxix] 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
[xc] Scottish Government 2022, *New Build Heat Standard: consultation - part two*. https://www.gov.scot/publications/new-build-heat-standard-consultation-part-ii/
[xci] 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

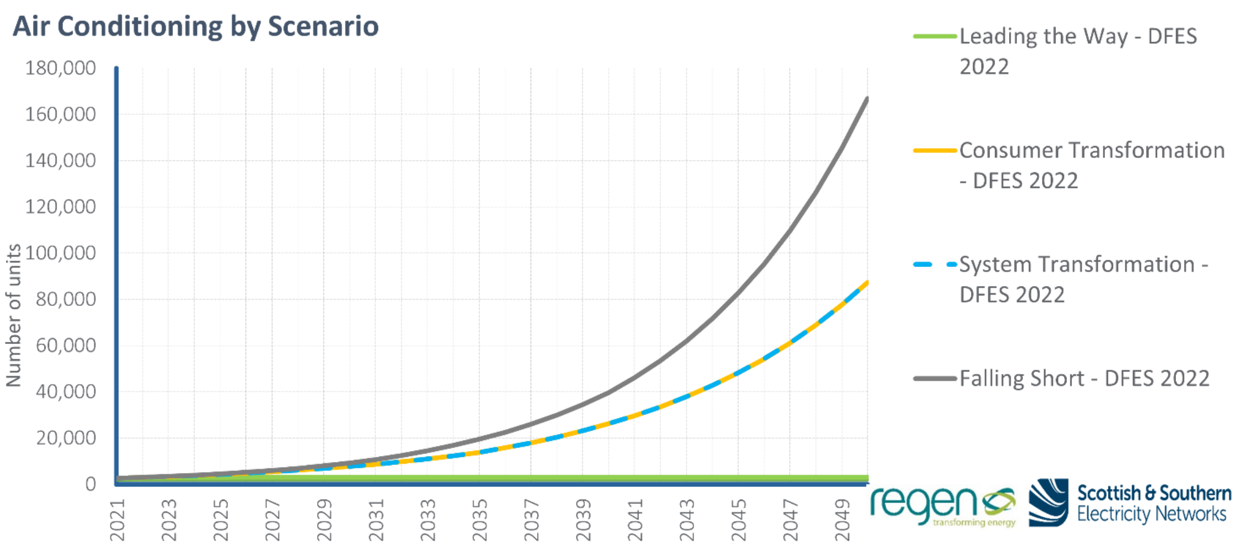
This analysis covers domestic air conditioning units, based on a typical portable or window-mounted unit in the North of Scotland licence area.

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	2	5	9	19	40	83	167
System Transformation		4	8	14	26	48	87
Consumer Transformation		4	8	14	26	48	87
Leading the Way		3	3	3	3	3	3

Figure 44: Air conditioning projections for the North of Scotland licence area



Summary

- The baseline for air conditioning (AC) units in the North of Scotland licence area, ~2,700 units, represents 0.44% of homes in the licence area. This is lower than the national baseline of c. 1% of UK homes currently containing AC units[xcii].
- The number of cooling degree days[xciii] 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[xciv], it has been assumed that AC units will not be added to new developments in the licence area.
- The small baseline numbers and high uncertainty around the future of domestic cooling have resulted in a broad range of scenario outcomes for the licence area. **Leading the Way** sees the lowest uptake of AC units (c.3,062) by 2050. **Falling Short** models domestic AC becoming much more common, with a projection of c. 166,955 new units by 2050.

Modelling and assumptions

Baseline (2021)	
Number of domestic units	**The proportion of homes with AC unit**
2,690	0.44%

Baseline modelling assumptions

We have aligned with the National Grid FES 2022[xcii] data, which provides a national baseline of around 296,000 domestic air conditions, equivalent to around 1.1% of homes in the UK.

In addition, a 2016 report by Tyndall Manchester[xcv] reviews AC installations in the UK, stating that 1-3% of households reported some form of AC.

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 days at or above 18.5 °C and a population density 49% below the national average[xcvi]. As a result, a proportionally smaller baseline of 0.44% of homes was modelled, equating to just under 2,700 AC units.

Near-term (2022-2025)

Scenario	Description
Falling Short System Transformation Consumer Transformation	Under these scenarios, uptake in domestic AC units increases due to more frequent summer heat waves. Most of these units are assumed to be in denser urban areas due to the “heat island effect”. The uptake of AC units is expected to be between c. 4.3-4.6 thousand units in homes by 2025 in these scenarios.
Leading the Way	The uptake of domestic AC is minimal, with households opting for passive cooling methods such as shading, ventilation and insulation. As a result, very few (if any) new AC units are installed by 2025 under this scenario.

