Distribution Future Energy Scenarios 2024

North of Scotland licence area

regen
transforming energy

Scottish & Southern Electricity Networks
DSO Powering Change

About Scottish and Southern Electricity Networks (SSEN)

SSEN Distribution is the electricity Distribution Network Operator (DNO) responsible for delivering power to 3.9 million homes and businesses across the north of Scotland and central southern England. With over 5,000 employees across the country, we manage and maintain over 128,000 km of overhead lines and underground cables, alongside 460 km of subsea cables which power our island communities.

We're working to get more people and projects connected to a growing electricity system. We're accelerating our Distribution System Operator (DSO) capabilities, enabling the delivery of local smart grids and flexibility services across our licence areas, while facilitating the uptake of low carbon technologies such as EV charging and domestic heat pumps. Our approach is tailored to local needs, to drive a just and fair transition, advising and guiding our customers and stakeholders in coordination with local communities.

About Regen

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

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

Acknowledgements

We would like to express our sincere appreciation to all those who contributed to the successful completion of this report.

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Prepared by	Regen
Approved by	Ray Arrell, Associate Director
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Contents

Section 1: Introduction

This report provides the technical overview and analytical results of the 2024 iteration of the Distribution Future Energy Scenarios (DFES) analysis for Scottish and Southern Electricity Networks (SSEN) North of Scotland licence area. In addition to this document, there is a separate technical report for the Southern England licence area and an introductory report which outlines the background, framework and context for the DFES analysis as well as an explanation of each of the DFES scenarios. These can be found online:

- Forecasting Future Needs of the Network - SSEN

The DFES analysis produces high granularity forecasts for the growth and/or reduction of electricity generation, demand and storage technologies connecting to SSEN's electricity distribution network. Underpinning the DFES analysis is the National Energy System Operator's (NESO) Future Energy Scenarios (FES) framework.[1] Published annually, the FES outlines different scenarios for the future of the whole energy system and the overarching assumptions that define these scenarios are integral to the DFES analysis. DFES builds on the FES scenarios by engaging a diverse and expert range of stakeholders, undertaking detailed investigations into the pipeline of projects seeking to connect, as well as extensive industry and local area insight to forecast future load on SSEN's network.

SSEN use the DFES analysis as part of an integrated network planning, optioneering and investment appraisal process. The DFES projections enable SSEN to model changes to future electricity demand across the network and subsequently assess where network improvements are needed, to ensure the capacity is available to meet future demand and deliver UK Government ambitions for both clean power 2030 and net zero 2050.

This technical report is divided into two sections. The first section provides some of the highlights for the current electricity load in the North of Scotland licence area and how this is projected to change in 2030 and 2050 under the Holistic Transition scenario (pages 2 to 8). The second part of the report provides the details for each individual technology included within the DFES 2024 analysis and describes the detailed assumptions, methodology and results (page 9 onwards).

Section 2: SSEN's North of Scotland Licence Area

The North of Scotland electricity distribution licence area refers to the area served by the low voltage (LV), 11 kV and 33 kV network that is managed by SSEN across the north of 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 Scottish Island groups, such as Shetland, Orkney, the Inner and 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 including Aberdeen, Dundee, Inverness and Perth.

The licence area comprises 15 local authority regions, either wholly or partially, including Aberdeen City, Aberdeenshire, Angus, Argyll and Bute, Clackmannanshire, Dundee City, Highland, Moray, Na h-Eileanan Siar, North Ayrshire, the Orkney Islands, Perth and Kinross, the Shetland Islands, Stirling and West Dunbartonshire.

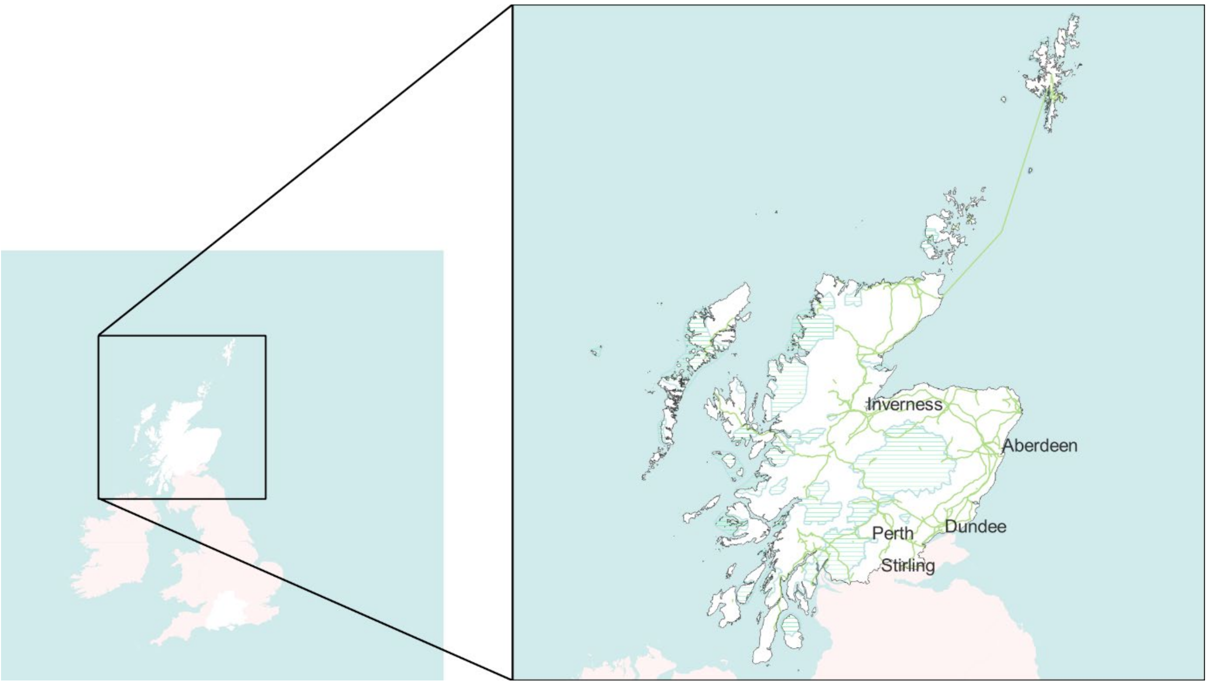


Figure 1 The North of Scotland licence areas, indicating grid infrastructure, cities and protected areas (source: Regen)

2.1. North of Scotland licence area baseline

There is currently 3.8 GW of generation and storage capacity connected to SSEN’s distribution network in the North of Scotland licence area and Figure 2 illustrates the spatial distribution of key baseline technologies.

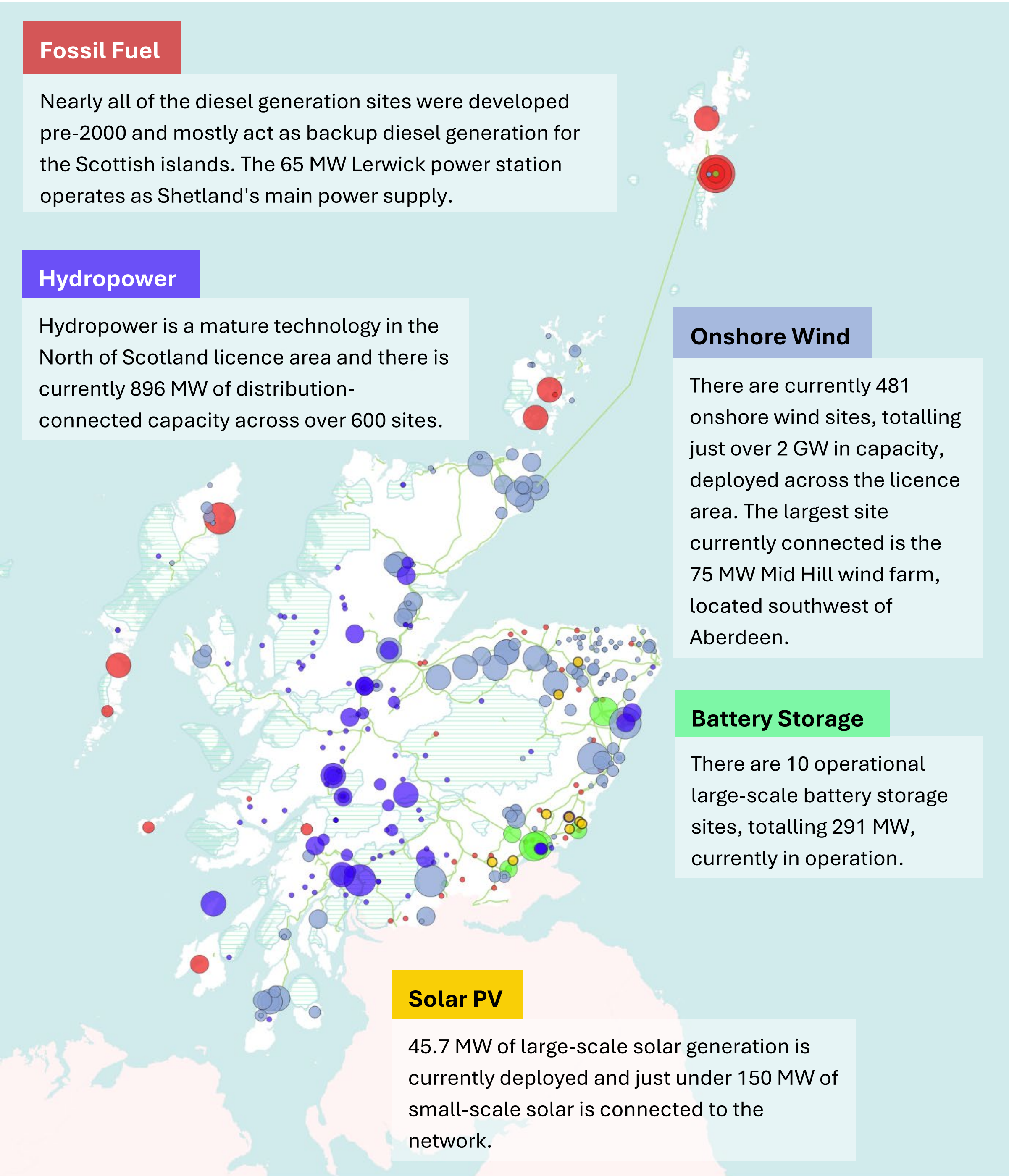


Figure 2 A map of the North of Scotland licence area and location of key baseline technologies (source: Regen)

2.2. North of Scotland licence area pipeline

There is 14.7 GW of generation and storage capacity that have connection offers to connect to SSEN’s distribution network and Figure 3 illustrates the spatial distribution of key pipeline technologies.

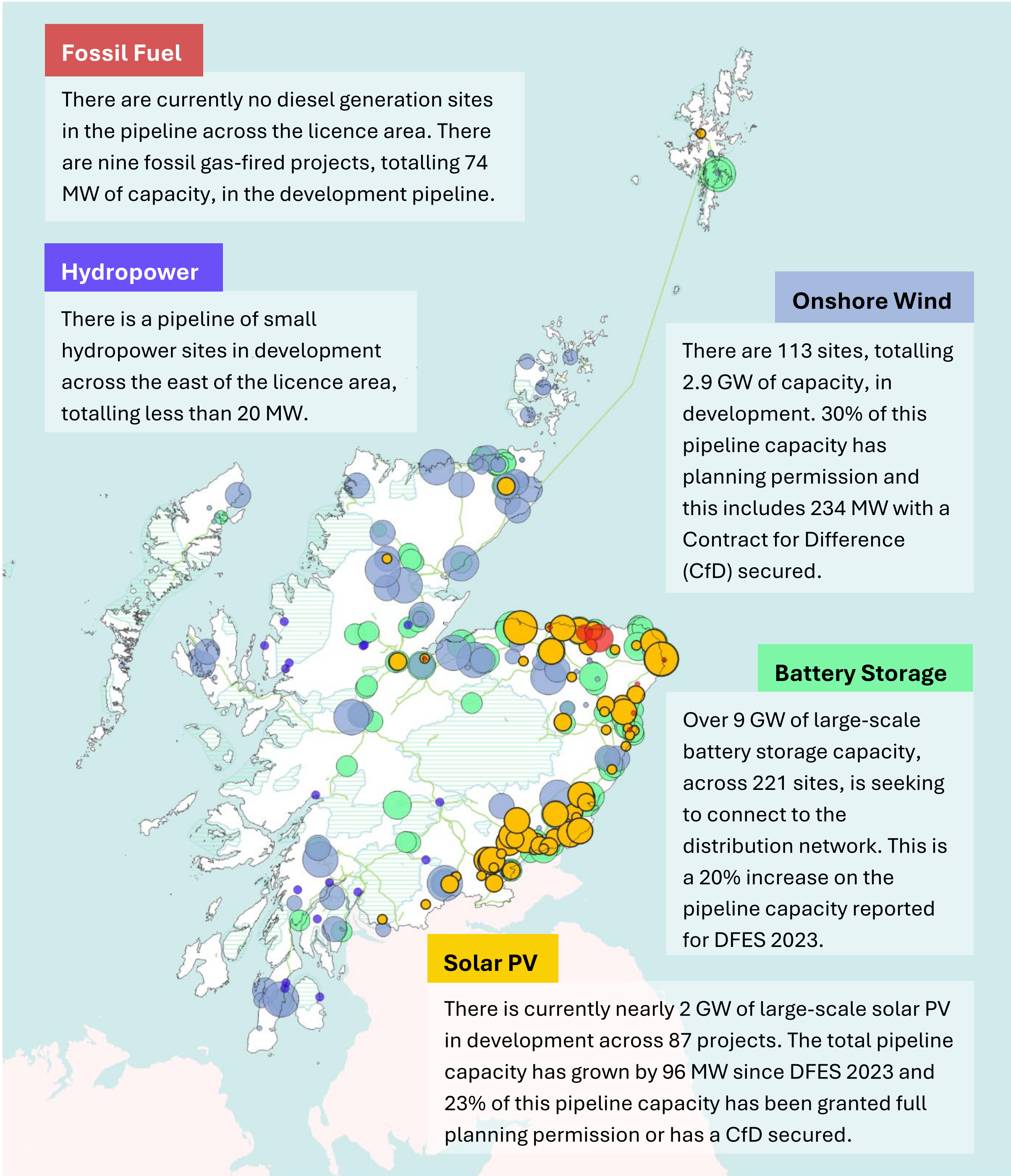


Figure 3 A map of the North of Scotland licence area and location of key pipeline technologies (source: Regen)

2.3. North of Scotland baseline summary

Renewable generation			
Solar 193 MW	**Onshore wind** 2.2 GW	**Marine** 21 MW	**Hydropower** 895 MW
There is currently a total of 3.3 GW of operational renewable generation in the licence area. Of these renewable technologies, small-scale solar has seen the highest growth over the past year.			

Waste and bioenergy generation		
Biomass 57 MW	**Waste** 35 MW	**Renewable engines** 32 MW
There is currently a total of 124 MW of operational waste and bioenergy generation, and these technologies have not seen significant growth over the past year.		

Fossil and gas generation		
Diesel 134 MW	**Gas** 48 MW	**Hydrogen generation** 0 MW
Relative to renewable generation, the licence area has a much smaller deployment of diesel and fossil gas-fired generation, totalling 182 MW. The fossil fuel generation technology with the highest deployed capacity is diesel generation, totalling 134 MW of capacity, and nearly half of this is back-up generation for the Scottish Islands.		

Sources of demand			Energy storage
EVs 25,400	**Domestic heat pumps** 48,000	**Electrolysis** 0 MW	**Large-scale batteries** 291 MW
There has been a 50% growth in non-hybrid EV ownership since DFES 2023. Relative to the rest of the UK, the North of Scotland licence area also has a much higher proportion of off-gas homes than the UK average and has seen the number of domestic heat pumps increase substantially since DFES 2023. The deployment of large-scale batteries has also continued to accelerate, with 110 MW connecting in the past year.			

2.4. 2030 highlights under Holistic Transition

Renewable generation			
Solar 1.3 GW	**Onshore wind** 3.9 GW	**Marine** 51 MW	**Hydropower** 940 MW

Renewable generation capacity is projected to double to over 6 GW in 2030, driven by significant growth in large-scale onshore wind and solar PV.

Waste and bioenergy generation		
Biomass 45 MW	**Waste** 71 MW	**Renewable engines** 37 MW

No additional biomass sites connect in the North of Scotland licence area. Several waste and renewable engine projects with existing planning permission are commissioned by 2030.

Fossil and gas generation		
Diesel 134 MW	**Gas** 17 MW	**Hydrogen generation** 18 MW

No additional diesel sites are deployed. Fossil gas generation capacity has begun to decommission and by 2030 some of these sites are modelled to convert to hydrogen generation.

Sources of demand		
EVs 207,000	**Domestic heat pumps** 229,000	**Electrolysis** 94 MW

2030 sees an eight-fold increase in the number of EVs and over a quadrupling in domestic heat pumps. Initial uptake of heat pumps is modelled to occur more commonly in off-gas houses and new-build homes.

Energy Storage	New developments	
Large-scale and small-scale batteries 4.0 GW	**Domestic** 41k homes	**Non-domestic** 5.7m sqm

Battery storage capacity increases significantly by 2030 due to the buildout of sites currently with planning permission. There are 41,000 new homes and 5.7m sqm of non-domestic floorspace have been built.

2.5. 2050 highlights under Holistic Transition

Renewable generation

Solar	Onshore wind	Marine	Hydropower
Solar 4.1 GW	**Onshore wind** 6.4 GW	**Marine** 206 MW	**Hydropower** 1.0 GW

By 2050 renewable generation capacity reaches just under 12 GW. This is over three times the current deployment and is driven by growth in large-scale onshore wind and solar PV of all scales.

Waste and bioenergy generation

Biomass	Waste	Renewable engines
Biomass 28 MW	**Waste** 61 MW	**Renewable engines** 19 MW

Conventional waste incineration is modelled to decommission, reflecting a reduced volume of waste in this scenario and the drive to reduce carbon emission. Sewage gas remains operational.

Fossil and gas generation

Diesel	Gas	Hydrogen generation
Diesel 69 MW	**Gas** 0 MW	**Hydrogen generation** 21 MW

By 2050, all diesel sites have decommissioned or switched to biodiesel. Fossil gas generation has fully decommissioned or converted to hydrogen once low-carbon hydrogen is locally available.

Sources of demand

EVs	Domestic heat pumps	Electrolysis
EVs 919,000	**Domestic heat pumps** 685,000	**Electrolysis** 518 MW

A wider-scale heat pump rollout is modelled for most housing stock by 2050. A core hydrogen transmission network is developed enabling more widespread commercial-scale hydrogen electrolysis.

Energy Storage	New developments	
Large-scale and small-scale batteries 5.0 GW	**Domestic** 103k homes	**Non-domestic** 9.7m sqm

Battery storage continues to deploy, though by 2050 the large-scale market has saturated and small-scale storage is the main source of growth. Growth in new domestic and non-development has slowed by 2050.