Medium-term and long-term (2025-2050)

Scenario	Description	Homes with AC units (1000s)	% Of housing stock	Homes with AC units (1000s)	% Of housing stock
		In 2035		In 2050	
Falling Short	The increasing frequency of heat waves and societal reluctance to engage in passive cooling leads to a more significant uptake of domestic AC, even in colder regions, as the ‘easiest’ route to comfortable internal temperatures.	19	2.3%	167	27.2%
System Transformation		14	3.2%	87	14.2%

Consumer Transformation	The uptake of domestic AC accelerates in urban areas due to heat island effects and the prevalence of smaller dwellings such as flats.				
Leading the Way	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.	3.0	0.5%	3.1	0.5%

Modelling assumptions	
Criteria	**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 is located in very densely populated areas, including the 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.

Cooling degrees days	Cooling degree days at 18.5 °C in the North of Scotland are the lowest in the UK, with ~9 recorded days in the licence area. This metric was used in all scenarios.
Future Home Standards	The Future Homes Standard Document O[xcvii][xciv] stipulates high energy efficiency for air conditioning and limits oversizing cooling systems in new homes. As a result, the DFES 2022 modelling assumes that the vast majority of domestic AC uptake is retrofitted in existing homes under every scenario.

Reconciliation with National Grid FES 2022:

- The FES 2022 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 2022 national average in every scenario.

Geographical Factors affecting deployment at a local level

Geographical Factors	Description
Population Density	Early uptake is focused in denser urban areas. Later uptake expands to areas of lower housing density in scenarios where domestic AC becomes more prevalent.
Affluence	The near-term distribution of domestic AC is influenced by net annual income after housing costs due to the relatively high upfront costs and running of domestic AC units.

Relevant assumptions from National Grid FES 2022

Scenario		3.1.2 - Uptake of Residential Air Conditioning
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)

[xcii] National Grid FES 2020, *Data workbook, ED2 worksheet Data Item for Residential Air Conditioning*. https://www.nationalgrideso.com/future-energy/future-energy-scenarios/archive
[xciii] Stark 2022, *Degree Days for Free*. https://www.stark.co.uk/degree-days-for-free/
[xciv] HM GOvernemtn 2021, *Building Regulations 2010 Overheating: Approved Document O*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1057374/ADO.pdf
[xcv] Tyndall Manchester 2016, *Air conditioning demand assessment*. https://www.enwl.co.uk/globalassets/innovation/enwl001-demand-scenarios--atlas/enwl001-closedown-report/appendix-3---tyndall-uom---air-conditioning-demand-report-may2016.pdf
[xcvi] Scotland 2011 Census-National Records of Scotland. https://www.scotlandscensus.gov.uk/census-results/flexible-table-builder/
[xcvii] UK 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

Hydrogen electrolysis

Summary of modelling assumptions and results

Technology specification

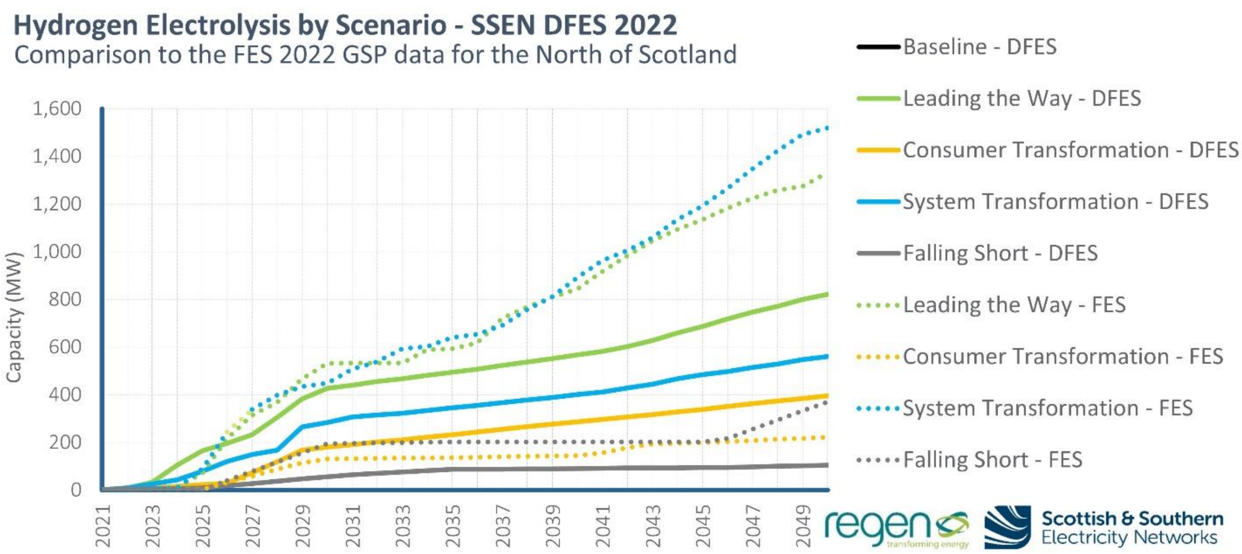
The analysis covers the capacity of hydrogen electrolysers connected to the distribution network in the North of Scotland licence area. The analysis does not include electrolysers that are directly powered by renewable energy without a dedicated grid connection ('off-grid') or large-scale electrolysers connected to the transmission network. Nor does it include 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	2	9	55	87	90	94	105
System Transformation		79	282	344	400	483	559
Consumer Transformation		23	179	231	286	338	395
Leading the Way		164	425	492	567	685	820