2.6. 2050 spatial deployment of low-carbon technologies under Holistic Transition

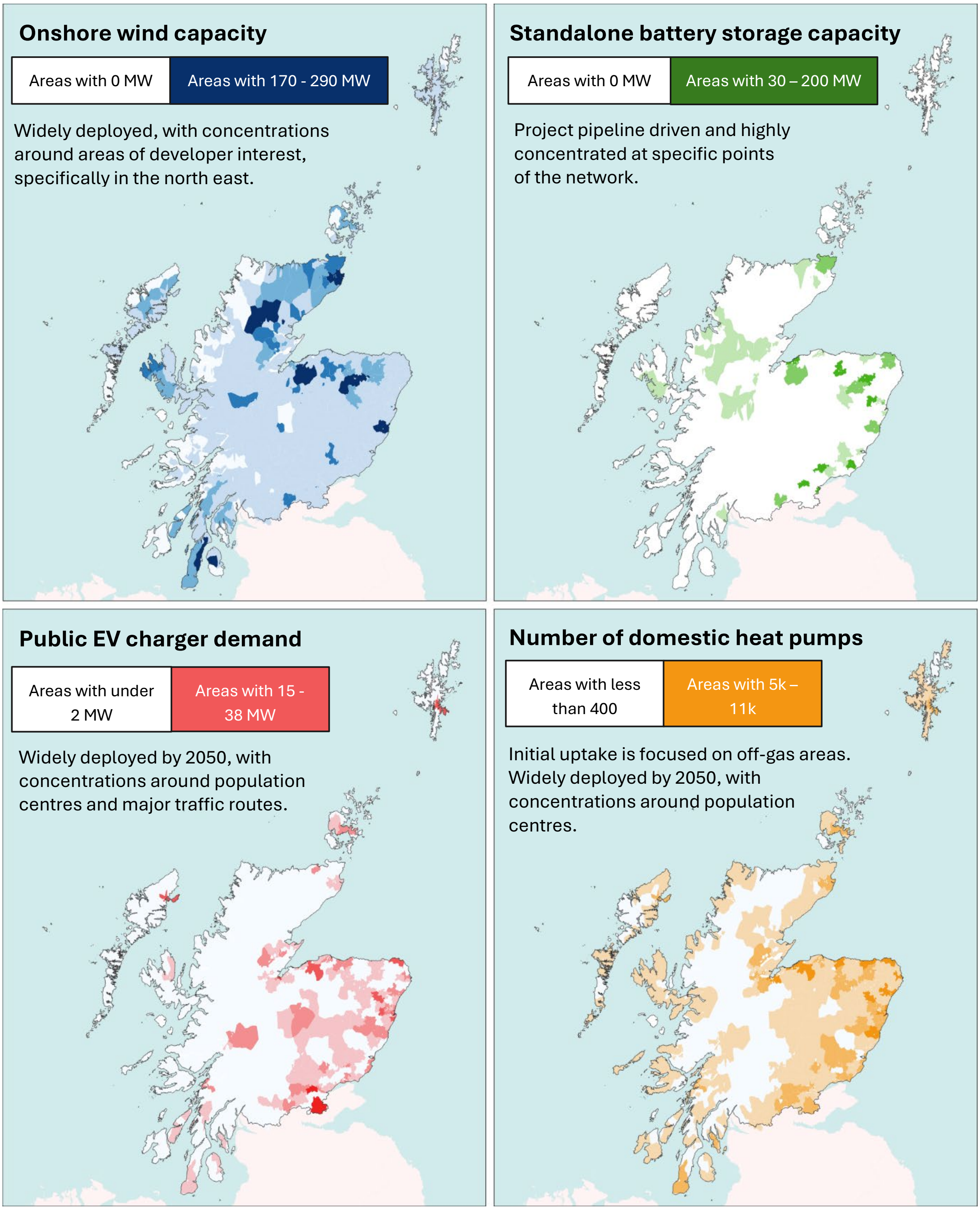


Figure 4: 2050 deployment of key technologies in the licence area under a Holistic Transition scenario (source: Regen)

Section 3: Distributed electricity generation technologies

Results and assumptions

This section includes the results and assumptions for the following technologies:

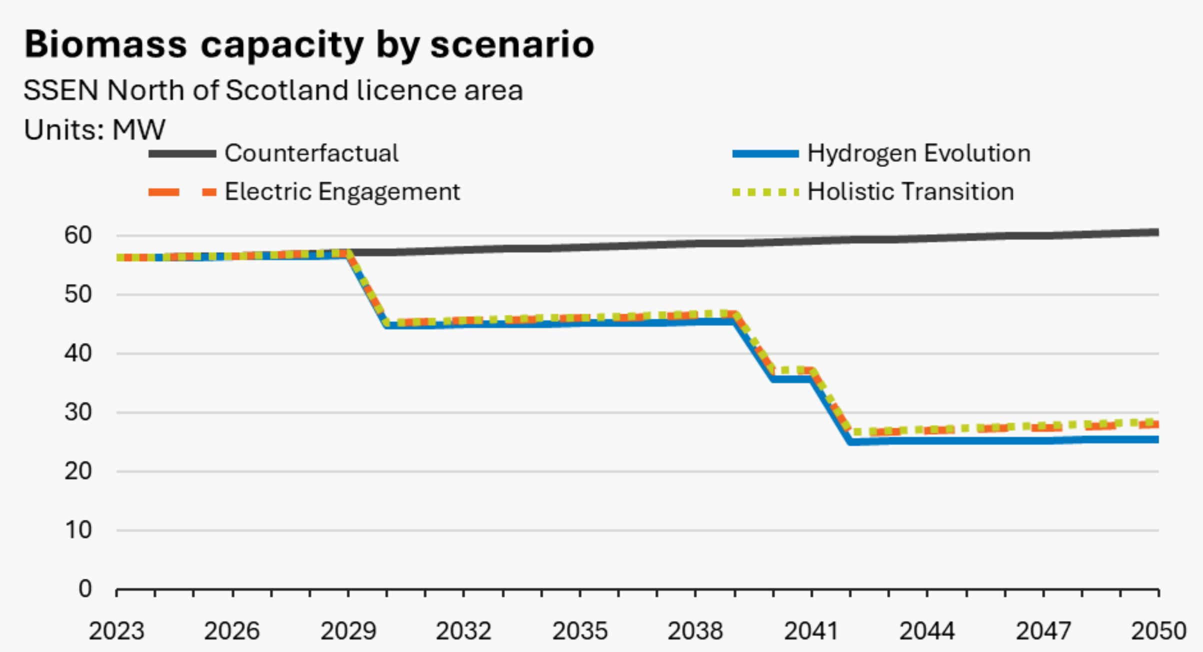
- Biomass generation
- Diesel generation
- Fossil gas-fired generation
- Hydropower
- Hydrogen-fuelled electricity generation
- Marine generation
- Offshore wind generation
- Onshore wind generation
- Other generation
- Renewable engines
- Solar PV (large-scale)
- Solar PV (small-scale)
- Waste-fuelled generation

3.1. Biomass generation

Technical specification	Building blocks
Biomass-fuelled electricity generation connecting to the distribution network, including biomass for standalone power generation and biomass combined heat and power (CHP).	Gen_BB010

3.1.1. Summary

- The future of biomass power generation on the distribution network is impacted by competing demands for bioenergy in sectors such as heat, industry and other hard-to-decarbonise sectors.
- Despite being a flexible, low-carbon generation technology, distribution-connected biomass generation capacity is modelled to decrease over time under the three net zero scenarios. This is primarily due to the use of biomass for power being prioritised for transmission-scale bioenergy with Carbon Capture and Storage (BECCS) generation.
- The North of Scotland licence area currently hosts over 50 MW of biomass electricity generation capacity, with most of this capacity at six sites of 5-12 MW each.
- Standalone biomass power generation is progressively decommissioned in the three net zero scenarios as bioenergy resources are prioritised for other uses, resulting in the vast majority of biomass generation capacity in the North of Scotland licence area decommissioning in the 2030s and 2040s.
- Under the **Counterfactual** scenario, a significant capacity of biomass generation remains in operation, as alternative uses of bioenergy in harder-to-decarbonise sectors are not progressed under this scenario.



3.1.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Above 1 MW	54	11	Much of the large-scale baseline is located in the Moray and Highland local authorities, where the gas network is less available for heat and power generation. Recent development has been limited, with only one site commissioning since 2017.
Below 1 MW	3	9	The small-scale biomass baseline is mainly located at businesses using biomass for combined heat and power, including a sawmill, a distillery and several farms.

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
All	0	There are no biomass sites in the SSEN connections pipeline for the North of Scotland licence area.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	45	28	Under the three net zero scenarios, large-scale biomass resource is prioritised for transmission-scale BECCS and other hard-to-decarbonise sectors. As a result, standalone biomass on the distribution network is modelled to decommission after 25 years of operational life. This operational life assumption is based on desktop research for several existing biomass power generation sites. Small-scale biomass, typically in the form of CHP capacity, sees some further deployment in the future to provide heat for industry and district heat networks.
Electric Engagement	45	28	
Hydrogen Evolution	45	25	
Counter-factual	57	61	Large-scale biomass generation remains connected in 2050, as decarbonisation progress in other sectors is slow, meaning that bioenergy resources that would otherwise be prioritised to these sectors remains in use for power generation. Small-scale biomass, typically in the form of CHP, sees a small amount of growth to provide heat for industry and district heat networks.

Spatial factors

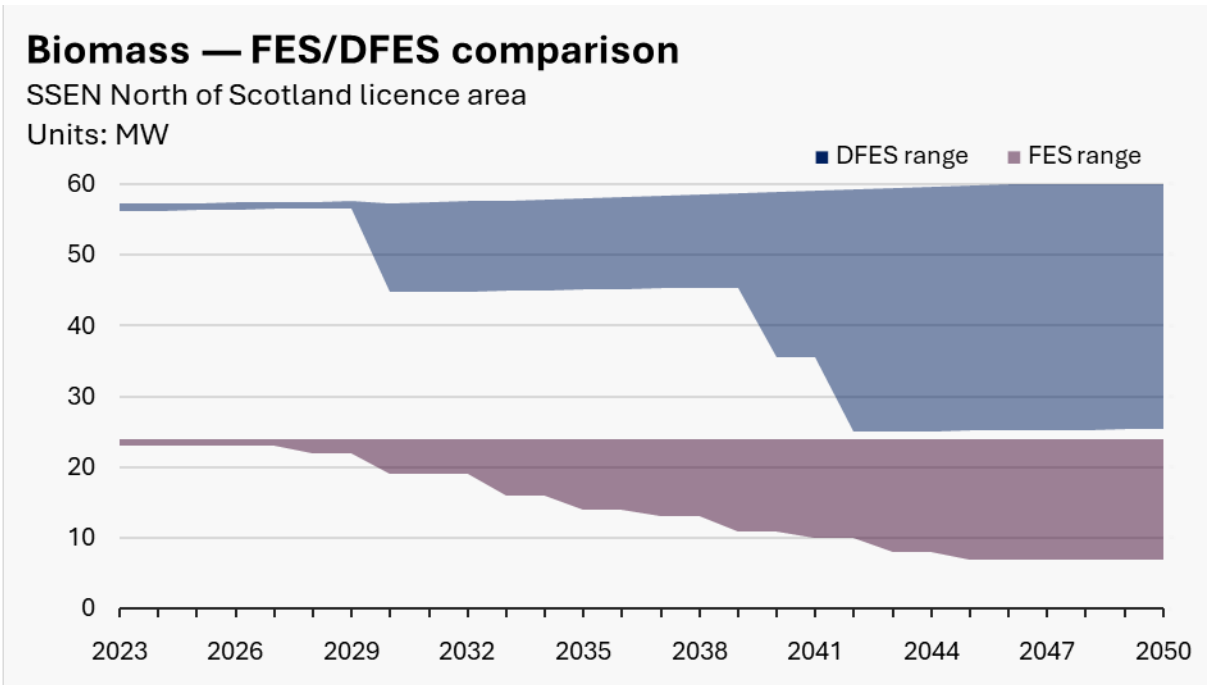
Factor	Description
Existing baseline and pipeline sites	Alongside the existing baseline and pipeline, growth in small-scale biomass CHP capacity is distributed to existing small-scale biomass connections.

3.1.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The DFES and FES projections follow a similar trend, with limited change in the near term followed by reduction in capacity under the net zero scenarios as biomass is prioritised for hard-to-decarbonise sectors.
- The DFES baseline is substantially higher than the FES baseline. This may be due to differences in how the baseline data has been categorised by technology. Sites in the DFES baseline have been individually researched and positively identified as biomass sites.



Comparison to DFES 2023

- **Electric Engagement** features one major change compared to the equivalent DFES 2023 scenario (Consumer Transformation). In DFES 2023, diesel backup generation on Scottish Islands were modelled to convert to biomass in the 2030s. Following engagement with Scottish Island stakeholders and SSEN, these are now modelled to instead convert to battery storage. More information can be found in the diesel technology summary.
- In DFES 2023, the equivalent **Hydrogen Evolution** and **Holistic Transition** scenarios (System Transformation and Leading the Way respectively) saw all biomass generation decommissioning by 2050. In DFES 2024, this decommissioning is limited to medium- and large-scale sites of 5 MW or higher, with smaller-scale sites modelled to remain connected until 2050. This is due to updated 2024 research of the baseline sites finding that most of the smaller-scale sites are fed by on-site biomass, such as at a sawmill and several farms, and as such are less likely to convert to an alternative fuel.

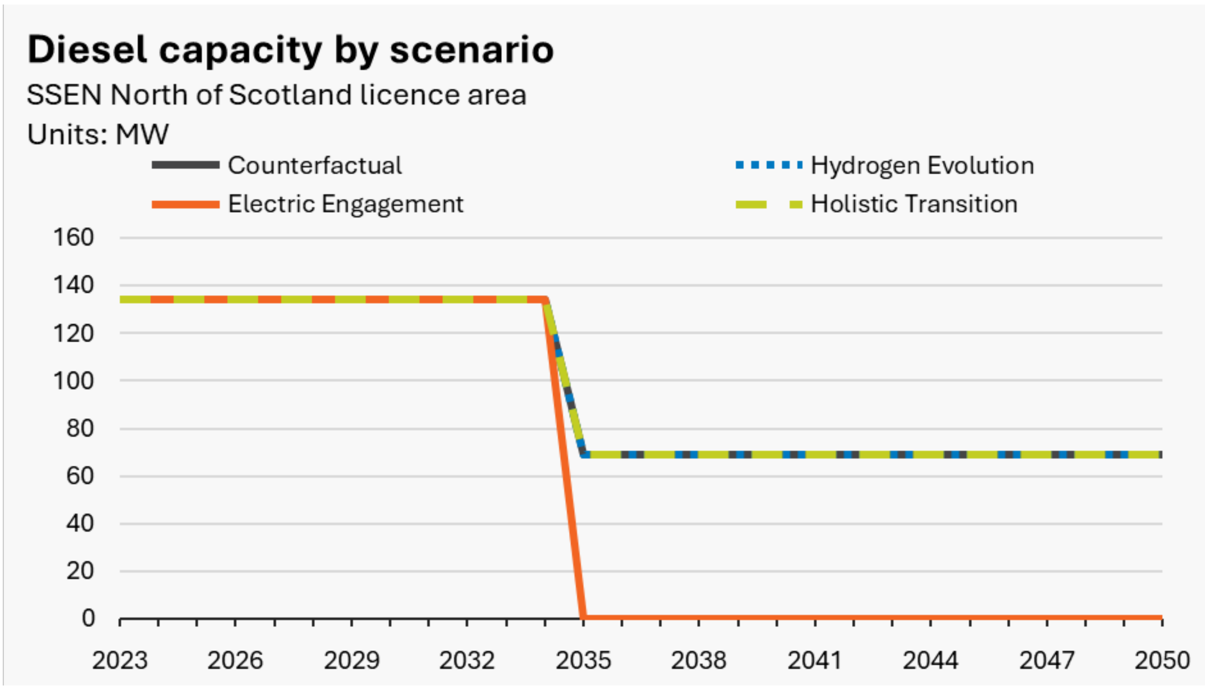
3.2. Diesel generation

Technical specification	Building blocks
Diesel generation	Gen_BB005

3.2.1. Summary

- The total installed capacity of diesel generation in the licence area is 134 MW. This includes a 3 MW backup generator that was commissioned at a Scottish Sea Farms site in Argyll and Bute in 2024.
- There are currently no diesel pipeline projects seeking a grid connection with SSEN as of 2024. In DFES 2023, a 5.5 MW diesel site near Oban had a connection offer to connect, however this site has since dropped out of SSEN's connections data and is assumed to no longer be seeking a connection.
- Diesel generation considered in the DFES analysis for the North of Scotland licence area includes the decommissioning of existing backup generators located on various Scottish islands, which are used to provide power when subsea cables or the primary network supply to the islands are unavailable.
- The use of unabated diesel generators conflicts with net zero emissions targets and operation is limited by the UK's adoption of the EU Medium Combustion Plant Directive (MCPD), which imposes strict air quality standards. From January 2025, existing standalone diesel plants of above 5 MWth (approximately 2 MWe) must comply with the MCPD regulations. The same applies for plants of 1-5 MWth by January 2030.[2] The MCPD exempts sites that fall under the limit of 500 operating hours per year. Therefore, island diesel generators that provide back-up and power supply stability services could remain online unless viable low carbon alternatives become available.
- Under **Electric Engagement**, all diesel sites are modelled to decommission by 2035, while all other scenarios see some amount of backup generation remaining online past 2050. As part of a study on future load growth in the Outer Hebrides, long duration battery storage is being considered as a potential replacement for backup diesel generation on the islands.[3] As a result, existing sites decommissioned in 2035 under **Electric Engagement** are modelled to be replaced by long-duration battery storage, which is reflected the battery storage model to continue providing back-up services.
- Under **Holistic Transition** and **Hydrogen Evolution**, it is assumed that existing diesel sites switch to biodiesel engines by 2030 and 2040 respectively, therefore retaining their grid capacity and remaining classified as diesel technology. No fuel switching is assumed under the **Counterfactual** scenario.
- Lerwick Power Station A and B (with a combined capacity of 65 MW) will transition to standby mode in November 2024 and is scheduled to decommission in 2035once a new transmission link is successfully commissioned, connecting transmission and

distribution systems at Gremista. Lerwick Power Station A and B is then modelled to come offline in all scenarios by 2035.[4]



3.2.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Above 1 MW	134	10	The increase in capacity from DFES 2023 is due to a 3 MW behind the meter site that commissioned in Argyll and Bute in October 2023 at Scottish Sea Farms. The baseline of diesel generation that is connected in the North of Scotland licence area is almost entirely developed pre-2000 and most sites act as backup diesel generators for various Scottish islands. There are backup sites located at Kirkwall on the Orkney Islands, Bowmore, Stornoway, Tiree, Barra and at Loch Carnan on South Uist.

			Two sites in Shetland were developed in 1997 as standalone diesel plants at Lerwick. In 2021, a 5.8 MW diesel backup plant was added to the existing Lerwick generation sites.
Below 1 MW	0	0	No sites in the data fall below 1 MW.

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
Total	0	There are no diesel sites with accepted connection offers or live planning applications in the licence area.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	134	69	Lerwick Power Stations A and B are modelled to come offline in 2035 under this scenario. All other sites remain connected past 2050 as backup generators, although fuel switching occurs, and biodiesel is used by all generators by 2030.
Electric Engagement	134	0	All sites are modelled to come offline by 2035 under this scenario. However, grid capacity is retained and modelled as being replaced by long-duration battery storage.
Hydrogen Evolution	134	69	Lerwick Power Stations A and B are modelled to come offline in 2035. All other sites remail connected past 2050 as backup generators, although fuel switching occurs, and biodiesel is used by all generators by 2040.
Counter-factual	134	69	Lerwick Power Stations A and B are modelled to come offline in 2035. All other sites remain connected past 2050 as

			backup generators, and no fuel switching is assumed under this scenario.

Spatial factors

Factor	Description
Baseline and pipeline locations	The DFES analysis for diesel generation focuses entirely on the decommissioning of existing baseline and pipeline sites. Therefore, no spatial distribution of future capacity and the known locations of these sites are directly reflected in the modelling.

Stakeholder input

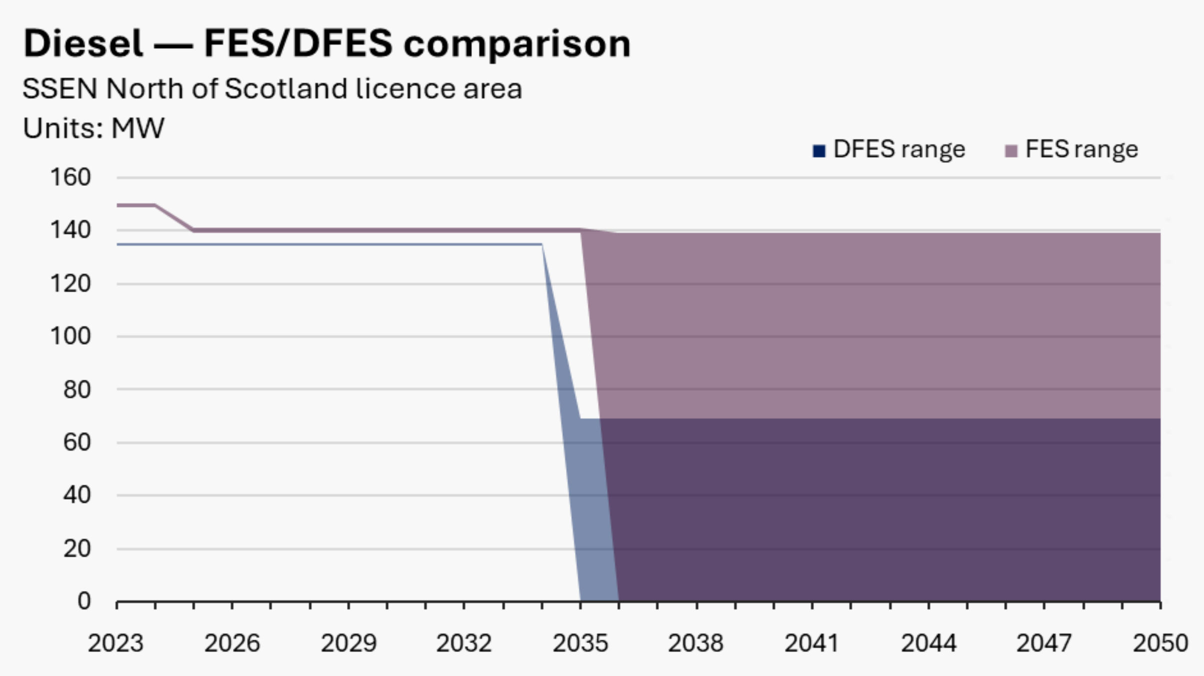
Stakeholder feedback	Impact on DFES analysis
SSEN HOWSUM project team. Extensive work is being undertaken at SSEN to understand the future potential decarbonisation scenarios specific to the Scottish Islands.	This engagement has led to the modelled decommissioning of Lerwick A and B by 2035 in all but the **Counterfactual** scenario, as well as the modelling decision to decommission all sites by 2035 under **Electric Engagement** and consider an option to replace them with long duration battery storage technology.
Regional engagement webinar. Stakeholders were asked about the future of fossil fuel generation in the region, with respondents highlighting that the majority of capacity will decommission in the medium term on similar timelines.	This has endorsed the approach we have taken to decommissioning unabated diesel (and fossil gas) generation projects under the net zero scenarios.

3.2.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The FES broadly matches the DFES baseline, any variance could be related to the capacity rating of existing sites or differences in technology classifications.
- The FES decommissions all diesel sites by 2036 in all net zero scenarios. Under the FES in the **Counterfactual** scenario there is no decommissioning of diesel sites, except for 6 MW in 2024, whereas the DFES sees a large degree of decommissioning across all scenarios. Notably, the FES does not reflect the decommissioning of Lerwick A and B (65 MW) in 2035, under any scenario, whereas DFES does so in all scenarios in line with SSEN's Shetland Standby Solution plans.[5]



Comparison to DFES 2023

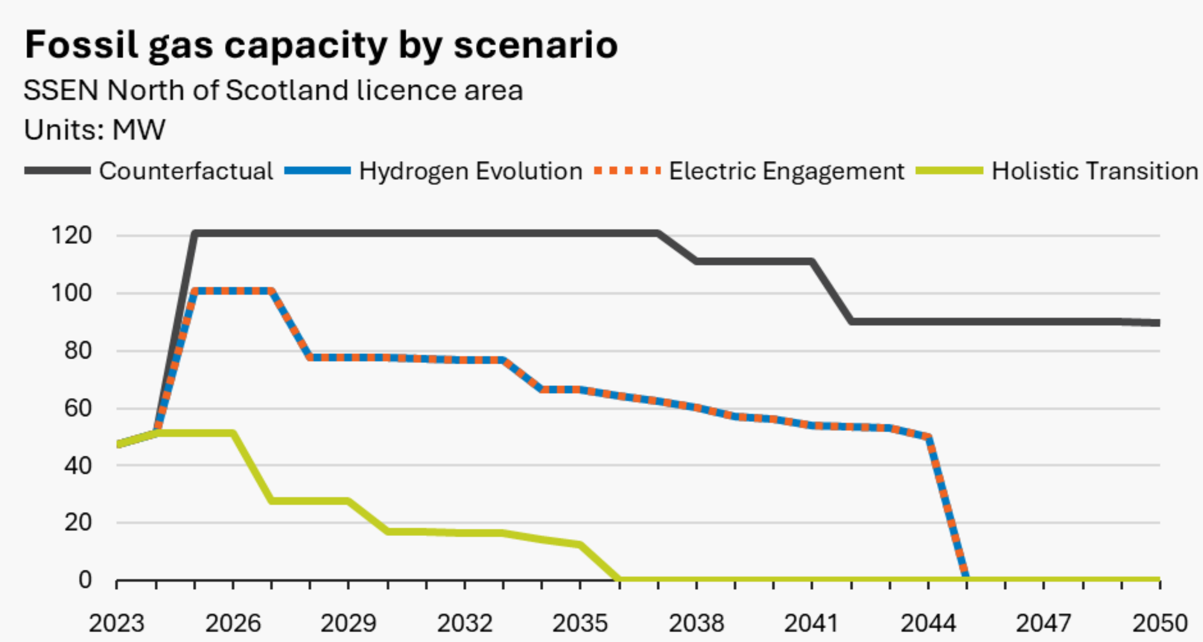
- The baseline capacity has increased by 3 MW from 131 to 134 MW.
- In DFES 2023, diesel sites were modelled under Consumer Transformation to be replaced by biomass generation sites. In DFES 2024, the decision has been made to model island backup diesel sites as being replaced with long-duration battery storage under **Electric Engagement** to be more in line with electrification goals.

3.3. Fossil gas-fired generation

Technical specification	Building blocks
Fossil gas-fired power generation connected to the distribution network, covering four fossil gas generation technology types: • Gas combined heat and power (CHP) • Gas reciprocating engines • Open cycle gas turbines (OCGT) • Closed cycle gas turbines (CCGT)	Gen_BB001 Gen_BB006 Gen_BB008 Gen_BB009

3.3.1. Summary

- There is just under 50 MW of fossil gas-fired electricity generation capacity currently operating in the licence area, split across a number of gas reciprocating engines and gas CHP installations.
- Deployment of gas-fired generation is slowing overall as the UK looks to decarbonise its electricity system. There are currently only nine projects, totalling 74 MW of capacity, with an accepted connection offer with SSEN, including a 50 MW CHP site.
- In the net zero scenarios, fossil gas generation capacity is modelled to decrease across the late 2020s and 2030s, as the UK moves to lower carbon forms of dispatchable generation such as batteries, hydrogen-fuelled generation and bioenergy, alongside demand-side flexibility. This aligns with the FES 2024 scenario framework, under which the three net zero scenarios achieve net zero power by 2035 at the latest (though some gas-fired power remains connected for backup purposes).
- All three net zero scenarios model some fossil gas generation sites to repower as hydrogen-fuelled generation plants, particularly under the **Hydrogen Evolution** scenario, where hydrogen is most readily available across the UK.
- Under the **Holistic Transition** scenario all fossil-gas generation is decommissioned by the end of 2035, and by the end of 2040 under **Electric Engagement** and **Hydrogen Evolution**, as the UK moves to net zero power.
- Slower progress towards decarbonisation results in most gas-fired electricity generation capacity remaining online beyond 2050 under the **Counterfactual** scenario, totalling 90 MW in the licence area.



3.3.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Above 1 MW	36	5	Two existing sites, totalling 28 MW, are located at oil and gas terminals on Orkney and Shetland. The remaining three baseline sites are CHP plants of 1-3 MW, providing heat and power at a university and a conference centre.
Below 1 MW	12	53	The connected baseline of small-scale gas generation is entirely comprised of gas CHP engines, providing heat and power to buildings such as hospitals, schools and hotels.

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
Total	74	Number of sites: 9 This represents a 30% decrease in total fossil gas generation pipeline capacity compared to DFES 2023.
Already operational	1.4	Two small-scale sites were found to already be operational based on desktop research. These sites have been modelled to connect in 2024 under all scenarios.
Under construction	0.5	One small-scale site is under construction and modelled to connect in 2024 under all four scenarios due to its small size.
Planning permission granted	50	A large 50 MW CHP site in Aberdeenshire has been granted planning permission and is anticipated to connect in 2025. This site is modelled to connect under all scenarios except **Holistic Transition**, which features the lowest increase in connected fossil gas capacity in the near term in the FES scenarios as cleaner dispatchable power generation alternatives are pursued.
No information	22	Four sites of less than 1 MW are modelled to connect in 2024 under all four scenarios due to their small-scale and not requiring formal planning consent. A 20 MW gas reciprocating engine project was found to have no planning or Capacity Market information and, as such, is only modelled to connect under the **Counterfactual** scenario.

Scenario projections

<table>
<tr><th rowspan="2">Scenario</th><th colspan="2">Capacity (MW)</th><th rowspan="2">Description</th></tr>
<tr><th>2030</th><th>2050</th></tr>
<tr><td>Holistic Transition</td><td>17</td><td>0</td><td>Fossil gas generation capacity decommissions quickly in the late 2020s and early 2030s as the UK looks to achieve a rapidly decarbonised electricity system. Sites are modelled to decommission at the end of their operational life, ranging from 15 years for reciprocating engines to 20 years for OCGTs, or by a backstop date of 2035. No capacity remains online by 2050 under this scenario.</td></tr>
<tr><td>Electric Engagement</td><td>78</td><td>0</td><td rowspan="2">Fossil gas generation capacity decommissions in the late 2020s and throughout the 2030s under these scenarios, as the UK looks to achieve a rapidly decarbonised electricity system. Sites are modelled to decommission at the end of their operational life, ranging from 20 years for reciprocating engines and CHPs to 25 years for OCGTs. Backstop dates for decommissioning have also been considered for CHPs, where 2040 is the latest year for electricity-only generation and 2045 for gas CHPs. No capacity remains online by 2050 under these scenarios.</td></tr>
<tr><td>Hydrogen Evolution</td><td>78</td><td>0</td></tr>
<tr><td>Counter-factual</td><td>121</td><td>90</td><td>Fossil gas generation remains online as progress towards net zero is slow and low-carbon alternatives to fossil gas generation see low uptake. Only older projects reaching the end of an extended operational life are modelled to decommission, resulting in a limited reduction in fossil gas capacity – including the larger baseline CHP sites on Orkney and Shetland – in the 2040s.</td></tr>
</table>

Spatial factors

Factor	Description
Existing baseline and pipeline sites.	The DFES projections are modelled directly on a site-by-site basis.

Stakeholder input

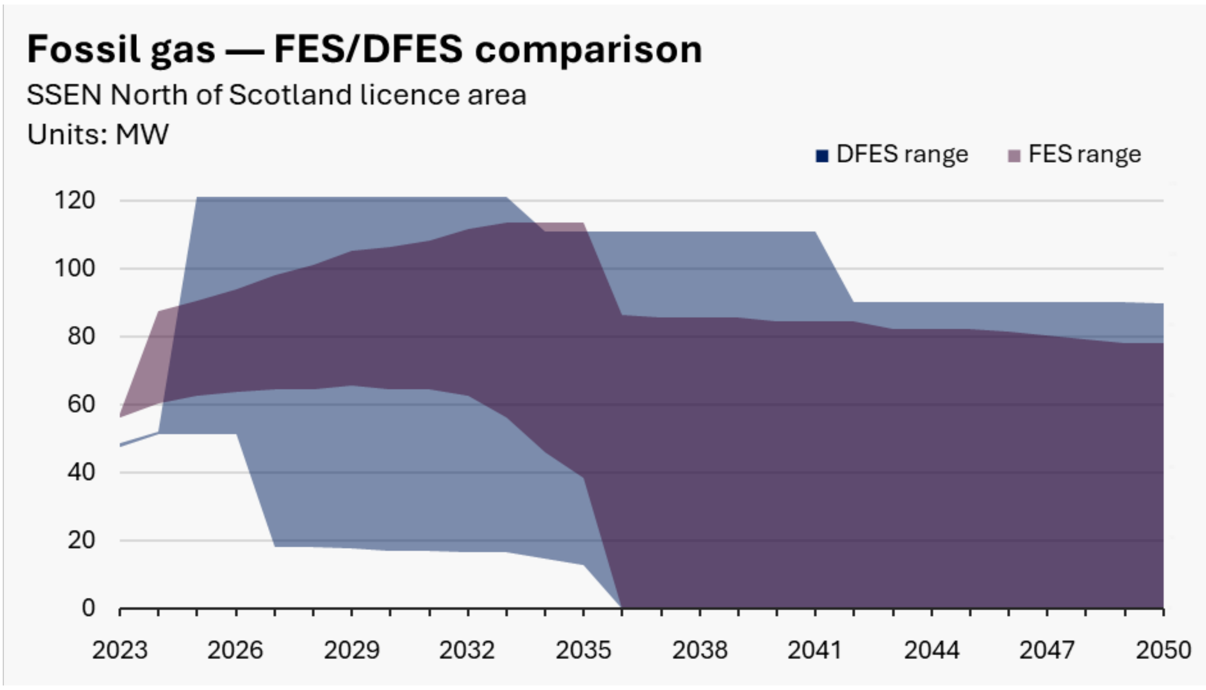
Stakeholder feedback	Impact on DFES analysis
A range of stakeholders were polled on the future of fossil gas-fuelled generation in light of upcoming clean power targets, as part of the North of Scotland regional DFES engagement webinar.	Stakeholders felt that there would be much less development of new fossil gas generation sites and gas plants would start to decommission in the near and medium term, most likely via a phased approach. This has been reflected in the pipeline analysis, with only sites with contracted Capacity Market contracts or very small sites progressing under the **Holistic Transition** scenario. Phased decommissioning then occurs mostly over the 2030s in all net zero scenarios, based on the type and age of individual baseline and pipeline sites.

3.3.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The FES and DFES baselines are broadly similar. The small difference of c. 10 MW may be due to differences in classifying fossil fuel technologies as gas, diesel or other forms of generation.
- The overall scenario trends are similar between the FES and DFES. Due to the age of some of the larger baseline sites, the DFES analysis sees earlier decommissioning of some gas generation plants under the **Holistic Transition** scenario compared to the equivalent FES outcomes in the North of Scotland licence area.



Comparison to DFES 2023

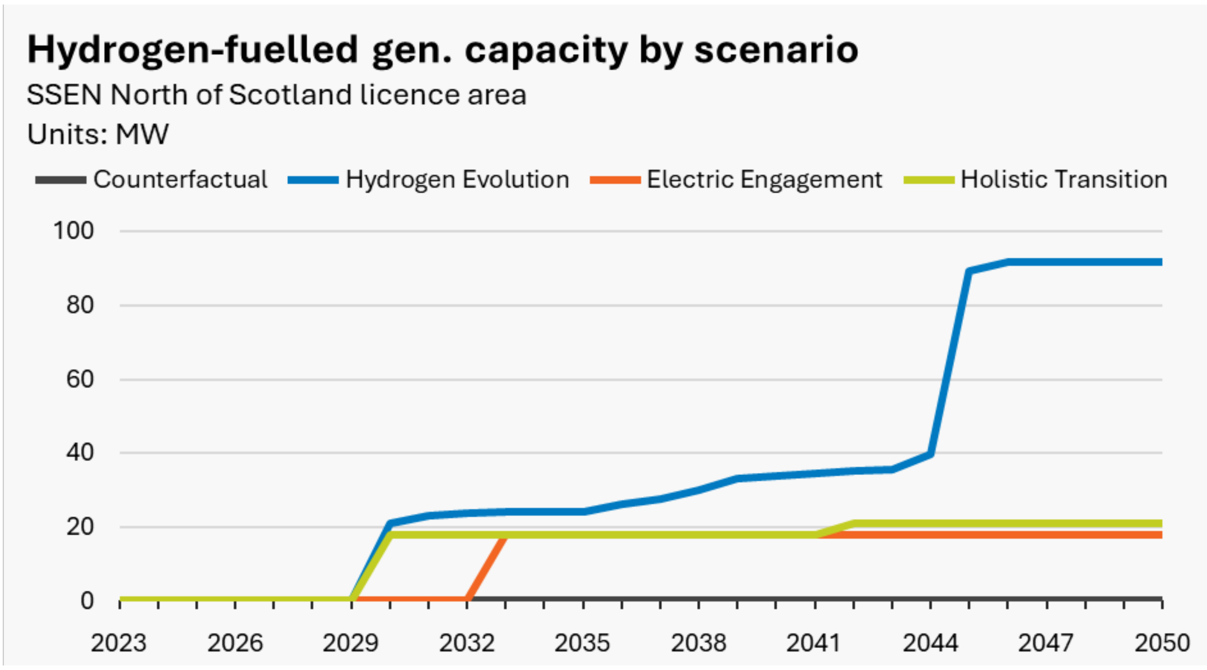
- The pipeline has evolved since the DFES 2023 analysis, with several sites dropping out of the connections pipeline and several sites progressing further in planning or in Capacity Market auctions. This has resulted in a narrower range of scenario projections in the near term, as the pipeline narrows from a wider range of less developed projects to a narrower range of more advanced projects.

3.4. Hydrogen-fuelled electricity generation

Technical specification	Building blocks
Hydrogen-fuelled electricity generation, which has been modelled to connect to the distribution network in areas where there is the potential for hydrogen gas supply. This links to the analysis undertaken for fossil gas capacity.	Gen_BB023

3.4.1. Summary

- Hydrogen-fuelled electricity generation is modelled based on the conversion of existing operational and in-development fossil gas generation sites to hydrogen-fuelled generation in the future. This is based on an analysis of 'if and when' low-carbon hydrogen becomes regionally and locally available under each of the four scenarios.
- Dispatchable low-carbon electricity supply such as hydrogen-fuelled generation is seen as a key component of a net zero power system based predominantly on variable renewable generation like solar PV and wind power, which occurs under all three net zero scenarios.
- Under the **Holistic Transition** and **Electric Engagement** scenarios low carbon hydrogen only becomes widely available in and around industrial clusters rather than across most of the UK. This results in less hydrogen-fuelled generation both nationally and in the licence area under these scenarios, reaching approx. 20 MW by 2050.
- The North of Scotland hosts significant oil and gas infrastructure on the east coast running from Aberdeen down to the rest of Scotland, which, under National Gas' Project Union plan, would be converted to transport hydrogen.[6] This results in an extensive supply of low carbon hydrogen for power generation under the **Hydrogen Evolution** scenario. However, the relatively small baseline and pipeline of fossil gas generation in the licence area, means that future capacity is limited even under this scenario. By 2050, over 90 MW of hydrogen-fuelled generation capacity is projected in the licence area under this scenario.
- There is no distribution-scale hydrogen-fuelled electricity generation anywhere in the UK under the **Counterfactual** scenario, in line with this scenario's slow progress towards decarbonisation.



3.4.2. Modelling and outcomes

Baseline and pipeline

Source: SSEN connections data

There are currently no connected hydrogen-fuelled generation projects or sites with accepted connection offers in the licence area. The existing baseline and pipeline of fossil gas-fired generation projects are used as a pipeline of prospective locations for future distributed hydrogen-fuelled power generation in the licence area in the medium and longer term.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	18	21	Existing connected and pipeline fossil gas-fired generation sites are modelled to convert to hydrogen once low-carbon hydrogen is locally available and the gas-fired plant has been decommissioned. Hydrogen availability is modelled based on distance to an anticipated hydrogen or industrial cluster, such as the East Coast Hydrogen project.[7] The FES framework assumes that hydrogen transmission infrastructure is limited under these scenarios. Under **Holistic Transition**, sites within 20 km of a cluster are able to convert to hydrogen from the early 2030s, expanding to over 150 km by the late 2040s. Total capacity reaches 21 MW by 2050 under this scenario. Under **Electric Engagement**, the development of hydrogen-fuelled generation is more limited, starting in the mid-2030s and only occurring at sites within 50 km of an anticipated cluster. Total capacity reaches 18 MW by 2050 under this scenario.
Electric Engagement	0	18	
Hydrogen Evolution	21	92	Existing connected and pipeline fossil gas-fired generation sites are modelled to convert to hydrogen once low-carbon hydrogen is locally available and the gas-fired plant has been decommissioned. Hydrogen availability is modelled based on the distance to a planned transmission hydrogen network, namely Project Union, or an anticipated hydrogen or industrial cluster, such as the HyNet or East Coast Hydrogen projects. Sites within 20 km of a cluster are modelled to convert to hydrogen from the early 2030s, expanding to over 150 km by the late 2040s. In addition, due to the wider availability of hydrogen under this scenario and the benefits of hydrogen as a high-capacity, low-utilisation 'peaking' technology, current

			gas reciprocating engines are modelled to replant with an additional 50% capacity.
Counter-factual	0	0	In alignment with the FES 2024 framework, there is no development of hydrogen-fuelled generation at any point under this scenario.

Spatial factors

Factor	Description
Existing baseline and pipeline of gas-fired generation.	The location of future hydrogen-fuelled generation sites is based solely on the location of baseline and pipeline gas-fired generation sites in the licence area.
Location of industrial clusters and planned hydrogen clusters.	Timing of the modelled conversion of gas-fired generation sites is based on the distance from industrial clusters and planned hydrogen clusters in all three net zero scenarios.
Location of planned hydrogen networks.	Timing of the modelled conversion of gas-fired generation sites is based on the distance from planned hydrogen networks under the **Hydrogen Evolution** scenario.