Figure 45: Hydrogen electrolysis projections for the North of Scotland licence area, compared to National Grid FES 2022 regional projections

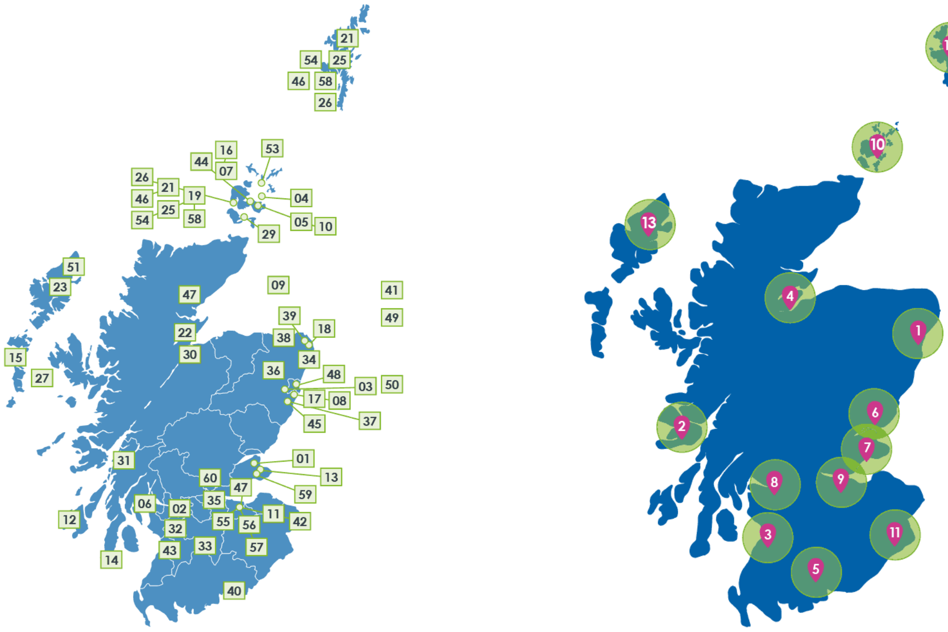


Summary

- There is uncertainty around the direction of travel for hydrogen electrolysis as an emerging technology.
- 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 EMEC offshore-generated electricity, are also seeking backup grid import connections to ensure the security of supply when on-site renewables aren't generating.
- The British Energy Security Strategy[xcviii] outlines 10 GW of low carbon hydrogen, of which 5 GW will be from electrolysis, by 2030. The Scottish Government Hydrogen Action Plan[xcix] 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.
- The UK government's electrolytic allocation round[c] will provide government subsidy support from 2023 onwards for both CAPEX, via capital grants, and OPEX, via ongoing revenue payments. Projects over 5 MW are eligible for support, with successful applicants announced in early 2023.
- Of all DNO licence areas, the North of Scotland is modelled to host between 6-9% 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** (821 MW) and **System Transformation** (560 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 46: Maps of current and planned hydrogen projects and Regional Hydrogen Hubs in Scotland



Source: Scottish Government Hydrogen Action Plan[xcix]