Stakeholder input

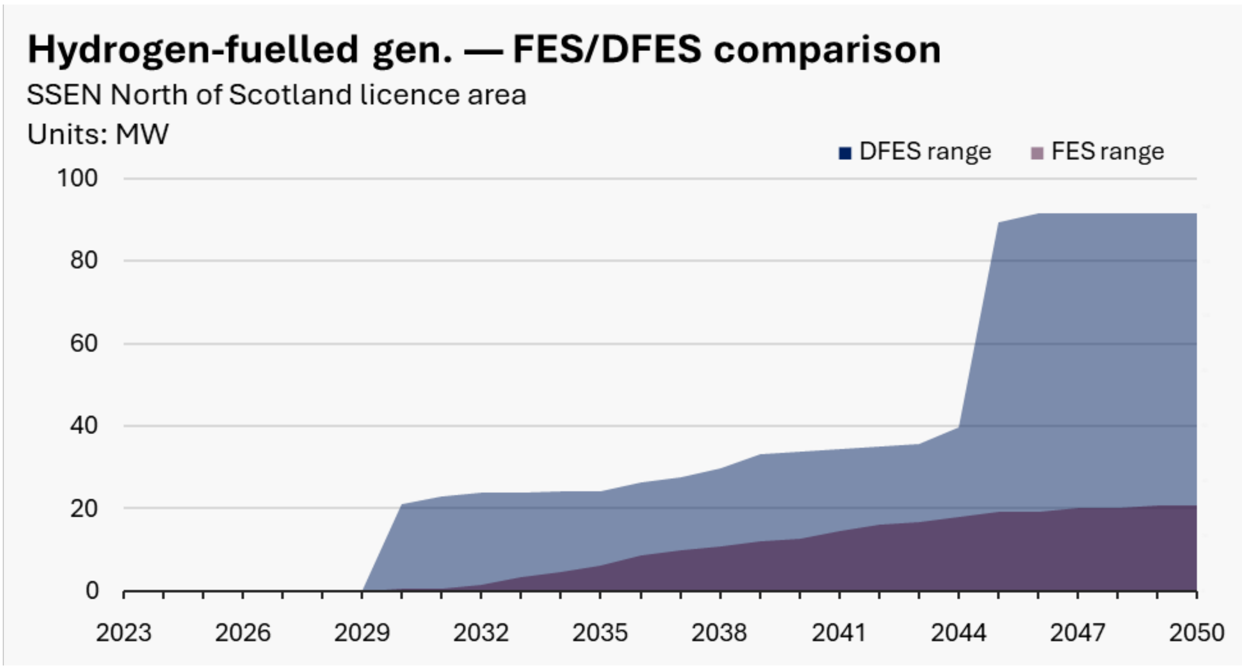
Stakeholder feedback	Impact on DFES analysis
Stakeholders were polled on the future of low carbon hydrogen in the North of Scotland regional DFES engagement webinar in October 2024.	Stakeholder feedback was that low carbon hydrogen could be used for energy security, as dispatchable generation, and on Scottish islands as an alternative to diesel as a backup fuel. This has been represented in the scenarios in alignment with the FES framework, with distribution network connected hydrogen-fuelled generation playing a varying role in the three net zero scenarios as a dispatchable form of generation. The existing baseline of fossil fuel generation sites on the Scottish islands, including at oil and gas terminals on Shetland and Orkney, are included in this conversion methodology.

3.4.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The DFES features a faster uptake of hydrogen-fuelled generation and higher maximum scenario outcome compared to the FES. The faster uptake aims to reflect the high potential for hydrogen production and use around Aberdeen and Grangemouth due to the associated oil and gas infrastructure (noting that Grangemouth itself is just outside SSEN's licence area).
- The major difference between the DFES and FES upper bound in the 2040s is due to modelling of a specific 50 MW pipeline fossil gas generation site in Aberdeen, which does not appear to be directly reflected in the FES modelling.
- The DFES and FES align in the **Counterfactual** scenario where no hydrogen-fuelled generation capacity is modelled to connect at all out to 2050.



Comparison to DFES 2023

- The outcomes for **Hydrogen Evolution** and **Holistic Transition** have been inverted compared to DFES 2023, mirroring the same change in the FES 2024 framework.
- While the scenarios trends are similar, there is a smaller pipeline of fossil gas-fuelled generation in DFES 2024 and this has resulted in lower overall projections for hydrogen-fuelled generation, as there is less modelled capacity available to convert to future hydrogen-fuelled generation. This results in a maximum scenario outcome of

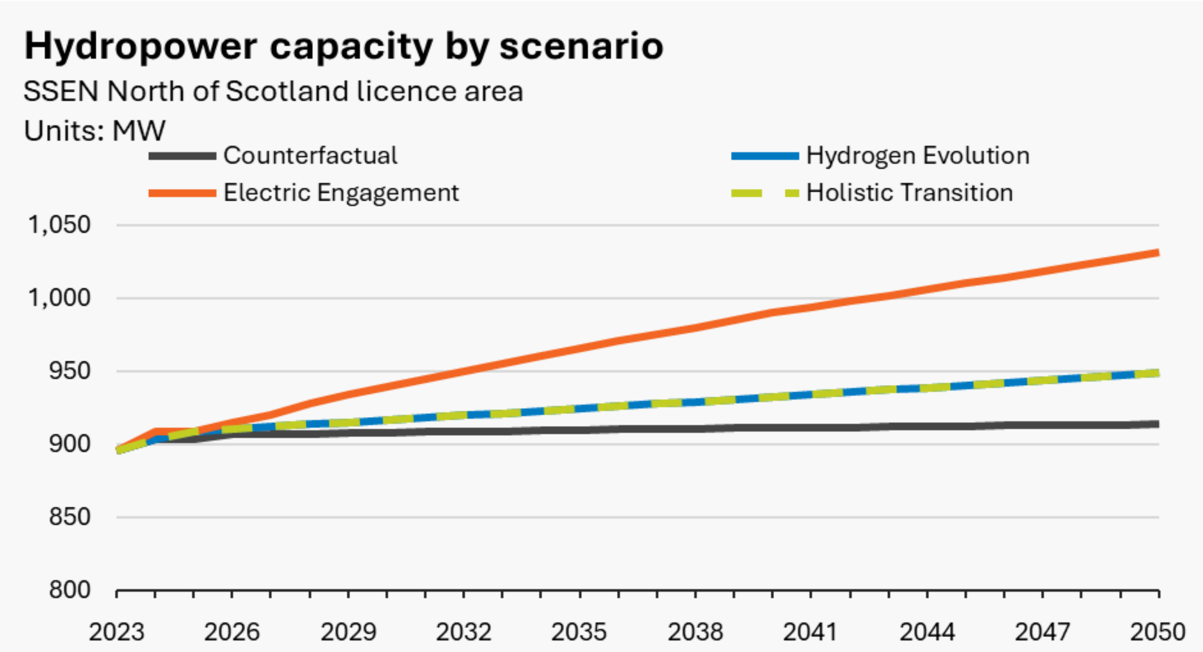
approximately 90 MW in the DFES 2024, compared to approx. 135 MW in DFES 2023. The fossil gas-fuelled generation summary contains more details of this baseline and pipeline position.

3.5. Hydropower

Technical specification	Building blocks
Hydropower generation connecting to the distribution network. This does not include pumped hydroelectric storage.	Gen_BB018

3.5.1. Summary

- There are currently over 600 distribution-connected hydropower sites, totalling 895 MW of capacity, operating in the North of Scotland licence area.
- There are a further 16 hydropower sites, totalling 17.2 MW, that hold a connection offer with SSEN. However, desktop research has revealed that 7.5 MW of this pipeline capacity has already connected to the network and have, therefore, been modelled to connect in the first year of the analysis.
- Additional hydropower capacity in the licence area is assumed to be proportionate to the trend seen in the FES 2024 for distributed hydropower for the licence area, which is a reflection of developers continuing to exploit the significant hydropower resource potential in the North of Scotland licence area. Some of the existing connected sites are also modelled to repower in the future.



3.5.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Above 1 MW	761	113	There are 113 operational hydropower sites with an installed capacity greater than 1 MW. Of these, 12 sites are individually greater than 20 MW. The largest site, Sloy Hydro, has an installed capacity of 72.5 MW. In 2022, a capacity extension of 52 MW was added to a site at Lochaber Smelter.
Below 1 MW	134	508	The majority of hydropower sites in the licence area are smaller/micro hydro sites with individual capacities lower than 1 MW. The majority of sites below 1 MW were commissioned as a result of the Feed-in Tariff, with over 50% of this proportion of the baseline coming online between 2011 and 2016.

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
Total	17.2	Number of sites: 16
Already operational	7.5	Two sites in the SSEN connection dataset were found to have recently connected to the network. These are Kinlochdamph Hydro (1 MW) and Tummel Bridge (6.5 MW).
Under construction	3.1	The 3.1 MW Allt Na Moine Hydro site is understood to be under construction.
Planning permission granted	2.6	Three additional sites with accepted connection offers have had planning permission granted. The largest of these, Three Lochs Hydro (2 MW), is anticipated to connect imminently.

Planning application submitted	0.16	Cour Burn Hydro (0.16 MW) has submitted a planning application and is awaiting a decision.
Pre-planning	2.1	Two sites totalling just over 2 MW were found to be in pre-planning stages.
No information	1.6	No development information could be found for six sites with accepted connection offers, totalling 1.6 MW. These are all small/micro hydro development sites.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	940	1,032	This scenario features support for large-scale renewable energy projects, so small renewable projects, such as micro hydropower, receive less support. Low growth is modelled out to 2050. Without small-scale hydropower subsidy support, projects are supported by the Smart Export Guarantee only. Connected hydropower capacity reaches just over 1 GW by 2050 under this scenario.
Electric Engagement	917	949	This scenario features favourable UK Government policies and support for small-scale renewable energy projects. Therefore, this scenario projects the highest development of additional hydropower. A moderate but sustained growth in hydropower capacity is projected out to 2050, driven by repowering. Connected hydropower capacity reaches just under 1 GW by 2050 under this scenario.
Hydrogen Evolution	917	949	This scenario features support for large-scale renewable energy projects, so small renewable projects, such as micro hydropower, receive less support. Therefore, low growth is modelled out to 2050. Without small-scale hydropower

			subsidy support, projects are supported by the Smart Export Guarantee only. Connected hydropower capacity reaches just under 1 GW by 2050 under this scenario.
Counter-factual	908	914	Under this scenario, other than sites currently under construction, no additional hydropower capacity growth has been modelled out to 2050, reflecting limited support for small-scale renewables under this scenario. Connected hydropower capacity flatlined at c. 0.9 GW by 2050 under this scenario.

Spatial factors

Factor	Description
Site location	The distribution of hydropower capacity is based on the location of known projects and resource availability. Additional small-scale, medium and long-term projections are distributed spatially based on areas of theoretical hydropower potential.

Stakeholder input

Stakeholder feedback	Impact on DFES analysis
Engagement with small-scale hydropower developers in the North of Scotland	As part of DFES 2021, several developers were asked about constraints and limitations in the industry. Economic viability was highlighted as a key limiting factor for new hydropower projects. Under the net zero scenarios, future policy support and alternative methods of project financing have been assumed to encourage future project development beyond the known pipeline.
Engagement with the British Hydropower Association	The British Hydropower Association were engaged in 2023 to understand the degree of resource potential in the UK as

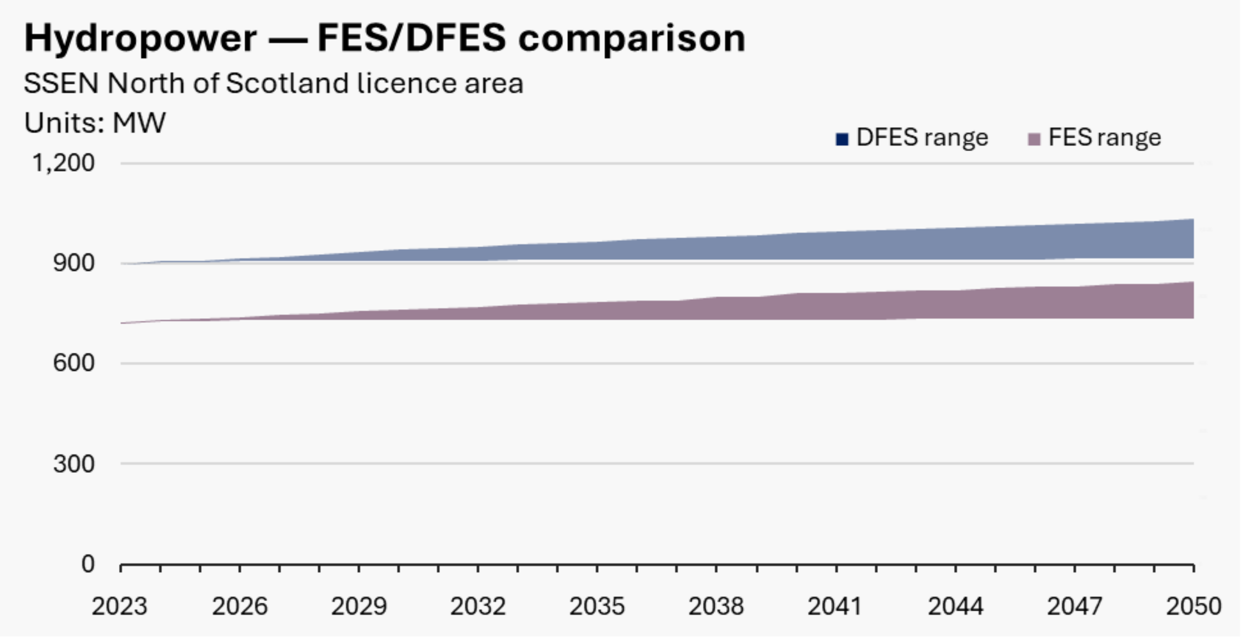
a whole. This engagement revealed that the state of the sector has remained similar to previous years of analysis.

3.5.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The FES has a notably lower baseline of installed hydropower capacity in the licence area, totalling 721 MW. The DFES site-by-site analysis of projects with connection agreements with SSEN revealed 896 MW of operational capacity in the licence area. The reason for this variance is unknown.
- As a result of this baseline variance, the FES projections for hydropower are resultantly lower than DFES 2024 by 2050. However, scenario trends and proportional capacity growth of the FES are reflected in the DFES, albeit from a higher baseline capacity.



Comparison to DFES 2023

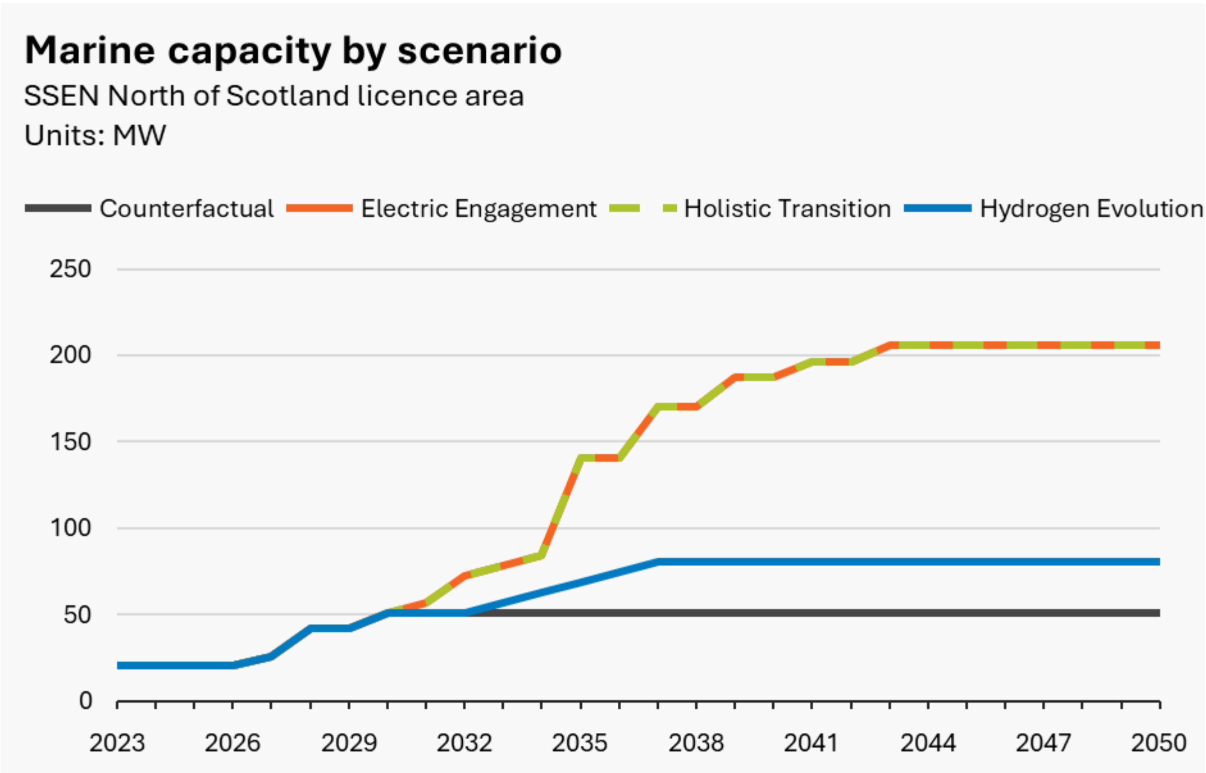
- The installed capacity of hydropower in the licence area has not changed on the value recorded for DFES 2023.
- There is very little change between the projection range in DFES 2023 and DFES 2024 in the long term.

3.6. Marine generation

Technical specification	Building blocks
Marine (tidal stream, wave power, tidal lagoon)	Gen_BB017

3.6.1. Summary

- There are seven grid-connected marine energy generation projects, totalling 20.4 MW, in the North of Scotland licence area.
- Since DFES 2023, an additional 3.2 MW tidal test facility has connected to the network.
- The near-term development of marine generation projects is expected to see some positive growth in all scenarios, following the recent Contracts for Difference (CfD) Allocation Round 6 (AR6), in which 18 MW of marine generation capacity secured agreements. The connection of projects with CfDs, including those from previous rounds, will almost double the connected capacity at the distribution level in the licence area before the end of the decade.
- In the longer term, there is a significant range in the future projections for marine generation under the scenarios. Under the **Holistic Transition** and **Electric Engagement** scenarios, a supportive policy environment enables marine capacity to increase to over 200 MW by the early 2040's.
- Under the **Counterfactual**, beyond pipeline developments, capacity flatlined to 2050.



3.6.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Wave	7.2	2	There are currently two wave sites, totalling 7.2 MW, that are operational in the licence area: • EMEC's wave energy test site at Billia Croo on Orkney (7 MW) • Craddach Wave, Islay (0.15 MW)
Tidal stream	13.5	5	There are six operational tidal generation sites, totalling 13.5 MW: • SAE MeyGen (5.7MW) • EMEC Eday test site (4 MW) • EMEC Tidal Test Centre (3.2 MW) • Shetland Tidal Array (0.5 MW) • Nova Innovation's Cullivoe Tidal berth (45 kW)

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
Total	60	Number of sites: 2
Contracts for Difference awarded	30.5	10 projects, totalling 30.5 MW of capacity, have secured CfDs across AR4, AR5 and AR6 and will be connecting in phases to the distribution network in the North of Scotland licence area. A further 50 MW of capacity has won a CfD in the region; however, this will be connecting at the transmission level.
No information	29.5	No information could be found for 29.5 MW of marine generation sites with accepted connection offers. These could be developed via future CfD rounds or other support schemes.

Scenario projections

<table>
<tr><th rowspan="2">Scenario</th><th colspan="2">Capacity (MW)</th><th rowspan="2">Description</th></tr>
<tr><th>2030</th><th>2050</th></tr>
<tr><td>Holistic Transition</td><td>51</td><td>206</td><td rowspan="2">Marine technologies receive good support across all scales and there is consistent industry development out to 2050 under these scenarios.

A steady increase in installed capacity continues after CfD AR6 winners have connected in the late 2020s, with tidal projects connecting to sites with accepted connection offers between 2030 to 2035.

Thereafter, development is assumed to continue based on information related to development opportunities that do not currently have connection offers.

Total installed marine generation capacity reaches 206 MW by 2050 under these scenarios.</td></tr>
<tr><td>Electric Engagement</td><td>51</td><td>206</td></tr>
<tr><td>Hydrogen Evolution</td><td>51</td><td>80</td><td>Support for marine generation technologies is lower than in the other net zero scenarios. Known future projects with accepted connection offers connect to the distribution network later than in the other net zero scenarios. Further possible opportunities without connection offers are assumed to not be developed.
Total installed marine generation capacity reaches 80 MW by 2050 under this scenario.</td></tr>
<tr><td>Counter-factual</td><td>51</td><td>51</td><td>There is low support for tidal stream overall. No further ring-fenced budgets for tidal stream are considered to be included in future CfD Allocation Rounds. As a result, projects in the North of Scotland licence area do not receive UK Government support, and no development beyond AR6 occurs.

Total installed marine generation capacity flatlines at 51 MW between 2030 and 2050 under this scenario.</td></tr>
</table>

Spatial factors

Factor	Description
Site locations	Location of known pipeline projects.

Stakeholder input

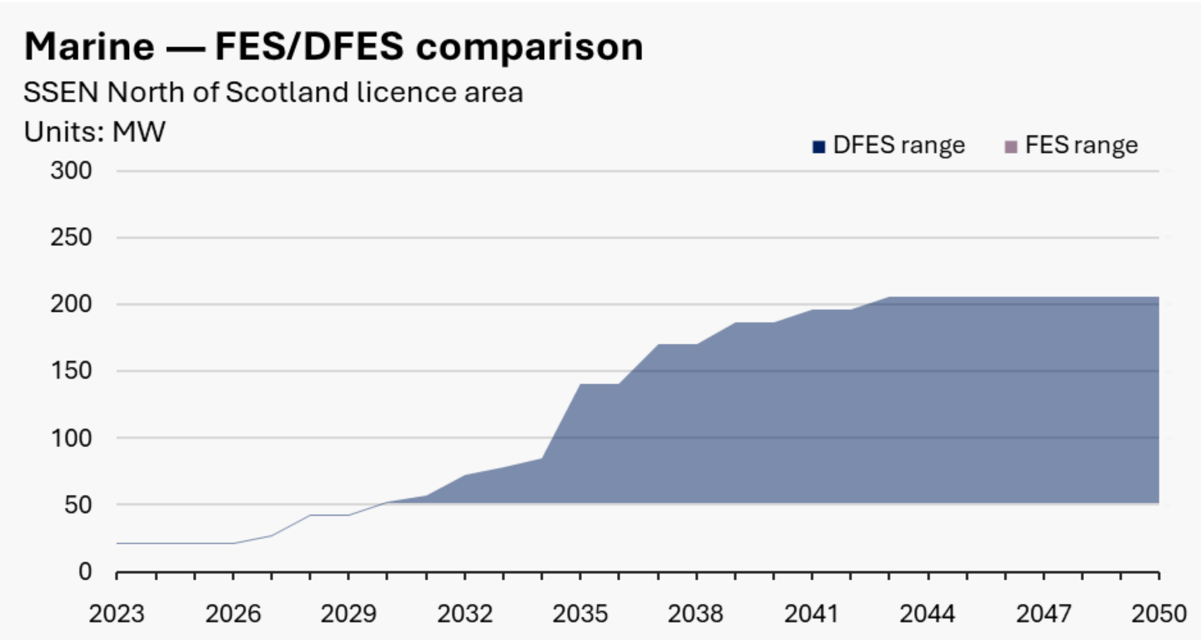
Stakeholder feedback	Impact on DFES analysis
Representatives from the EMEC, MEC and the marine energy development sector have previously been engaged	Information related to sites without a connection offer was provided and included in the projections.