Modelling and assumptions

Baseline (2021)		
Number of Sites	Total Capacity	Description

4	2 MW	As of the end of 2021, there were four known electricity networked hydrogen electrolysis sites, the largest of which is the 1 MW refuelling station at Kittybrewster[ci]. 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[cii]. The European Marine Energy Centre (EMEC) is commissioning a 670 kW electrolyser at the ITEG facility on Orkney. This site is a demonstration project that is due to run until 2023. Several other sites have not been modelled as networked due to the presence of on-site, behind-the-meter renewable generation, as these sites will likely not directly impact the network. There is uncertainty around whether sites hold electricity import agreements, for instance, to supplement on-site renewable generation to maximise electrolyser output and keep down costs. Unless confirmed to hold an import agreement, these operational yet potentially non-networked sites (e.g. JIVE[ciii] and ACHES refuelling station[civ]) have been excluded from the DFES projections. The BIG HIT demonstration[cv], which concluded in 2022, was also excluded as it consumed limited curtailed on-site renewable energy generation[cvi].

Pipeline (2022-2030)

Number of pipeline sites	Total capacity
2	36.4 MW

Description

Several prospective hydrogen electrolysis projects have been identified in the licence area, of which ten could be connected to the distribution network, and two have known electrolyser capacities. One of these projects, the Project HyLaddie Project[cvii], may connect within the existing agreed supply capacity of the site's existing connection agreements and operate as a behind-the-meter asset. In this case, they have been modelled as 0 kW capacity. Networked sites with unknown capacities are reflected through the near-term projections for new electrolysis capacity, co-located alongside areas with hydrogen hubs.

There are many hydrogen demonstrator and pilot projects across the North of Scotland. However, many of these sites could fall out-of-scope of the analysis due to deriving hydrogen from off-network sources and not seeking a grid connection. Desk-based research suggested that at least 21 electrolyser projects in the licence area could be non-network connected. 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, thereby minimising costs[37]. 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

There is an additional uncertainty as to whether hydrogen electrolysis is to 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.

[37] 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.

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

Networked 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 is awaiting a decision.	Falling Short	2026
		System Transformation	2024
		Consumer Transformation	2024
		Leading the Way	2023
North of Scotland Hydrogen Programme Distilleries Project, **35 MW**[cix]	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	2024

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, provides some impetus for the sector[c]. Successful projects, which must be 5 MW minimum to be eligible to apply, are due to be announced in early 2023.

While the North of Scotland hosts numerous regional hydrogen innovation hubs, many known projects are destined for transmission or gas grid connection as standalone sites. 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[cx]. 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 will likely increase in the medium term across all scenarios. This is driven by the uptake of hydrogen-fuelled heavy vehicle fleets and the introduction of mainstream hydrogen fuel cell public transport. This transition to low carbon heavy vehicles will be further incentivised by wider transport decarbonisation policy measures, such as the ban on the sale of new petrol and diesel cars by 2030, though it is understood that the majority of smaller road vehicles will be very likely be battery electric vehicles.

In the longer term, hydrogen electrolysers are expected to scale their capacity 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	Capacity by 2050
Falling Short	All the GB (very limited) electrolysis development remains distribution network-connected out to 2030 and 85% by 2050. Small industrial and heavy transport demand further limit growth in the North of Scotland.	87 MW	105 MW
System Transformation	Moderate growth is mainly driven by the presence of renewable generation in the licence area and demand for marine transport to some degree. 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.	344 MW	559 MW
Consumer Transformation	Factors determining the uptake of hydrogen electrolysis are diversified, with industrial customers and clusters being the strongest factor, followed closely 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.	231 MW	395 MW
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 further expanded to support export capabilities. The establishment of a national hydrogen network boosts projections.	492 MW	820 MW

Network-connected electrolysis projections – methodology overview

To determine licence-area projections beyond known projects, FES 2022 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.

Hydrogen licence area weighting factors					
Factor	Leading the Way	Consumer Transformation	System Transformation	Falling Short	Presence of this factor in the North of Scotland
Industrial energy demand	Medium	Medium	Medium	High	Low
Heavy transport demand	Medium	Medium	Medium	Medium	Low
Large-scale hydrogen storage	Low	Low	Low		Low
Location of maritime activity	Low	Medium	Low		Medium
Access to the gas network	Low		Low	Low	Low
Renewable energy resource	Medium	Medium	Medium		Medium
Hydrogen innovation projects	High	High	High	High	High
Rail network decarbonisation	Low	Low	Low		Medium
Existing grey hydrogen sites	Low	Low	Low	Low	Low

The presence of known hydrogen innovation projects is a strong near-term determining factor across all scenarios until at least 2030. Hydrogen produced via electrolysis will be used for transport across all scenarios, favoured over CCUS-enabled hydrogen due to its increased quality/purity.

Scenario	Description
Falling Short	Known hydrogen innovation projects are more important than other regional factors until 2040. Industrial customers and clusters are also significant factors, followed by heavy transport with less importance. Existing grey hydrogen locations are relatively high compared to other scenarios from 2026 onwards. Hydrogen storage facilities, marine demand, network proximity, renewable generation and potential for hydrogen trains are not considered.
System Transformation	Importance is weighted towards heavy transport demand in the early projection years from 2023 onwards. In contrast, industrial customers and clusters take over as the strongest uptake factor in the longer term out to 2050. Renewable generation is stronger than other regional factors in the licence area.
Consumer Transformation	Factors determining the uptake of hydrogen electrolysis are diversified, with industrial customers and clusters being the strongest uptake factor, followed closely by heavy transport and marine transport demand. Proximity to hydrogen storage sites and renewable generation is weighted less strongly. Less importance is given to the potential for hydrogen rail transport and the conversion of existing grey hydrogen sites in this scenario.
Leading the Way	Areas with a high density of renewable generation projects and areas with high industrial demand are given high importance from 2023 onwards, as well as heavy transport demand. The North of Scotland has a large amount of renewable energy but lower levels of heavy transport and industrial demand than other licence areas.

Comparison to DFES 2021

Several key differences exist between the scenario projections for hydrogen electrolysis capacity in DFES 2021 and DFES 2022 due to substantial modelling and data improvements, resulting in notably different projections in the near, medium and long term. The reasons for these variations include:

- The FES 2022, for the first time, has detailed specific data on the split of hydrogen electrolyser capacity that could be connected to the distribution and transmission networks separately. This has allowed for more accurate reference projections for capacity connecting at distribution network voltages, a key area of uncertainty in the DFES 2021 modelling. An overall reduction in the projections for distribution-connected electrolysers in DFES 2022 has been modelled as a result, particularly for **Consumer Transformation**. In DFES 2021, it was assumed that c. 74% of total electrolyser capacity would be connected to the distribution network by 2050 in this scenario; however, in the latest FES 2022 analysis, only 17% is modelled to be distribution-connected by 2050. Hence, following FES 2022 assumptions has resulted in a significant decrease in capacity projected under **Consumer Transformation** in DFES 2022.
- The UK government's increased ambition for hydrogen electrolysis capacity (1 GW by 2025 and at least 5 GW by 2030) has increased the potential uptake of electrolysis in the near term. As a result of the 2022 energy cost crisis, the FES 2022 analysis focuses more on electrolytic hydrogen over CCUS-enabled hydrogen, particularly in **System Transformation**.

The proportion of GB electrolysis capacity assumed to be distribution network connected by 2050

Scenario	DFES 2021	Capacity by 2050 (MW)	DFES & FES 2022	Capacity by 2050 (MW)
Falling Short	100%	163	85%	370
System Transformation	22%	903	17%	1,519
Consumer Transformation	74%	2,012	17%	222
Leading the Way	31%	1,549	20%	1,334

Reconciliation with National Grid FES 2022

Modelling Stage	Reconciliation
Baseline	The DFES and FES 2022 are aligned.
Pipeline	Early pipeline years see a higher overall uptake in the North of Scotland in DFES 2022 than in FES 2022. Known projects and hydrogen hub locations in the licence area likely drive this. The DFES analysis method considers licence area proportions of the FES GB level projections. The North of Scotland represents c. 38% of known innovation projects in GB, a key near-term factor.
Projections	Medium and long-term growth decreased under the DFES 2022, whereas growth remains quite high in the North of Scotland under FES 2022. 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 2022 in the licence area by 2050 is unclear.

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 2022. 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 bubs and road traffic count for light commercial vehicles, heavy goods vehicles, coaches and buses.
Renewable resource	Based on the in-house Regen large-scale solar and wind resource assessments
Pseudo-pipeline	This factor is used to direct near-term projections to ESAs where pipeline projects are known to connect, but the capacity of these projects is unknown.
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 2022

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.
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	How this has influenced our analysis
Storegga	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 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	Webinar participants with expertise in hydrogen 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 most preferred uses of hydrogen. 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.