3.6.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The FES 2024 has no marine generation capacity across the North of Scotland licence area out to 2050. DFES 2024, and prior DFES studies, have shown that there is installed capacity currently in operation and that there is significant potential for future growth.



Comparison to DFES 2023

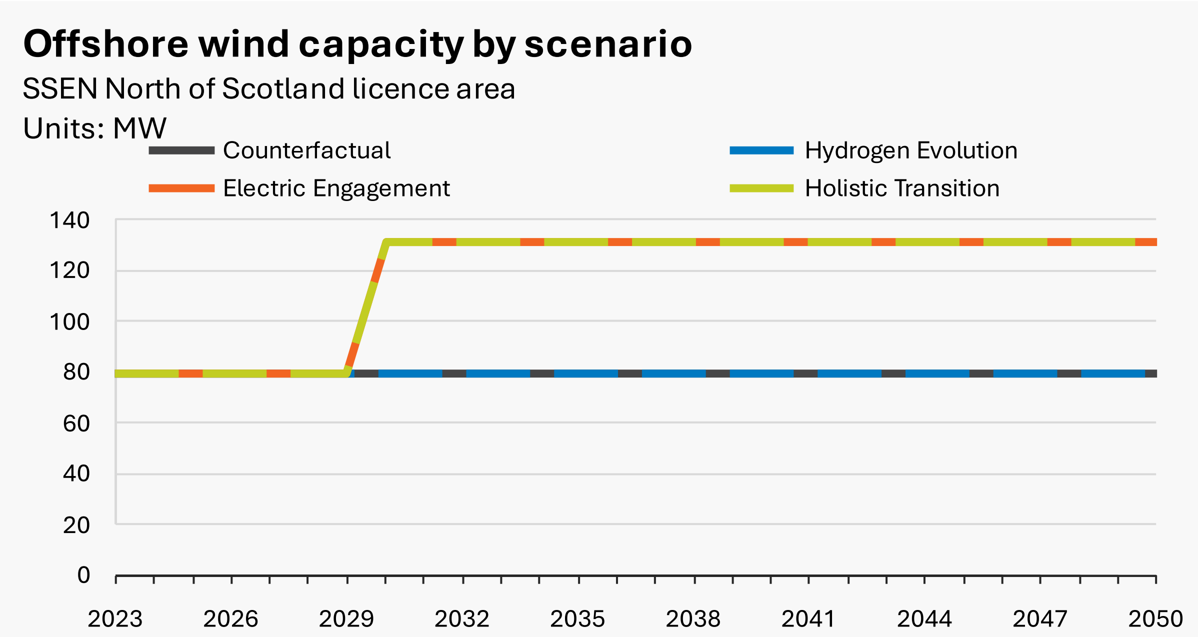
- The range of DFES projections have not changed significantly year on year.
- As the DFES 2023 projections anticipated, the baseline capacity has increased. The rate of growth has been faster than the 2023 projections projected.
- The **Counterfactual** has significantly higher installed capacity in the long term than the DFES 2023 Falling Short scenario, this is due to significant anticipated growth in the near-term from projects that have successfully won CfDs.

3.7. Offshore wind generation

Technical specification	Building blocks
Offshore wind generation	Gen_BB024

3.7.1. Summary

- There is 80 MW of offshore wind capacity connected to the distribution network in the North of Scotland licence area. This is the same as was seen in DFES 2023.
- Two sites were found to be in development: the European Marine Energy Centre (EMEC) Test Facility in Billa Croo, Orkney, and the BP Project Flora at Peterhead. The EMEC facility has not been modelled since the site only connects to the distribution network as a temporary measure, due to the expectation of a significant transmission network upgrade. BP Project Flora is modelled to connect in 2030 under **Electric Engagement** and **Holistic Transition**.
- The Scottish Offshore Wind Policy Statement sets out an ambition to install 8-11 GW of offshore wind capacity by 2030 in Scotland.[8] However, the DFES does not model long-term projections for offshore wind, considering that most, if not all, projects will connect directly to the transmission network. Only known small-scale or demonstrator projects in the pipeline are considered.
- As a result, connected capacity increases to just over 130 MW under **Electric Engagement** and **Holistic Transition**, but no further capacity is modelled to connect under **Hydrogen Evolution** and the **Counterfactual**.



3.7.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Total	80	2	There are two operational offshore wind sites connected to the distribution network in the licence area, both of which are off the coast of Aberdeenshire. These are the 30 MW Hywind offshore wind site (30 MW), energised in 2017, and the Kincardine offshore wind farm (49.6 MW), energised in 2018.

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
Total	111	Number of sites: 2 There is one additional pipeline site compared to DFES 2023. The BP project (51 MW) won an Innovation and Targeted Oil and Gas (INTOG) lease with the Crown Estate Scotland. A second site (60MW) is the EMEC test and demonstration site at Billa Croo, Orkney. This site is not modelled to connect permanently under any scenario, since it is a temporary demonstration site. Both pipeline sites are in pre-planning stages.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	131	131	Under Electric Engagement and Holistic Transition, the single known pipeline site (that is not a temporary demonstrator site) is modelled to connect in 2030, increasing the installed capacity from 80 MW to 131 MW. Capacity remains at this value to 2050, due to offshore wind exclusively connecting to the transmission network.
Electric Engagement	131	131	
Hydrogen Evolution	80	80	No new sites are modelled to connect under this scenario without significant planning evidence. Large-scale hydrogen production is much more likely to be co-located with transmission scale onshore wind sites and assumed not to be sited with small-scale distribution connected sites.
Counter-factual	80	80	No new offshore sites are modelled to connect under this scenario without significant planning evidence.

Spatial factors

Factor	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.

Stakeholder input

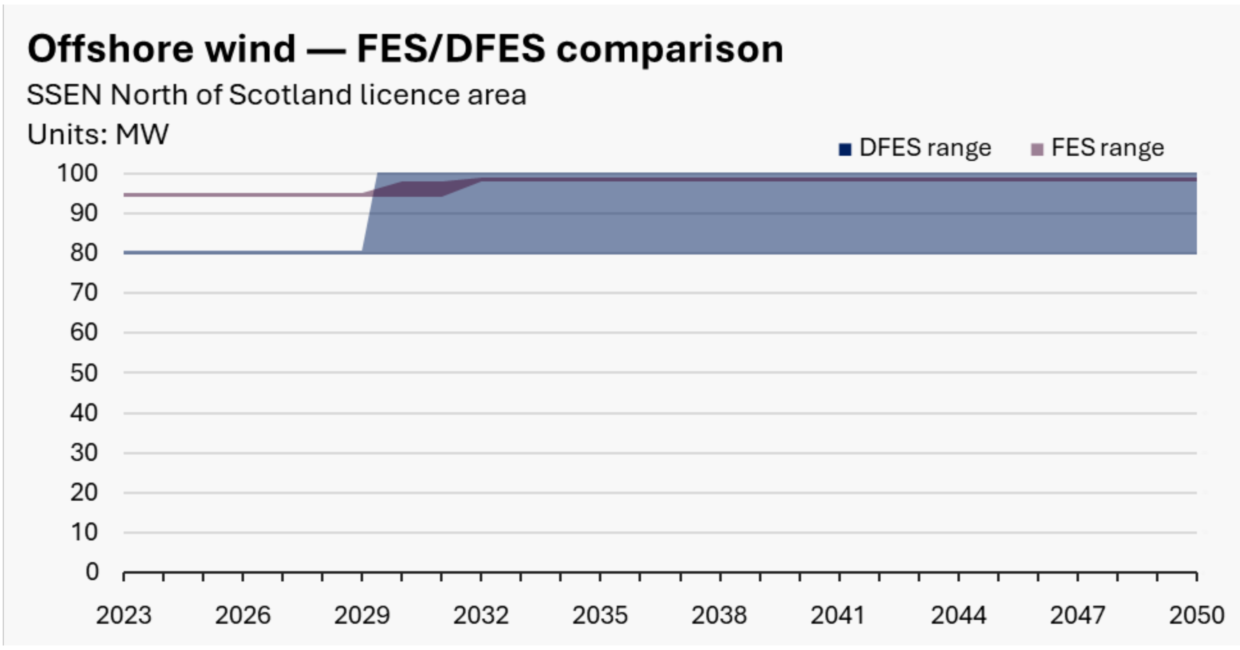
Stakeholder feedback	Impact on DFES analysis
Prior engagement with representatives from EMEC	Engagement with the EMEC team previously provided updates on the EMEC Floating Wind Demonstrator project as well as shared information about the state of the sector and anticipated project timelines.

3.7.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- There is a notable variance in the baseline between the FES and DFES. The FES baseline is 94 MW, whereas the analysis of SSEN's connection data has found evidence of only 80 MW of operational offshore wind capacity, from two sites. The reason for this variance is unknown.
- The FES 2024 and DFES 2024 long-term projections are largely aligned, although a broader range of projections is modelled under the DFES.
- The DFES models a significant pipeline increase of 51 MW by 2030 under two scenarios, reflecting known pipeline capacity, whereas the FES models an increase of only 4 MW under each scenario between 2030 and 2032.



Comparison to DFES 2023

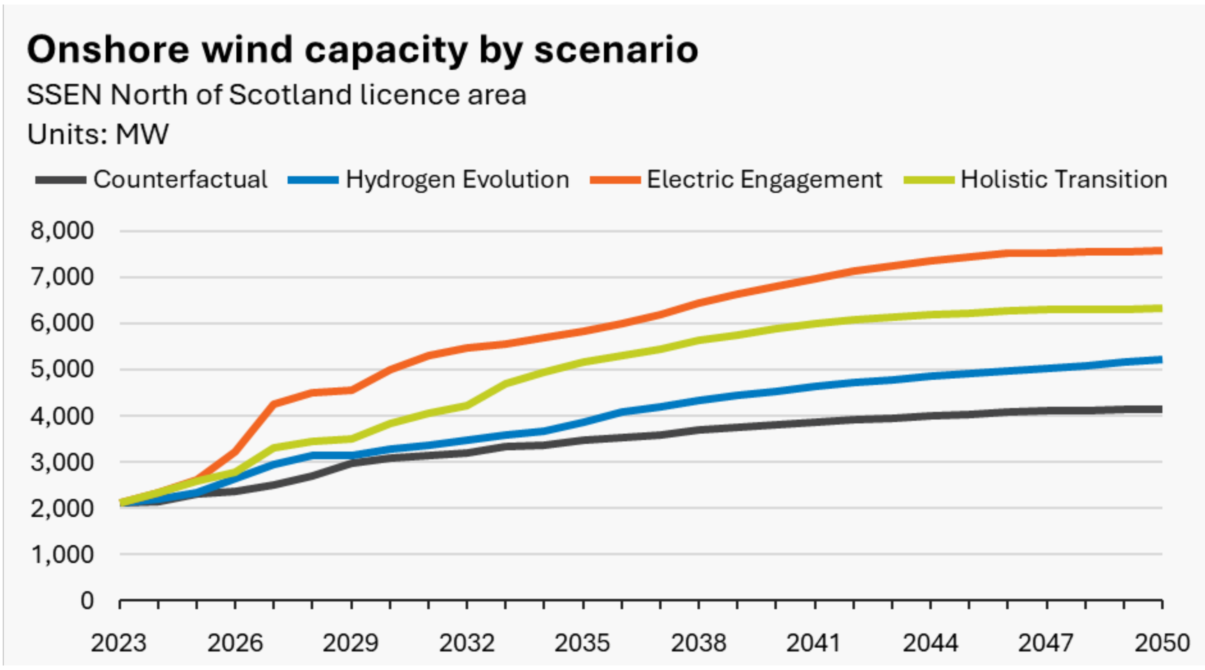
- The baseline has not changed since DFES 2024.
- A new pipeline site has resulted in an increase in the medium-term projections by 2030 under **Holistic Transition** and **Electric Engagement**.

3.8. Onshore wind generation

Technical specification	Building blocks
Large-scale onshore wind generation (>= 1MW)	Gen_BB015
Small-scale onshore wind generation (<1 MW)	Gen_BB016

3.8.1. Summary

- There are currently 481 onshore wind sites, totalling 2,135 MW in capacity, deployed in the North of Scotland licence area.
- In addition to this, there are also 113 sites (totalling 2,990 MW of capacity) that currently hold an accepted connection offer with SSEN.
- There is a supportive policy environment for onshore wind in the licence area and wider Scotland:
    - In December 2022, the Scottish Government adopted a target of 20 GW of onshore wind capacity by 2030.[9] It is assumed that this target is met in the ambitious **Electric Engagement** and **Holistic Transition** scenarios, with deployment in the North of Scotland licence area playing a key role.
    - The Scottish Government Energy Consents Unit (ECU) have been active in overturning local authority rejections to large-scale onshore wind sites.
    - The 2024 CfD Allocation Round 6 (AR6) awarded funding to four more projects in the licence area, totalling 157 MW.
    - Ofgem's 2022 Access SCR has reduced overall connection charges and introduced non-firm contracts, enabling projects to connect in congested areas of the network. [10]
- Significant ongoing connections reform is being clarified, which will prioritise projects that can provide evidence that they are able to build out ahead of 2030 and can align with the requirements of the Labour Government's Clean Power 2030 plan. This will aim to streamline the planning process and fast track necessary grid infrastructure upgrades.
- Beyond this development pipeline, a wind resource assessment has informed long-term capacity projections in the licence area. As a result, large-scale onshore wind capacity could reach 7.6 GW by 2050 under **Electric Engagement**. The lowest scenario, **Counterfactual**, sees 4.2 GW by 2050.



3.8.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Above 1 MW	1,999	162	The average capacity of the onshore wind baseline in the licence area is 12.4 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	166	323	Most small-scale onshore wind sites were funded through the Feed-in Tariff, with over 100 MW of capacity connecting between 2011 and 2016 in the licence area. Since 2017, only 15 small-scale sites, totalling approximately 37 MW, have been connected.

Pipeline

Source: SSEN connections data

A range of outcomes for this significant pipeline have been modelled under the scenarios. With significant ongoing reforms to manage the very large queue of projects seeking to connect to the network and wider regional 'technology caps' under the UK Government's Clean Power 2030 plan, the proportion of the pipeline of onshore wind projects that will move through to connection, and by when, is still unclear. The evidence collected for these sites has been considered at the time of the analysis and it is recognised that some projects may drop out of the connection queue in SSEN's licence areas into 2025 as these policies are enacted.

Status	Capacity (MW)	Description
Total	2,990	Number of sites: 113
Under construction	73	Seven sites with a total capacity of 73 MW are currently under construction or due to commission imminently. This includes the 38 MW 'Camster 2' wind farm in Wick, which has been awarded a CfD. These sites are modelled to commission in either 2024 or 2025 under all scenarios.
CfD awarded	234	Six sites totalling 234 MW have been awarded a CfD. This includes Clashindarroch 2 (77MW), Goltíclay (58 MW) and Tacher (13 MW) under the latest allocation round, AR6. These sites all have planning permission and CfD delivery years between 2026 and 2028. These years are modelled in all scenarios other than the **Counterfactual**, which model a two year delay.
Planning permission granted	693	28 sites with a total capacity of 693 MW have received planning approval. This is 30% of the total pipeline and includes nine sites that are individually 40 MW or higher. Four sites between 35-40 MW have had appeals against previously refused planning permission granted though the Scottish Government ECU. All sites with planning permission granted are modelled to build out by 2030, based on the year they received approval.

Planning application submitted	307	Ten sites with a total capacity of 307 MW have submitted full planning applications. This includes four sites over 40 MW and specifically, the 77 MW 'Strath Oykel' wind farm in Doune. These sites are modelled to build out by 2031 in all net zero compliant scenarios, based on the date that they submitted their application. However, under the **Counterfactual**, the larger-scale sites over 40 MW do not deploy, reflecting a less accommodating planning environment in this scenario.
Pre-planning	1,023	25 onshore wind projects, at just over 1 GW in total, have submitted pre-planning applications – this includes screening opinion submissions. This is 35% of the pipeline and a significant increase on DFES 2023, where only 517 MW of onshore wind capacity was in pre-planning. This indicates that projects are progressing through the planning process. The average capacity of these sites is 40 MW, significantly larger than those sites with accepted connection offers which have either submitted applications or received full planning permission. This indicates the near-term appetite from developers for larger sites and economies of scale. However, it is possible, that the planning process may result in these sites downscaling their capacities. At 110MW, 'Windburn Windfarm' in Perth and Kinross, which is in pre-planning, would become the largest site in the licence area if it progresses to build-out. These pre-planning sites are modelled to deploy between 2027 and 2030 under only the two most ambitions scenarios, **Electric Engagement** and **Holistic Transition.** Rapid progress through planning and into operation is aided by the Scottish Government, working toward its 2030 onshore wind deployment target.
No information	507	There is no evidence in local authority planning databases for the additional 29 sites that hold accepted connection offers, totalling 507 MW. These sites are modelled to build out between 2028 and 2031, only under **Electric Engagement** as the scenario which is most supportive of distributed renewable energy.

		At 17% of total pipeline capacity, this is a relatively small percentage of sites with no planning information. The solar PV and battery storage pipelines contain greater numbers of sites with no evidence in planning.
Refused planning, withdrawn or abandoned	152	Eight sites that hold an accepted connection offer, totalling 152 MW, have either withdrawn planning applications or their applications have been rejected by local planning authorities. The Scottish Government's ECU have been active in overturning local authority rejections to a number of larger-scale projects. A 50 MW 'West Torrisdale' site is currently under review by the ECU. However, currently, these eight sites are not modelled to build out under any scenario based on the current available information.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	3,867	6,361	Continued efforts to achieve both Scottish and UK decarbonisation targets result in an accelerated deployment of onshore wind in the licence area throughout the late 2020s and beyond under this scenario. Projects with existing accepted connection offers and evidence of progress in the planning system connect rapidly, with all sites with this evidence connecting by 2035 at the latest. Deployment continues throughout the 2030s and 2040s at a similar rate. Existing sites larger than 5 MW are modelled to repower with an additional 40% capacity, reflecting more efficient and larger turbines when these sites reach the end of their operational life. This results in an additional 1 GW of installed onshore wind capacity in the licence area by 2050. Assuming the Scottish Government's target for 20 GW of onshore wind capacity by 2030 is met, this scenario sees the North of Scotland licence area hosting 19% of total onshore wind in Scotland in 2030. This is a slight decrease from the current proportion, where the licence area hosts 22% of total Scottish onshore wind capacity.[11] This scenario sees significant overall growth in installed onshore wind capacity, with 6.4 GW deployed by 2050, three times the current baseline.
Electric Engagement	5,029	7,606	Continued efforts to achieve Scottish and UK decarbonisation targets results in an accelerated deployment of onshore wind in the licence area throughout the late 2020s under this scenario. Sites that have not yet entered the planning system are able to rapidly progress through it, securing approvals, and all existing sites with accepted connection offers are modelled to connect by 2031. Assuming the Scottish Government's target for 20 GW of onshore wind capacity by 2030 is met, this scenario sees North of Scotland licence area hosting 25% of total onshore wind in Scotland in 2030. This is an increase on the 22% of total Scottish onshore wind capacity it currently hosts.

			Onshore wind deployment continues throughout the 2030s at a reduced rate. Existing sites larger than 5 MW are then modelled to repower with an additional 50% capacity due to more efficient and larger turbines at the end of operational timelines. This results in an additional 1.2 GW of capacity in the licence area by 2050. This scenario sees the largest growth in onshore wind capacity, with just over 7.6 GW deployed by 2050. This is over three times the current baseline.
Hydrogen Evolution	3,309	5,249	This scenario sees a greater focus on transmission network-connected electricity generation to achieve net zero targets, resulting in a more limited deployment of onshore wind on the distribution network. Despite this, the existing pipeline of sites with both accepted connections offers and strong evidence of progress through the planning system, connecting in the late 2020s. This deployment directly contributes to meeting Scottish Government decarbonisation targets. The repowering of baseline sites with an additional 25% capacity results in an additional 600 MW connecting at these sites in the 2030s and 2040s. By 2050, 5.2 GW of onshore wind is deployed in the licence area under this scenario.
Counter-factual	3, 124	4,186	The least ambitious scenario, the **Counterfactual,** has the lowest level of growth in onshore wind capacity. However, those sites with accepted connection offers and planning approval, or those with planning applications submitted, are modelled to connected over a longer, more delayed timeframe. 4.2 GW is modelled to connect by 2050, which is over double the current baseline.