[xcviii] UK Government 2022, *British Energy Security Strategy 2022.* https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy
[xcix] Scottish Government 2022, *Scottish Government Hydrogen Action Plan 2022.* https://www.gov.scot/publications/hydrogen-action-plan/pages/2/
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[ci] BOC 2022, *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
[cii] Outer Hebrides Local Energy Hub n.d., *Innovation Projects.* https://communityenergyscotland.org.uk/projects-innovations/ohleh/
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[cviii] Integrating n.d., *Tidal Energy Storage into the European Grid*. https://es.catapult.org.uk/project/integrating-tidal-energy-storage-into-the-european-grid/
[cix] Scottish Power 2021, *Green Hydrogen Set for Port of Nigg.* https://www.scottishpower.com/news/pages/green_hydrogen_set_for_port_of_nigg.aspx
[cx] GGN 2022, *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. Therefore forecasts of new housing and commercial and industrial (C&I) 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.). Relevant FES technology blocks are as follows:

- **Gen_BB001a – number of domestic customers**
- **Gen_BB002b – meters squared of I&C customers**

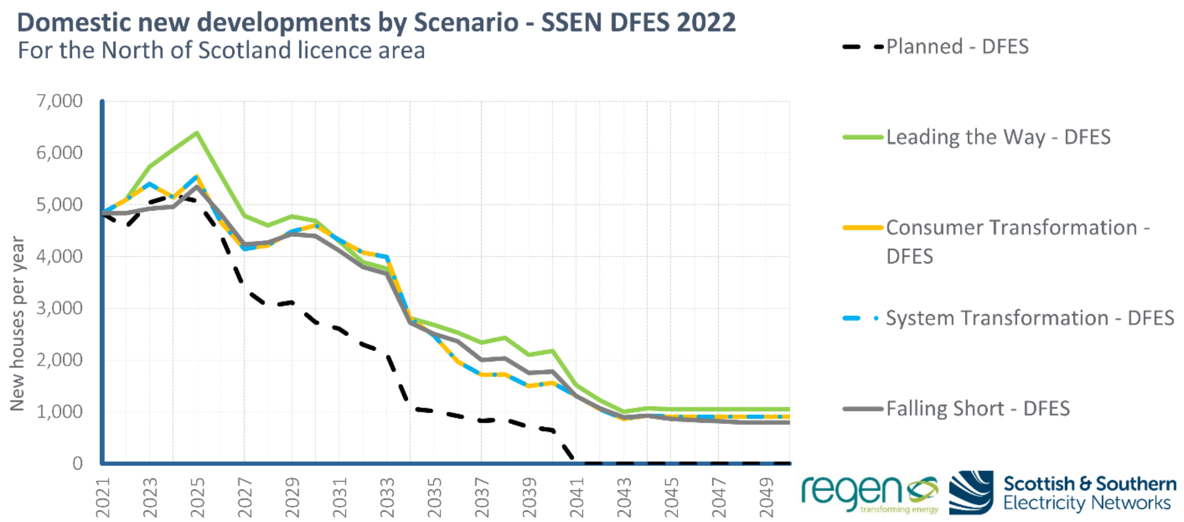
Data on planned domestic and non-domestic developments for the SSEN licence areas have been gathered through data exchange with all local authorities (LAs) in the North of Scotland licence area. This process used an online data portal and individual engagement with local authority planners and data providers.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

Alongside historic build rates and ONS household projections[cxi], the data provided by the LAs are 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 (thousands)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	--	20	42	59	69	74	78
System Transformation		21	43	61	69	74	79
Consumer Transformation		21	43	61	69	74	79
Leading the Way		23	48	65	77	83	88

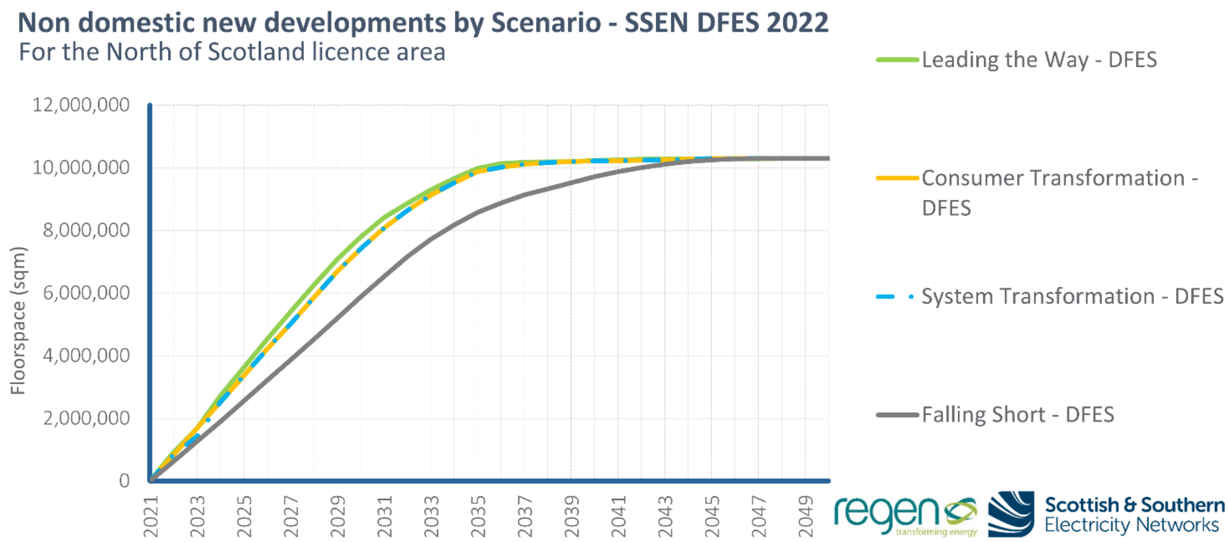
Figure 47: Non-cumulative new domestic development projections by scenario for the North of Scotland licence area.



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

Floorspace (sqm, 100,000s)	Baseline	2025	2030	2035	2040	2045	2050
Falling Short	0	25	59	86	97	103	103
System Transformation		34	74	99	102	103	103
Consumer Transformation		34	74	99	102	103	103
Leading the Way		36	78	100	102	103	103

Figure 48: Cumulative non-domestic developments by scenario in 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 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 until 2042, so new longer-term housing developments out to 2050 were modelled based on an analysis of ONS household projections[cxi]cxi above
- By 2050, this modelling results in between 78,000 and 88,000 new homes in the North Scotland licence area, representing a 13%-15% increase in domestic customers.
- An additional 10.3 million square meters of non-domestic floor space is also modelled to be in the North Scotland licence area under each DFES scenario.

Modelling and assumptions

Baseline (2022)	
The focus 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 2022 to September 2042)	
Data exchange with all local authorities in the licence area	A SharePoint database hosts individual registers for all LAs within the North of Scotland licence area. Regen engages with the LA planning departments to ensure these registers of new property developments are updated and refreshed for the DFES analysis. 66% of Local Authorities within the North of Scotland licence area have updated their datasheets within the last three years.
Database update	This data provided by the LA 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 • Developments of less than 1000 sqm (non-domestic)
ESA assignment	All sites are assigned an 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**), Medium (**System Transformation** and **Consumer Transformation**) and Low (**Falling Short**). For new domestic developments, this is carried out using ONS projections[cxi] data. In contrast, non-domestic projections are determined from the 8-year, 10-year, and 15-year averages of planned developments of new non-domestic premises.

Domestic housing pipeline

Number of development sites identified	Total number of houses
379	55,672

The local authorities with the highest number of planned homes are detailed below:

Local Authority	Number of homes	Number of Sites	Largest development site
Highland	14,861	120	Dalcross new settlement (1,375 houses)
Aberdeen City	13,277	27	Grandhome Community (3,434 houses)
Perth and Kinross	12,643	76	Bertha Park (1,880 houses)

Aberdeen City has 27 housing sites planned, averaging 490 homes per site. In addition to the Grandhome Community site, three other large sites of 1,000 homes or greater are planned in the area:

- A 1,600-home site with full planning permission

- Two sites are under construction, with 1,625 and 2,620 homes, respectively.

Of the 120 housing sites planned in the **Highland Council** area**,** there is only one site, in addition to the Dalcross new settlement, larger than 1,000 homes. The local authority has developments with an average of 125 homes per site. However, no buildout data has been provided.

The 76 planned sites in **Perth and Kinross** average 166 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 permission and is set to begin construction in 2024

Moray is the only other Local authority in the North of Scotland licence area that has planned housing sites that are greater than 1,000 homes.

- One site of 1,500 homes is currently under construction, averaging homes per year and is set to complete in 2036.
- The other site consists of 1,000 homes that have been allocated and are slated to begin construction in 2031, adding 125 homes per year until 2038.