Spatial factors

Factor	Description
Onshore wind resource assessment	Regen's in-house resource assessment, taking into consideration wind resource, land availability and planning constraints in the licence area, is used to inform the spatial distribution of post-pipeline onshore wind capacity.
Island interconnectors	Several islands in the North of Scotland licence area rely on new interconnectors to facilitate new renewable generation projects such as onshore wind. SSEN are assessing the

	long-term requirements and security of supply considerations for a number of subsea cables supplying the Scottish Islands. This is being assessed through the Hebrides and Orkney Whole System Uncertainty Mechanism (HOWSUM) project. The Needs Case for the Orkney to Caithness subsea cable has now been met and approved by Ofgem. Developers are aiming for this to connect in 2025/26. The Western Isles transmission reinforcement project commissions in 2027. Except for under the **Counterfactual**, this is not assumed to delay current pipeline sites with positive planning evidence. However, much of this additional capacity will be allocated to an individual onshore wind project: the 300 MW Stornoway Wind Farm, that has secured a CfD.
Local ambition	Local ambition is also reflected in the distribution of post-pipeline capacity. This includes local authority policy landscape, localised commitments to renewable energy development and wider net zero goals/targets.

Stakeholder input

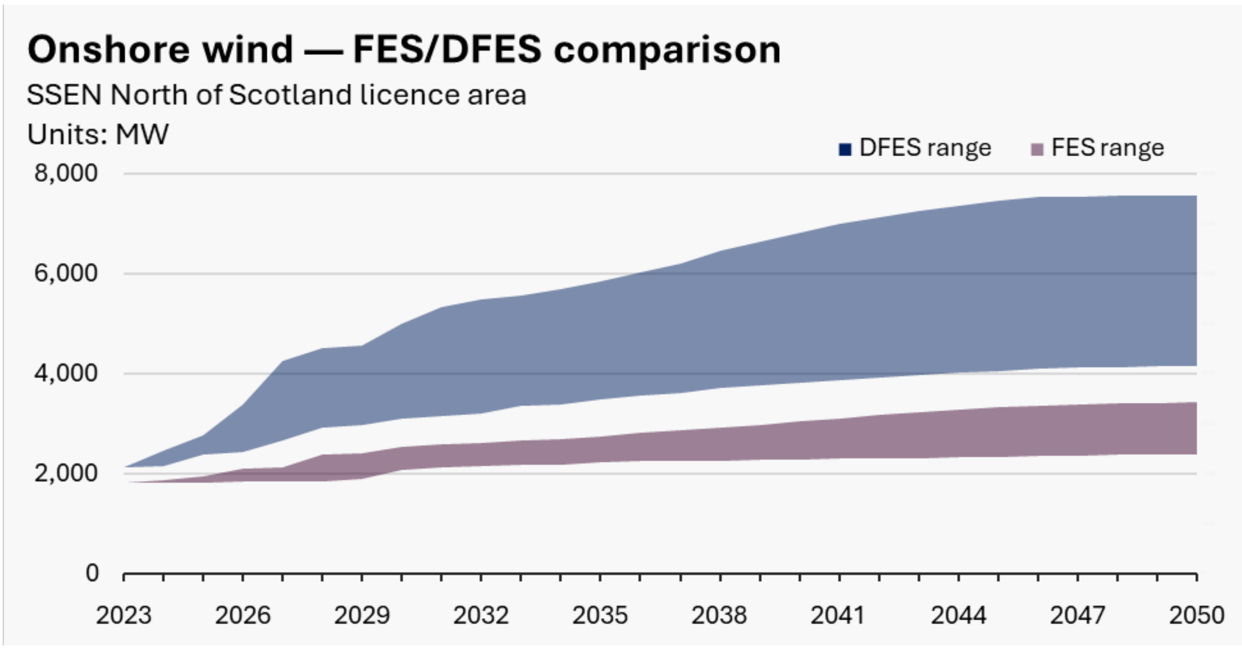
Stakeholder feedback	Impact on DFES analysis
Local Area Energy Plans	Explicitly stated local targets for wind power through available LAEPs inform the distribution of post-pipeline capacity. DFES projections are also checked against these targets to ensure they are captured within the envelope of scenarios, where applicable and viable.
Stakeholder poll on the balance of distribution and transmission connected onshore wind at the North of Scotland regional webinar	Attendees at the North of Scotland licence area regional webinar in October 2024 were asked whether transmission or distribution scale of onshore wind projects would be most common in the region going forward. 80% responded that medium scale projects (between 5 MW and 50 MW) would be most common. This has been reflected in **Electric Engagement**, where the greatest degree of distributed, medium-scale onshore wind capacity contributes to meeting net zero targets.

3.8.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- FES 2024 projections have decreased relative to FES 2023 and they are significantly lower than DFES 2024 projections in all scenarios. The DFES projections are based on a detailed analysis of sites with accepted connection offers in the licence area and the majority of these sites were found to have evidence of progress through local authority planning systems.



Comparison to DFES 2023

- The DFES 2024 projections are broadly similar to the equivalent DFES 2023 projections.
- The more ambitious scenarios, **Electric Engagement** and **Holistic Transition**, have slightly lower pre-2030 growth than the most ambitious scenarios within DFES 2023. This is primarily due to updated pipeline evidence.

3.9. Other generation

Technical specification	Building blocks
Connected or contracted generation sites that could not be positively identified as a specific technology type.	n/a

3.9.1. Summary

- Other generation sites are typically small-scale fossil-fuel generation sites, but they could not be specifically identified as such in the SSEN connections data.

3.9.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Above 1 MW	0	0	Only a single baseline site could not be identified as a specific form of generation.
Below 1 MW	0.2	1	

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
Contracted	19	This single 19 MW site in Perth and Kinross is a hybrid renewable and battery storage site that could not be split into its constituent capacities. It is modelled to connect in 2024 under all scenarios.

Scenario projections

There are no scenario projections for other generation.

Spatial factors

Factor	Description
Location of connected and in-development sites	The DFES projections are wholly based on operational and in-development sites, as identified through SSEN's connection data.

3.9.3. Comparisons

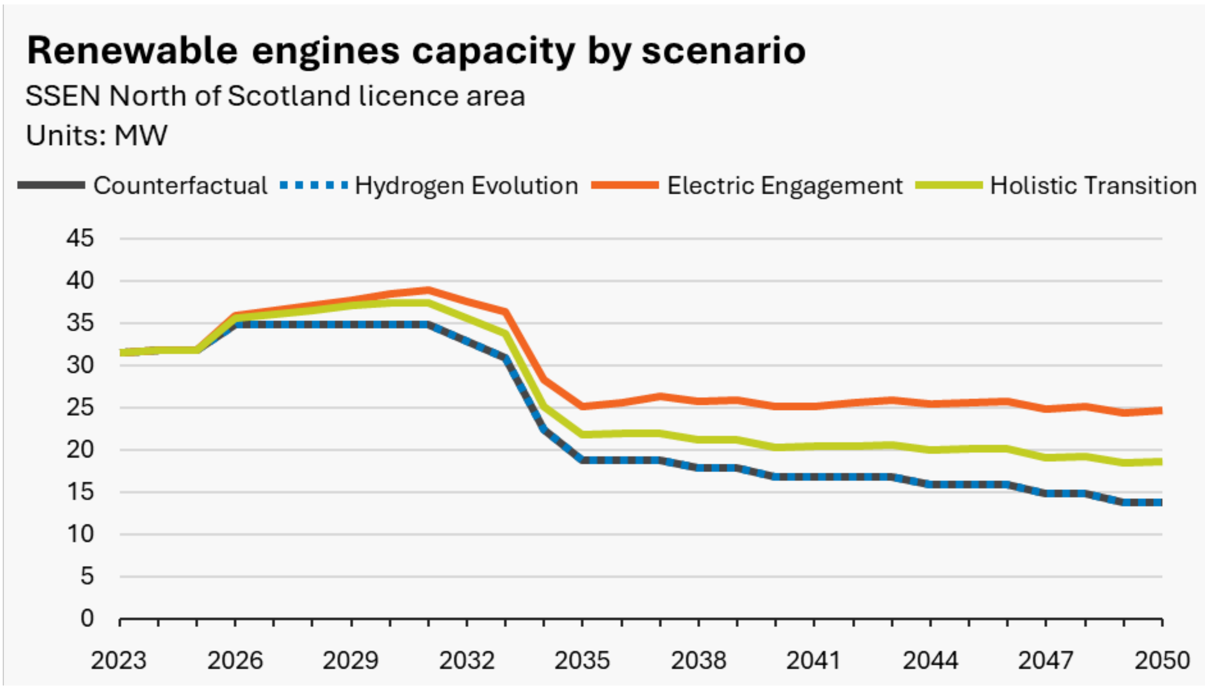
Due to the nature of other generation sites, a comparison between FES 2024 or DFES 2023 data is not possible.

3.10. Renewable engines

Technical specification	Building Blocks
Electrical capacity of gas engines and combined heat and power (CHP) fuelled by renewable and low-carbon gas, including sewage gas, landfill gas and biogas from anaerobic digestion of biogenic feedstocks such as crop waste and animal slurry.	Gen_BB004

3.10.1. Summary

- Renewable engines comprise three types of sites: landfill gas, the anaerobic digestion of farm and food waste, and sewage gas at sewage treatment plants.
- Landfill gas, which makes up two-thirds of the baseline capacity in the North of Scotland licence area, is modelled to decommission over time in every scenario, as the UK moves towards more sustainable waste treatment and an overall reduction in waste.
- Anaerobic digestion, accounting for around one-quarter of the renewable engines baseline capacity, is projected to increase under the **Electric Engagement** and **Holistic Transition** scenarios. However, bioenergy resource is prioritised, where possible, in all scenarios for harder-to-decarbonise sectors such as industry, aviation and shipping, thereby limiting its role in electricity generation.
- Sewage gas, which makes up the remainder of the baseline capacity, is assumed to remain relatively stable in all scenarios, with much of the sewage gas resource already being captured and used for electricity and CHP generation at sewage treatment works.
- Combining these trends results in an overall reduction in renewable engines capacity in the licence area, from 31 MW currently operational to between 25 MW in **Electric Engagement** and 14 MW in the **Hydrogen Evolution** and **Counterfactual** scenarios.



3.10.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Above 1 MW	22	13	The vast majority of baseline sites with capacities above 1 MW are landfill gas sites based at landfill sites near to population centres.
Below 1 MW	10	27	The majority of the baseline sites with capacities below 1 MW are anaerobic digestors located on farms. There are also two biogas plants located at distilleries, providing heat and power.

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
Total	3.5	Number of sites: 2
Under construction	0.4	A single sewage gas site in Perth is already under construction and, therefore, modelled to connect in 2024 under all scenarios.
Planning permission granted	3.1	A single anaerobic digestor site in Moray was granted planning permission in 2024. Based on analysis of the typical time between attaining planning permission and commissioning for this type and scale of site, this site is modelled to connect in 2026 under all scenarios.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	37	19	Landfill gas sites that are operational or in development are modelled to have an operational lifespan of 30 years under every scenario, after which point the connection is decommissioned. This reflects desktop research on landfill gas output over the lifetime of the project. Sewage gas sites that are operational or in development are modelled to remain connected at a consistent capacity out to 2050 under every scenario. The lack of projects being developed indicates there is low potential for growth in sewage gas capacity, but that existing sites have long operational lifespans. Previous engagement with water companies suggested that further development of sewage gas resources would be focused on on-site heat and power generation rather than exporting to the grid.
Electric Engagement	38	25	
Hydrogen Evolution	35	14	
Counter-factual	35	14	

			There is potential for anaerobic digestion deployment in the licence area where agricultural land is present. Under **Electric Engagement** and **Holistic Transition**, anaerobic digestion sees a small amount of deployment throughout the scenario timeframe, whereas under **Hydrogen Evolution** and **Counterfactual** there is no further deployment beyond the pipeline.

Spatial factors

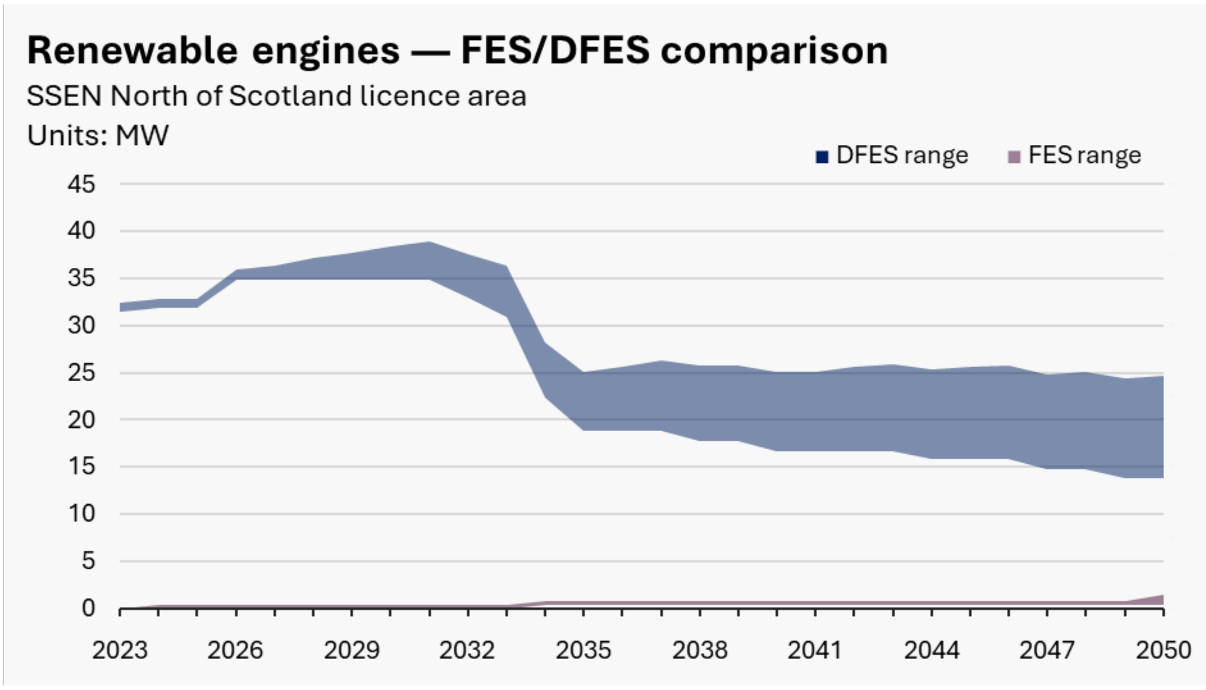
Factor	Description
Existing baseline and pipeline sites	The baseline, pipeline and decommissioning are modelled directly on a site-by-site basis. Growth in anaerobic digestion capacity is distributed to existing anaerobic digestion sites.

3.10.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The FES and DFES baselines in the licence area are not well aligned, with the FES data containing no baseline capacity in the North of Scotland licence area. The reason for this is unclear but it could be related to differences in technology classifications.
- The FES models almost no growth in capacity in any scenario. Combined with the lack of baseline, this means a reconciliation with the DFES outcomes is not possible.



Comparison to DFES 2023

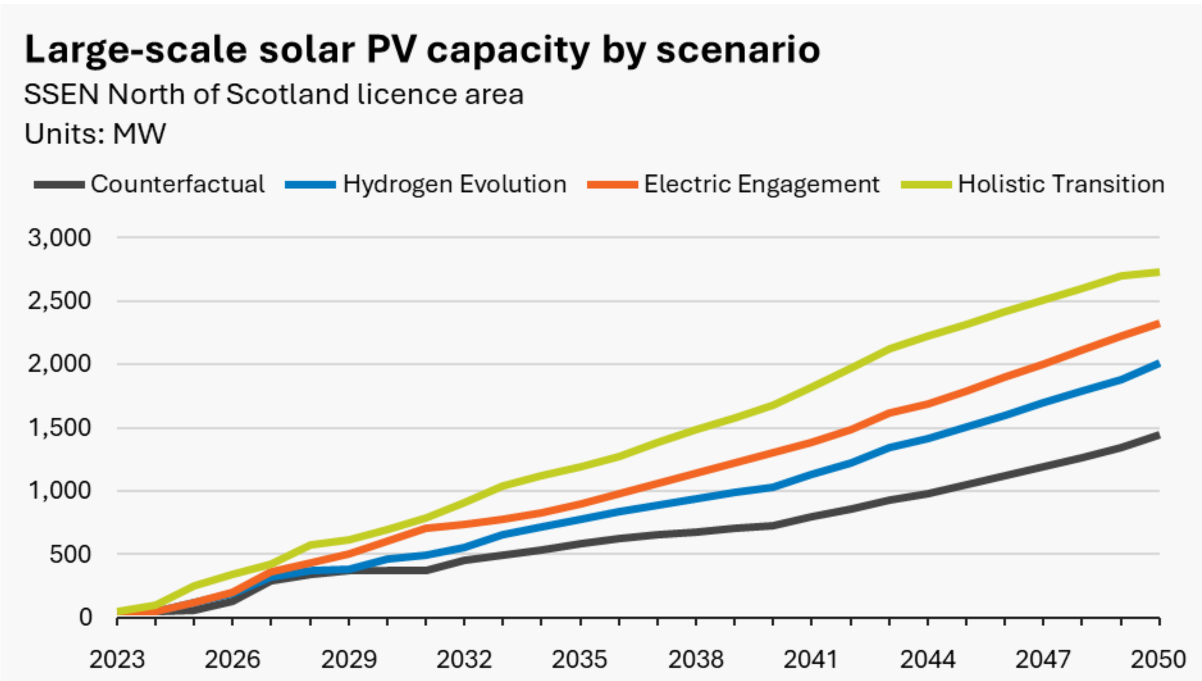
- The outcomes and modelling methods for renewable engines are similar between DFES 2023 and DFES 2024. The near-term growth in anaerobic digestion capacity under the three net zero scenarios has been reduced, reflecting the minimal pipeline of developing projects.

3.11. Solar PV (large-scale)

Technical specification	Building blocks
Large solar generation (G99)	Gen_BB012

3.11.1. Summary

- The Scottish Government's Energy Strategy and Just Transition Plan, set to be published in 2025 after a draft was circulated for consultation in April 2023, includes the commitment to a target of 4-6 GW of solar PV capacity, at all scales, by 2030.[12]
- The baseline of large-scale solar PV in the North of Scotland licence area currently totals 45.7 MW.
- There is 1.9 GW of large-scale solar PV in the pipeline, across 87 projects, with an accepted connection offer in the North of Scotland licence area. This is a marginal increase of 96 MW over the last 12 months. 52% of these sites have entered the planning system and 25% having been granted full planning permission.
- The CfD Allocation Round 6 was favourable for large-scale solar, with 11 sites, totalling 132 MW, awarded contracts in North of Scotland licence area.
- By 2050, the capacity of large-scale solar PV in the North of Scotland licence area ranges from 1.4 GW under the **Counterfactual** scenario, twice the current baseline, to 2.7 GW under **Holistic Transition**, which is nearly four times the current baseline.



3.11.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Above 1 MW	45.7		The connected baseline of large-scale solar PV capacity has not changed since the DFES 2023 analysis was completed.

Pipeline

Source: SSEN connections data

A range of outcomes for this significant pipeline have been modelled under the scenarios. With significant ongoing reforms to manage the very large queue of projects seeking to connect to the network and wider regional 'technology caps' under the UK Government's Clean Power 2030 plan, the proportion of the pipeline of large-scale solar that will move through to connection, and by when, is still unclear. The evidence collected for these sites has been considered at the time of the analysis and it is recognised that some projects may drop out of the connection queue in SSEN's licence areas into 2025 as these policies are enacted.

Status	Capacity (MW)	Description
Total	1,951	Number of sites: 87 The total capacity of large-scale solar PV with accepted connection offers, or connection offers issued, is roughly the same as was seen in DFES 2023, with only 10 more sites, totalling 96 MW, entering the SSEN connections database. The most significant shift change in this pipeline of prospective solar sites was the number of sites currently in pre-planning, which totalled an additional 257 MW, for many of which no information could previously be found.

Contract for Difference Allocation Round 6	132	CfDs were awarded to 11 sites, totalling 132 MW, in Allocation Round 6. All of these sites have been modelled to connect by their relevant delivery years (2026/28), except for sites that are in areas of grid constraint. These sites were modelled to connect by their delivery year under all three net zero scenarios and were modelled to connect by the year that statement of works upstream network reinforcement is set to complete under **Counterfactual**.
Planning permission granted	323	In addition to the sites that secured CfDs, there are 22 sites in the North of Scotland licence area with granted planning permission, totalling 323 MW. This includes eight sites that are individually greater than 20 MW. The two largest sites are the Bilbo and Frodo solar farms in Aberdeenshire (67 MW) and Milltown in Moray (49.9 MW).
Planning application submitted	196	There are also seven sites in the licence area, totalling 196 MW, that have submitted planning applications and are awaiting a decision. Of these, two sites (both of which are larger than 50 MW) are modelled to connect in the mid to late 2020s under **Holistic Transition**. Under **Electric Engagement**, four sites with a capacity of less than 20 MW were modelled to connect in the late 2020s. Two sites are modelled to connect in the late 2020s and early 2030s under **Hydrogen Evolution** based on an analysis of planning status. Under the **Counterfactual** scenario, three sites in areas with high levels of historic planning success for large-scale solar PV or also holding a CfD are modelled to connect.
Pre-planning	412	Pre-planning includes sites with evidence of pre-development beyond an accepted connection offer, such as a screening opinion for the need for an environmental impact assessment (EIA) or early-stage community engagement. Sites in the pre-planning stages are only modelled to connect under the three net zero scenarios. Under **Electric Engagement** and **Hydrogen Evolution**, 25% of the 412 MW capacity is modelled to connect based on an analysis of local

		ambition and historic planning permission success rates. Under **Holistic Transition**, the proportion of this pre-planning capacity that is modelled to come online increases to 50%.
No information	949	Due to the size of the large-scale PV pipeline, there are several sites where no evidence of development could be found. While this could be an indication that the site is unlikely to connect, many of these sites have only recently accepted a connection offer with SSEN. Therefore, 30% of this capacity is modelled to connect under **Holistic Transition** and **Electric Engagement**.
Refused planning, withdrawn or abandoned	70	70 MW of large-scale solar sites with accepted connection offers have been rejected in planning, withdrawn their planning applications or abandoned development. These sites are not modelled to connect under any scenario.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	723	2,727	This scenario sees the largest growth in large-scale solar PV capacity out to 2050, driven by a high proportion of the known pipeline being modelled to connect. Baseline sites are modelled to repower with an additional 50% capacity at the end of a 20-year operational life. Solar capacity resultantly reaches over 2.7 GW by 2050 in the licence area under this scenario.
Electric Engagement	657	2,385	Solar PV deployment increases substantially under this scenario, reaching 2.4 GW by 2050. Repowering of baseline sites at the end of a 25-year operational life is modelled to increase capacity by 25%.
Hydrogen Evolution	534	2,081	Solar PV deployment increases steadily under this scenario, driven by high levels of local ambition, reaching over 2 GW by 2050. Repowering of baseline sites at the end of a 25-year operational life is also modelled to increase capacity by 25%.

Counter-factual	400	1,473	While the least ambitious of the four scenarios for renewable energy development, a significant capacity increase of nearly three and a half times the baseline by 2050 is modelled under this scenario, reaching 1.4 GW by 2050. This is driven by the high proportion of pipeline sites with granted planning permission connecting with longer development timelines, pushing development out to the late 2030s, where growth in new solar capacity levels off. Repowering is assumed to also have a minimal impact under this scenario, with most site owners choosing to extend the life of their existing panels, rather than increasing capacity.

Spatial factors

Factor	**Description**
Solar resource assessment (Solar irradiance data, Natural England, OS Addressbase)	Regen's in-house resource assessment, taking into consideration solar resource, land availability and planning constraints in the licence area, is used to identify potential future areas for large-scale solar development.
Local ambition (Climate Score Cards, DFES local authority energy strategy survey, Local Area Energy Plans)	Local ambition, including the local authority policy landscape and commitment to renewable energy and net zero goals, is reflected in the large-scale solar projections at a local authority level.

Stakeholder input

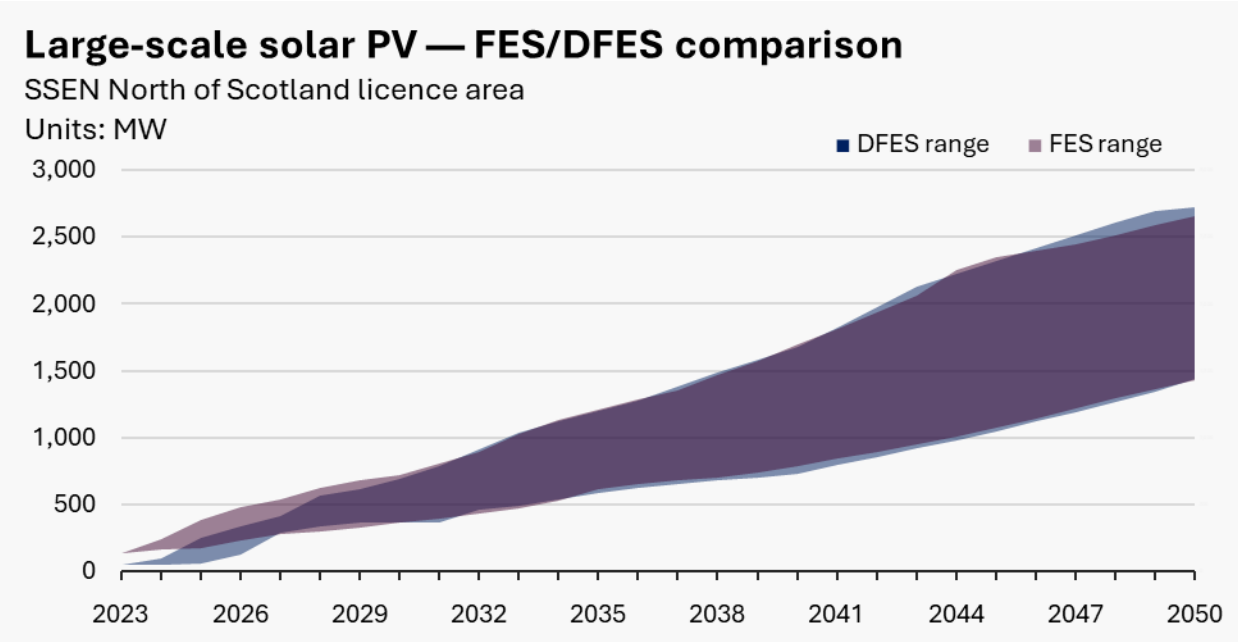
Stakeholder feedback	**Impact on DFES analysis**
During the webinar for the North of Scotland licence area, stakeholders were asked whether previous support from local authorities was a good indicator for the future support of large-scale solar projects.	The response from stakeholders was that they did not think previous support from local authorities was a good indicator of future support for large-scale solar projects. Previous DFES modelling used historic planning status as an indicator for future connections for all scenarios. However, for DFES 2024, this factor was removed for all the net zero scenarios to align with the stakeholder feedback received, except under the **Hydrogen Evolution** and **Counterfactual** scenario.
Solar developers were contacted by email and phone to supplement desktop-based research on progress with planning applications and the expected commissioning years of individual projects in SSEN's connection pipeline.	Feedback from developers was incorporated into the pipeline analysis. Direct feedback was prioritised over information published online when assigning pipeline commissioning years in each scenario and the commercial confidentiality of projects was preserved in the DFES analysis.

3.11.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The FES 2024 baseline is around 91 MW higher than the DFES 2024 baseline for the North of Scotland licence area. This could be due to erroneous assignment of solar farms to GSPs on the edge of the licence area in the FES data.
- Over the scenario timeframe beyond the baseline, the FES and DFES projections are closely aligned.



Comparison to DFES 2023

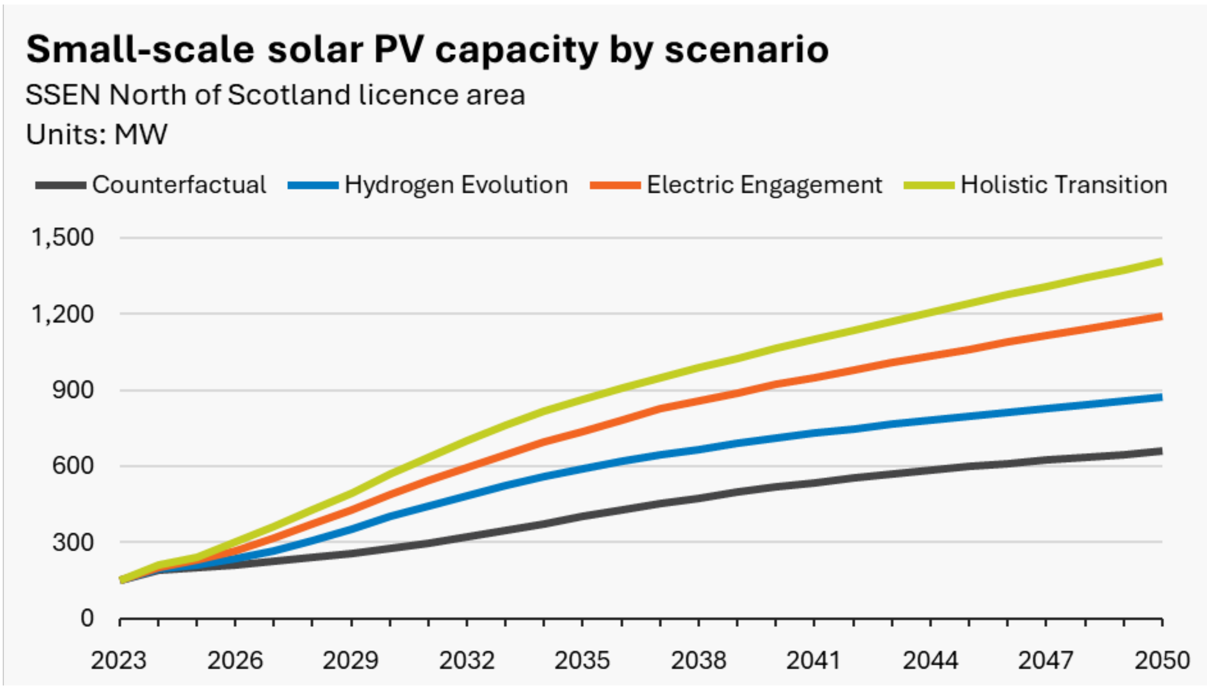
- There are no major differences between DFES 2023 and DFES 2024 outcomes.

3.12. Solar PV (small-scale)

Technical specification	Building Blocks
Solar generation sites with <1 MW of installed capacity, including domestic rooftop PV (<10 kW) and commercial rooftop PV (10 kW – 1 MW)	Gen_BB012 Gen_BB013

3.12.1. Summary

- High energy prices over the past few years have resulted in an increase in small-scale solar PV deployment across the UK, reaching its highest level of annual deployment in over a decade. In the North of Scotland licence area, installed small-scale solar capacity currently totals c. 150 MW, with 35 MW of this installed on domestic rooftops.
- This trend is projected to continue as solar panel and installation costs continue to fall and domestic solar generation remains attractive for households and businesses, especially when paired with a domestic battery or EV.
- High levels of electrification of transportation and heating drive the uptake of small-scale solar in homes and businesses under the net zero scenarios.
- By 2050, c. 1.4 GW of small-scale solar PV capacity is connected to the distribution network in the North of Scotland licence area under **Holistic Transition**, 1.2 GW under **Electric Engagement** and 0.9 GW under **Hydrogen Evolution**.
- The **Counterfactual** reflects lower levels of electrification but still shows significant growth in small-scale solar PV, with 0.7 GW of capacity deployed by 2050 under this scenario.



3.12.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Domestic (<10 kW)	112	32,831	The majority of small-scale solar was deployed in the FiT era in the 2010s, with the annual installation rate for rooftop solar in the licence area peaking at 18 MW installed in 2012.
Commercial (10 kW – 1 MW)	35	1,128	The North of Scotland licence area is currently seeing high levels of ongoing deployment of small-scale solar, with 20 MW of new capacity connecting in the last year alone. This deployment is driven by several factors, including continued high electricity and gas prices and a recent decrease in solar installation costs.

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
All	32	Number of sites: 151 Due to rooftop solar PV being small-scale and quick to install in most cases, all pipeline sites have been modelled to connect in 2024 in all scenarios. Almost all pipeline capacity comprises commercial-scale rooftop solar PV.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	571	1,408	Very high levels of consumer engagement with smart electricity usage, dynamic electricity tariffs and high levels of green ambition in homes and businesses, helps to boost small-scale solar deployment under the Holistic Transition and Electric Engagement scenarios. This is augmented by solar deployment on new-build homes, which is modelled to occur on 80% of new homes and a high proportion of new non-domestic buildings. This is based on recent updates to Scottish building standards which, while not necessitating solar PV on new-build homes, do require low carbon measures.[13] Small-scale solar PV capacity reaches 1.4 GW in the licence area by 2050 under the Holistic Transition scenario.
Electric Engagement	491	1,189	
Hydrogen Evolution	403	872	With the need to decarbonise electricity demand quickly to meet carbon reduction targets, solar PV deployment is also high under the Hydrogen Evolution scenario. However, due to customers being less engaged with smart energy and dynamic tariffs, and an overall lower level of electrification of heat and transport, the uptake of rooftop PV is not as high as in the other net zero scenarios. This is, however, augmented by solar deployment on new-build homes, which is modelled to occur on 80% of new homes and a high proportion of new non-domestic buildings, reflecting Scottish building standards. Small-scale solar PV capacity reaches 0.9 GW in the licence area by 2050 under the Hydrogen Evolution scenario.
Counter-factual	275	659	Reflecting an overall lower uptake of low-carbon technologies, smart tariffs and lesser engaged consumers, the **Counterfactual** scenario results in lower uptake of small-scale solar. This is augmented by solar deployment on new-build homes, which is modelled to occur on around

			50% of homes and a moderate proportion of new non-domestic buildings by the 2030s. Small-scale solar PV capacity reaches 0.7 GW in the licence area by 2050 under the **Counterfactual**.

Spatial factors

Factor	Description
Building type	The building type of domestic homes, such as detached, terraced and flats, is the primary distribution factor for domestic rooftop solar PV, used as a proxy for available roof space.
Tenure	The tenure of domestic homes, such as owner-occupied, social-rented or private-rented, is a secondary distribution factor for domestic rooftop solar PV, with more uptake on owner-occupied and social-rented homes.
Affluence	Affluence plays a minor role in the distribution of domestic solar PV in the near term, as stakeholder feedback and analysis of baseline trends show that the cost of solar PV is still a major contributing factor to uptake. Affluence is modelled using the ONS census Socio-economic Classification (NS-SEC) variable.
Non-domestic buildings with potential for rooftop solar PV	Based on engagement with stakeholders, we have identified existing non-domestic buildings with potential for rooftop solar to be included in the modelling. This includes schools, universities, warehouses, hospitals, shopping centres and offices.

Stakeholder input

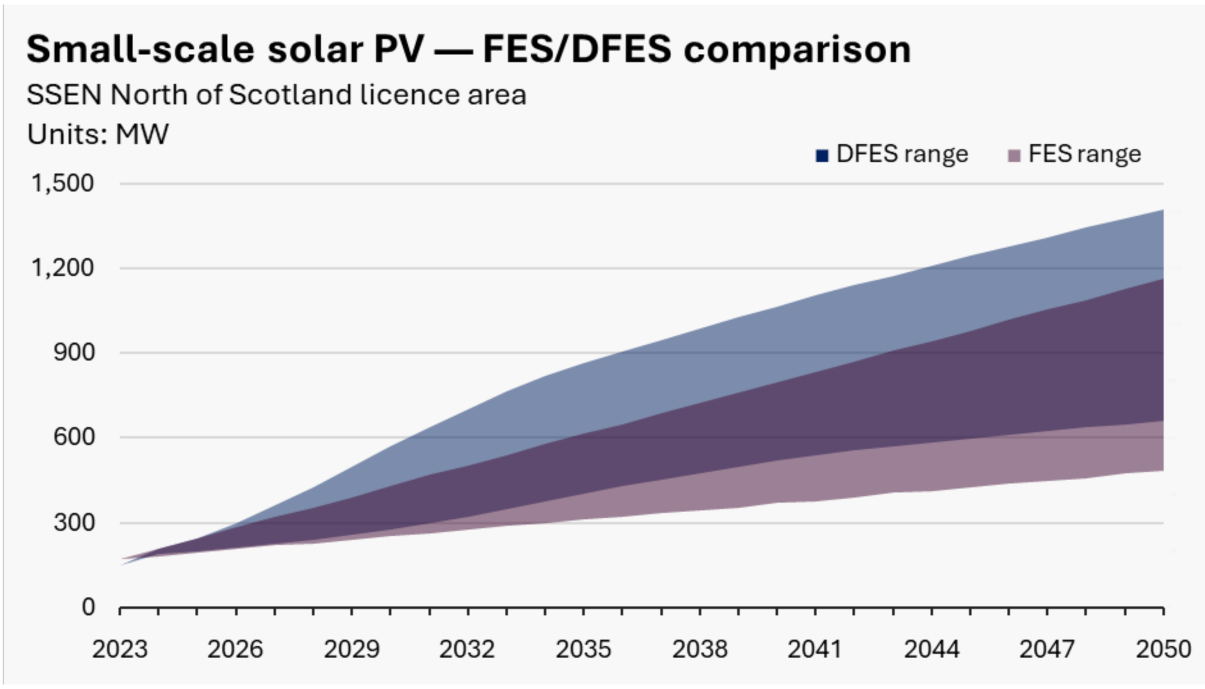
Stakeholder feedback	Impact on DFES analysis
LAEP targets	Where local authorities have targets for small-scale solar PV or overall capacity solar PV, these have been reflected in the modelling, where possible.

3.12.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The DFES 2024 outcomes have a comparable trend to FES 2024. However, the longer-term projections in the DFES 2024 analysis are slightly higher than the FES 2024 projections. This is likely due to the DFES 2024 analysis including a high proportion of new build homes being built with rooftop solar PV, in line with recent updates to Scottish building standards which, while not necessitating solar PV on new-build homes, do require low carbon measures.[14] It is not clear if the FES accounts for Scottish new build home policies to a similar degree.
- The installation capacity of small-scale solar PV reaches a peak in the mid-2030s. After this year, although installation capacity increases, it does so at a lower rate. This is due to the slowing of projected new build housing and non-domestic properties – see the New Developments summary sheet for further details. The FES has a consistent growth rate for new rooftop solar installations out to 2050.



Comparison to DFES 2023

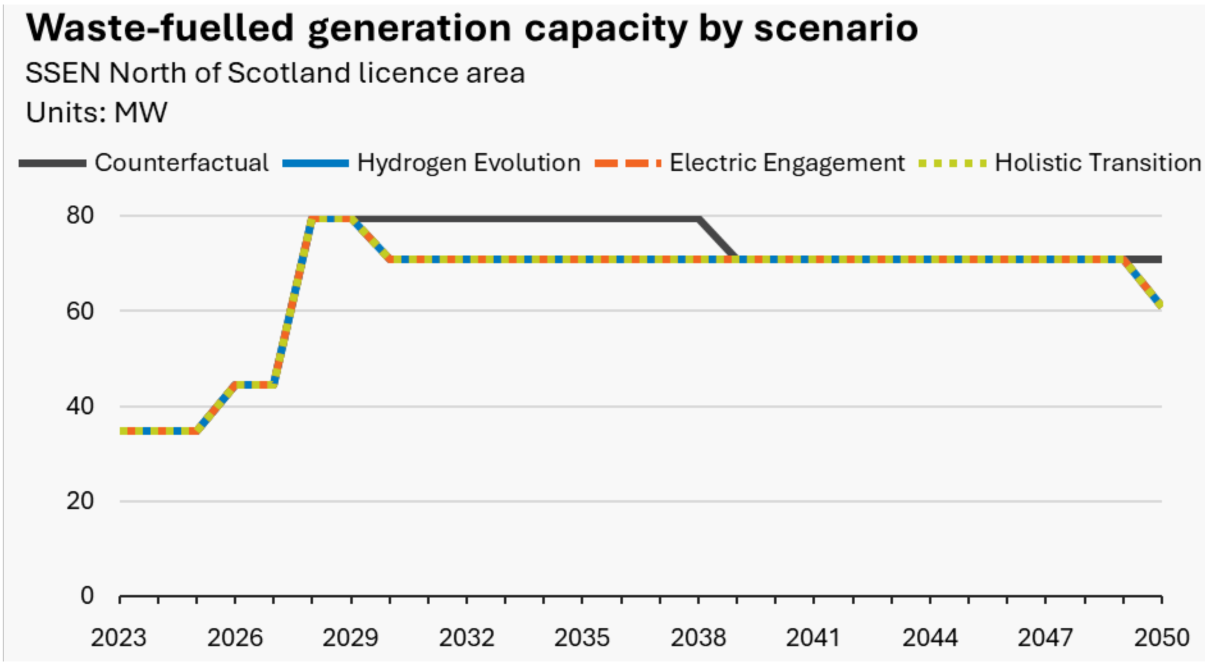
- Similar to the FES comparison, the DFES 2024 outcomes have a comparable trend to the DFES 2023 outcomes. However, the DFES 2024 projected capacities are higher than the DFES 2023 projections. In addition to the increase in domestic solar PV modelled on new build houses, this is also due to recent analysis of uptake of small-scale solar PV across the UK over the past four years, which suggests that current uptake is more evenly spread across the country, rather than predominantly in the south of the UK, resulting in higher projections in regions such as the north of Scotland.