Non-domestic development pipeline

Regen category	Sites		Non-domestic floorspace (sqm)	
	Number	Proportion	Total per category	Proportion of total
Factory and warehouse	351	50.1%	5,451,200	53.0%
Office	300	43.2%	3,764,480	36.6%
School and College	11	1.6%	117,756	1.14%
Retail	4	0.6%	48,800	0.47%
Other (e.g., medical, hotel, restaurant, sport & leisure)	29	4.2%	917,254	8.9%

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 89% of the planned non-domestic build. **Aberdeenshire** is the local authority with the most planned non-domestic developments in the licence area, with 256 sites totalling 1,415,410 sqm.

Unclassified "other" developments total c. 917,000 sqm. Of that, c. 620,000 (68%) is designated to Scolpaig on North Uist in the Outer Hebrides. This is intended to be a spaceport with a site size of 278 ha and was modelled with only 22% of the total site being allocated as floorspace to reflect a more accurate picture of the future electricity demand of this site.

Planning logic and assumptions					
Buildout-Timeline: The buildout start year is assigned based on the status and development stage provided by the LA. A construction year was 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	2022	2023-2025	2026-2028	2029-2031	2023-2031

Buildout rate: The rate at which a site is constructed is modelled using data from the pipeline site data 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 by Regen category, 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 LA. Using current and historical DFES data for sites with both a site area and floorspace, a ratio was calculated for each Regen development category. This ratio was then used to assign a floorspace to any site where this was not directly provided not provided by dividing the given site size (converted to sqm) by the category ratio.

Delay factors: For network planning, the DFES modelling applies scenario-specific delay factors to planned buildout timescales provided by the LA. This method enables the location and scale of the development to be maintained, but the period over which the sites are built out is extended.

For domestic builds, a delay factor is applied differently for the high, low and central trajectories and used for modelling post-planned developments out to 2050.

For non-domestic, this is used to model the three scenarios based on the rate of the development buildout. Each scenario is modelled by applying a delay factor to maintain a buildout based on a yearly average:

- **Leading the Way** reflects an 8-year average buildout rate.
- **System Transformation** and **Consumer Transformation** reflect a 10-year average buildout rate.
- **Falling Short** is delayed reflecting a 15-year average buildout rate.

All scenarios are modelled to keep non-domestic floorspace the same as planned but change the rates at which the projects are completed. This is partly because new developments' timelines and build rates are key sources of uncertainty. By applying three scenarios and associated delay factors, very ambitious development is captured in the **Leading the Way** scenario, and heavy unforeseen delays are captured in the **Falling Short**.

Modelled developments (October 2022 to September 2050)

Domestic housing

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 2022 and 2050.

Residual developments	These are small-scale developments of less than 100 homes, under the threshold of the data collection with 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.

Post-plan developments	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 based on ONS household projections[cxi].

Non-domestic
The non-domestic scenario projections are based on planned developments only.

Reconciliation DFES 2021
A few methodology changes have been made between the 2021 and 2022 DFES that have resulted in a reduction in projected domestic housing developments. • **Central Projections:** DFES 2021 utilised a central delay factor (10-year average), and when Local Authority data dropped off, it was infilled with a constant value until 2050. As explained in the methodology section, this was changed for the DFES 2022 projections using three scenarios and government projections data. This methodology change resulted in a change from 118,000 homes in DFES 2021 to 88,000 homes in DFES 2022 by 2050. For non-domestic developments, a change from c. 14 mil sqm to 10.3 mil sqm of floorspace projections was seen between DFES 2021 and DFES 2022. This change was a result of a modification to Regen category ratios. Other factors affecting this change were: • The dropping of planned data from local authorities falling in the 2021 calendar year, with limited data to replace it. This removed c. 1 mil sqm of floorspace from the near-term planned development projections. The majority of planned non-domestic developments occur in the near term, and new developments do not use a baseline. Therefore, if new data is not provided, there is limited data to replace the previous year of the analysis being removed. • The category ratio for **'Office'** changed this year to 18% of the site area allocated as floorspace. This is a change from DFES 2021, which had an assumed 33% of site area allocated as floorspace. This change occurred as a result of more data collection.

Reconciliation with National Grid FES 2022

- The FES scenarios do not include a section on new property developments that can be directly reconciled against the DFES. 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 2022, 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	Modelled sites 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 provided	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. Three of the 15 local authorities in the licence area provided updated or new data through a SharePoint site or directly to the project team. For the remaining Local Authorities, Regen's existing project database was used.

[cxi] 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