3.13. Waste-fuelled generation

Technical specification	Building Blocks
Capacity of distribution connected Energy from Waste (EfW) sites, including incineration and Advanced Conversion Technologies (ACT).	Gen_BB011

3.13.1. Summary

- Energy from waste, conventionally in the form of waste incineration, has historically been used alongside the landfill of waste that cannot been reused or recycled. There is a 35 MW baseline of energy from waste projects currently operating in the licence area.
- In the near term, energy from waste capacity increases in all scenarios as several projects with existing planning permission are commissioned. Pipeline sites with less development evidence are only modelled to connect under the **Counterfactual**.
- Waste incineration is highly carbon intensive and, therefore, sites are modelled to decommission under the three net zero scenarios out to 2050 as cleaner approaches to waste management become commonplace. More efficient energy from waste plants, such as advanced conversion technology (ACT) gasification plants, operate beyond 2050 under all four scenarios. However, the majority of the North of Scotland licence area capacity is either recently commissioned or sites in the pipeline that are modelled to connect in the near term. As a result, a higher proportion of energy from waste capacity remains online in 2050 under all four scenarios compared to the rest of the UK.
- In contrast, only one older waste incineration plant is modelled to decommission under the **Counterfactual**, with 70 MW of energy from waste capacity still operating in 2050.



3.13.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Above 1 MW	35	3	The waste-fuelled generation baseline consists of three connections. Two of these connections, at 8.7 and 10 MW respectively, are located at the same site on the outskirts of Dundee. The final site, with a capacity of 16 MW, is located in Aberdeen.
Below 1 MW	0	0	

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
Total	45	Number of sites: 2

Under construction	10	A single site is detailed as under construction by the developer and set to be operational in early 2026. As a result, this site is modelled to connect in 2026 under all four scenarios.
Planning permission granted	35	A single site in Aberdeenshire has been granted planning permission. Based on an analysis of the typical time between attaining planning permission and commissioning for this type and scale of site, this site is modelled to connect in 2028 under all scenarios.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	71	61	Under the net zero scenarios, conventional waste incineration sites are projected to decommission after 30 years of operational life, reflecting a reduced volume of waste in these scenarios and the drive to reduce carbon emissions. More efficient sites, using ACT gasification or sites classified as 'Energy Recovery Facilities' (incineration sites that meet higher energy efficiency criteria), are not projected to come offline under any scenario out to 2050. This assumes that any remaining waste in the 2030s and 2040s is processed at less carbon-intensive, highly efficient ACT sites under these scenarios.
Electric Engagement	71	61	
Hydrogen Evolution	71	61	
Counter-factual	80	71	Lower levels of societal change and limited progress towards carbon emission reduction means that waste incineration sites continue to operate up to 40 years after their commissioning date.

Spatial factors

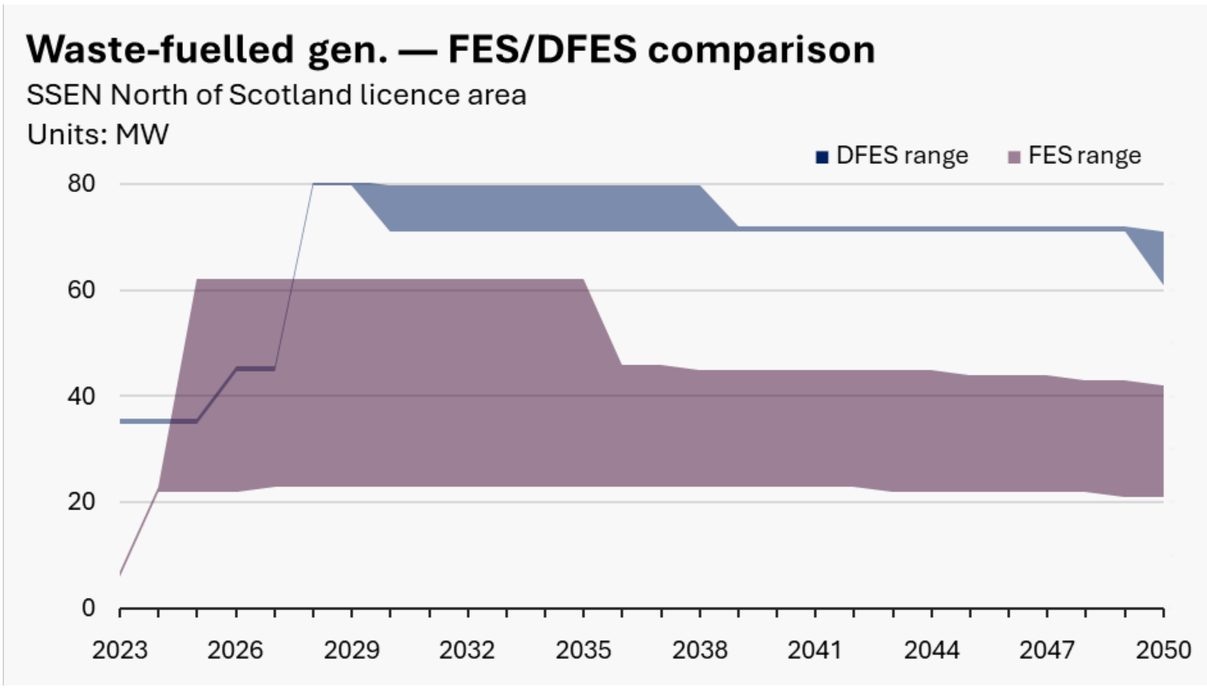
Factor	Description
Location of existing baseline and pipeline sites	All energy from waste spatial modelling is based on existing baseline and pipeline sites.

3.13.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The FES and DFES baselines in the licence area are not well aligned, with the FES baseline being much lower than the DFES. The reason for this is unclear but could be related to differences in technology classifications.
- The pipeline of prospective sites connecting in the 2020s in the DFES modelling is reflected in the FES modelling, albeit the DFES modelling is more conservative in terms of connection timescales.
- In the medium- and long-term, the FES and DFES projections follow a similar trend, with waste-fuelled generation capacity remaining relatively steady under all four scenarios.



Comparison to DFES 2023

- The outcomes and modelling methods for waste-fuelled generation are similar between DFES 2023 and DFES 2024.

Section 4: Electricity storage technologies

Results and assumptions

This section includes the results and assumptions for the following technologies:

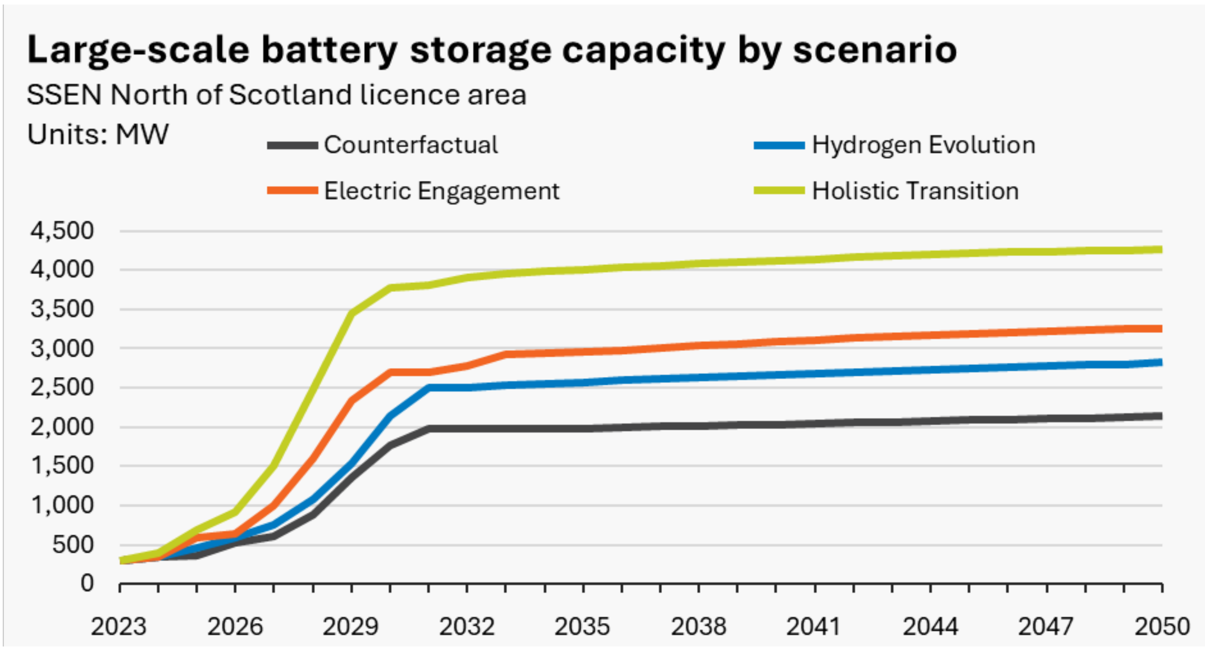
- Battery storage (large-scale)
- Battery storage (small-scale)
- Liquid Air Energy Storage

4.1. Battery storage (large-scale)

Technical specification	Building Blocks
Large-scale battery storage	Srg_BB001

4.1.1. Summary

- Grid-scale battery storage has become one of the most active development sectors in the UK, with numerous developers and four listed capital investment funds seeking to develop battery storage projects at various scales across the country.
- In the context of the wider UK energy system, low-carbon dispatchable power and flexibility are required to manage variable generation, meet peak demand, ensure security of supply, manage network constraints and maximise the economic value of abundant renewable energy when it is available. As the UK looks to achieve Clean Power by 2030 and a net zero power system by 2035, the rapid deployment of new large-scale (almost entirely lithium-ion based) battery storage is projected under every scenario as a key component to achieving these goals.
- The North of Scotland licence area currently has 10 operational large-scale battery storage sites, totalling 291 MW. This is a significant increase on the DFES 2023 baseline of five sites totalling 183 MW of capacity.
- The pipeline of sites that have a quote issued or accepted connection offer with SSEN has now grown to 9.3 GW across 221 sites in the licence area. This is a 20% increase on the 7.8 GW pipeline reported in DFES 2023.
- However, with significant reforms to network connection policy and battery storage asset revenues becoming challenging for new entrants, it is likely that only a limited proportion of this pipeline will progress through to development, even in the longer term. This is partially evidenced by only 2.3 GW (c.25% of the full pipeline capacity) being found to have obtained planning approval to date.
- As a result, even under more ambitious scenarios, only sites with evidence of full planning submissions or permissions are modelled to build out. **Holistic Transition** is the scenario that supports the highest uptake of decentralised battery storage, reaching 3.8 GW by 2030, while the **Counterfactual** reaches less than 1.8 GW in the same timeframe.
- Deployment of large-scale battery storage is projected to slow in the 2030s and 2040s, as the market becomes saturated and alternative sources of flexibility see increased uptake, for instance smaller-scale battery storage, thermal storage and V2G.
- The development of a new market mechanism for long-duration electricity storage (LDES) creates the potential for other storage technologies to begin to build out in the longer term, though many of these may end up connecting to the transmission network, due to their scale (e.g. new strategic pumped hydropower sites).



4.1.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Status	Capacity (MW)	Sites	Description
Operational	291	10	Most of the 291 MW of operational battery storage capacity has commissioned over the past two years. Half of the 10 connected sites (equating to 110 MW of capacity) have deployed in the past year alone. These sites are primarily standalone battery storage sites providing grid balancing services. The baseline includes three 50 MW sites, the largest individual site capacity scale seen in the licence area so far.

Pipeline

Source: SSEN connections data

A range of outcomes for this significant pipeline have been modelled under the scenarios. With significant ongoing reforms to manage the very large queue of projects seeking to connect to the network and wider regional 'technology caps' under the UK Government's Clean Power 2030 plan, the proportion of the pipeline of battery storage projects that will move through to connection, and by when, is still unclear. The evidence collected for these sites has been considered at the time of the analysis and it is recognised that some projects may drop out of the connection queue in SSEN's licence areas into 2025 as these policies are enacted.

Status	Capacity (MW)	Description
Total	9,340	Number of sites: 221 A 20% increase in capacity on the 7.8 GW recorded for DFES 2023.
Under construction	167	Six sites totalling 167 MW are currently under construction or due to commission imminently. This includes three 50 MW sites, which are modelled to connect in 2024 or 2025 under all scenarios.
Planning permission granted	2,359	56 sites totalling over 2.3 GW of capacity (a quarter of the total pipeline capacity) have secured planning permission. The growing scale of individual battery storage projects is evidenced by 17 sites in this group that are individually between 50 MW and 75 MW. Five of these sites totalling 352 MW have prequalified for, or won, a Capacity Market agreement. These sites are modelled to connect in the relevant contract delivery year under every scenario. Projects not found to be active in Capacity Market auctions, which make up the majority of the sites with planning approval, are projected to connect between five and seven years from the date they obtained planning permission. Any sites subject to Statement of Works schemes have been considered to connect in the relevant completion years of these works under the **Counterfactual** scenario. This proportion of the battery storage pipeline capacity that is progressing to being 'construction ready' has grown significantly from the 1.6 GW recorded in DFES 2023. This is evidence that battery storage developers are looking to progress through the planning system and retain their accepted connection offers with SSEN.
Planning application submitted	1,155	27 sites totalling 1.2 GW have submitted applications for full planning permission.

		The total capacity of battery projects with planning applications submitted have nearly doubled over the past year since DFES 2023. This is an indication that a backlog of planning applications for battery sites is beginning to build up. Without additional planning resource or further reforms, Local Authority planning assessment processes could become a bottleneck in the buildout of new battery sites. Due to the significant scale of the battery storage pipeline, and information around NESO's Clean Power 2030 advice to the UK Government, sites with granted planning permission are likely to represent enough capacity to meet 2030 and 2035 targets for large-scale battery storage capacity in SSEN's licence areas. This, alongside proposed reforms to connection processes, may mean that the pipeline of battery projects may evolve significantly in the coming year. As a result, sites with submitted planning applications have only been modelled to progress under the **Holistic Transition** scenario. The exception being a single site which pre-qualified in a Capacity Market auction, which builds out in the delivery year under **Electric Engagement**.
Pre-planning	2,611	52 sites totalling over 2.6 GW have submitted documents to local authorities ahead of full planning applications. The average scale of a project in this pre-planning category is 50 MW. A notable project in this group is the 100 MW Shetland Backup BESS which will operate in the event of a failure of the Shetland transmission link. The capacity of projects in pre-planning has grown by 1 GW over the past year, which is an indication that even more battery projects are seeking to enter the planning system. Sites with pre-planning applications have not been modelled to progress under any scenario.
No information	2,904	77 sites totalling 2.9 GW could not be found in local authority planning databases. This is 31% of the total pipeline capacity. Around half of this proportion of the pipeline accepted a connection offer with SSEN in 2024 and half in 2023. Only four

		sites without any planning evidence have held connection offers with SSEN for more than two years. These sites have not been modelled to progress under any scenario.
Refused planning, withdrawn or abandoned	142	Three sites between 40 and 50 MW have had planning applications refused or planning permission expire. These sites do not progress under any scenario.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	3,775	4,259	In the four main DFES scenarios, individual pipeline project evidence drives the vast majority of large-scale battery storage capacity deployment in the licence area. Additional deployment beyond the pipeline, starting in the early 2030s under the three net zero scenarios and the mid-2030s under the **Counterfactual**, is modelled mostly as battery storage co-located with the deployment of large-scale solar PV and onshore wind generation in the licence area across the 2030s and 2040s. Overall, post-pipeline development of large-scale battery storage is limited, owing to the high levels of deployment seen in the 2020s and early 2030s, as the UK aims to achieve Clean Power by 2030 and a net zero power system by 2035. However, the deployment of battery storage continues in the licence area, through the uptake of small-scale battery installations in homes and businesses, as detailed in the small-scale battery storage section of this report.
Electric Engagement	2,692	3,255	
Hydrogen Evolution	2,149	2,820	
Counter-factual	1,766	2,136	

Spatial factors

Factor	Description
Location of existing baseline and pipeline sites	The vast majority of projected large-scale storage capacity is based on existing baseline and pipeline sites within SSEN connections data.
Distribution of large-scale solar PV and onshore wind	Beyond the pipeline, the location of additional battery storage capacity in the late 2030s and 2040s is aligned to the distribution of large-scale solar PV and onshore wind capacity within SSEN DFES 2024.

Stakeholder input

Stakeholder feedback	Impact on DFES analysis
Electricity Storage Network (ESN) engagement	Regen, through its management of the UK Electricity Storage Network (ESN) has an ongoing dialogue with grid-scale storge project developers. The past year has seen a challenging environment for battery storage revenues, with some developers selling off portfolios and diversifying.
Connections reform engagement	Regen is also engaging with Ofgem, DESNZ and NESO on the ongoing connections reform process; this has given insight into the potential treatment of existing pipeline sites. This is reflected in the DFES 2024 with moderated near-term deployment rates, and more conservative assumptions around site buildout, when compared with DFES 2023.
Fossil fuel back-up supply engagement	Direct engagement with SSEN over the future of the licence area's multiple fossil fuel back up supplies has resulted in the modelling of 11 battery storage sites across the licence area, (including on the Western Isles, Shetland and Orkney). These are modelled to deploy in 2033 under **Electric Engagement,** where it is assumed they can replace some of the functionality of these diesel backups.
Local stakeholder regional webinar	At the North of Scotland stakeholder webinar, held in October 2024, attendees were asked if the storage co-location business model would become more attractive in future. The majority of respondents believed that it would

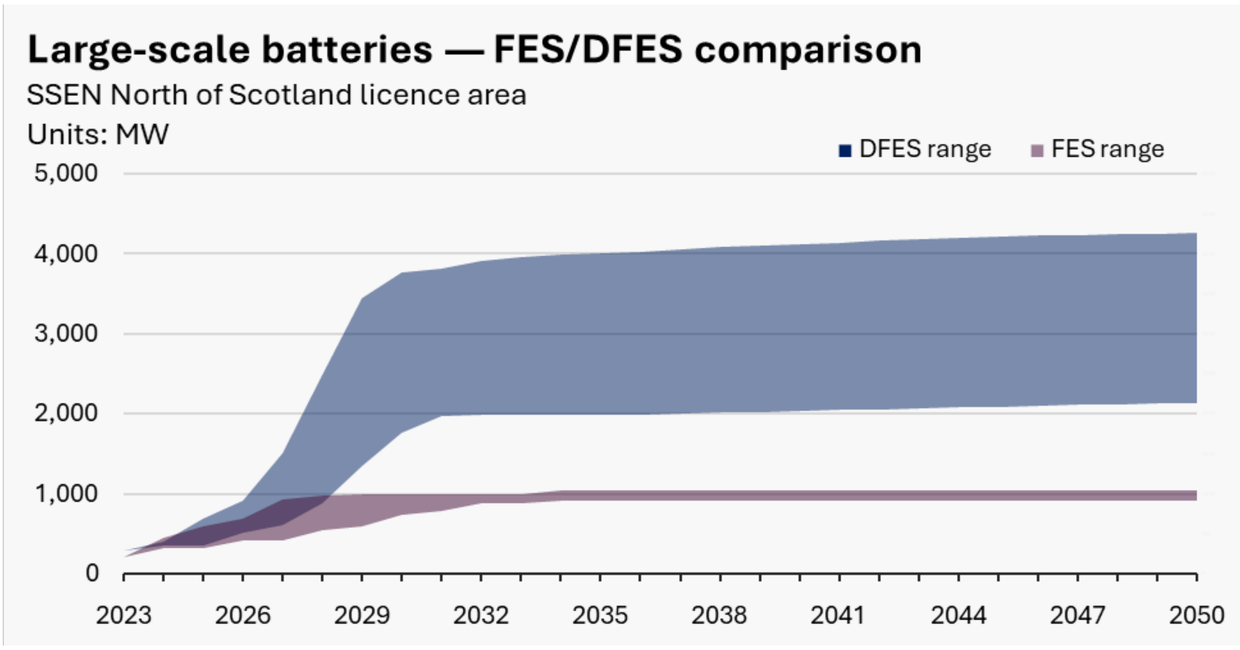
be. The DFES models most of the post-2030 battery storage capacity deployment coming from co-located sites.

4.1.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- DFES 2024 reports a baseline of 292 MW which is higher than the 205 MW for FES 2024. The DFES baseline is based on an extract of SSEN's connections database.
- The DFES 2024 projections diverge from FES 2024 projections in all scenarios; more ambitious scenarios diverge earlier with higher annual deployment rates. These rates are driven predominantly by the larger pipeline of sites with accepted connection offers with SSEN and sites found to have secured planning permission and Capacity Market agreements/pre-qualifications.
- Variance between FES 2024 and DFES 2024 becomes significant in the medium-term in the most ambitious scenarios, reaching a 3 GW difference by the early 2030s.
- Post-2030 deployment across the scenarios is similar in DFES 2024 and FES 2024 and this means differences in overall projected capacity are maintained out to 2050.
- Whilst it is understood that Clean Power by 2030 may result in a more restricted deployment of battery storage in the licence area, the details of this plan from the UK Government and the supporting policies around grid connection reform (including grandfathering) are still to be fully bottomed out.



Comparison to DFES 2023

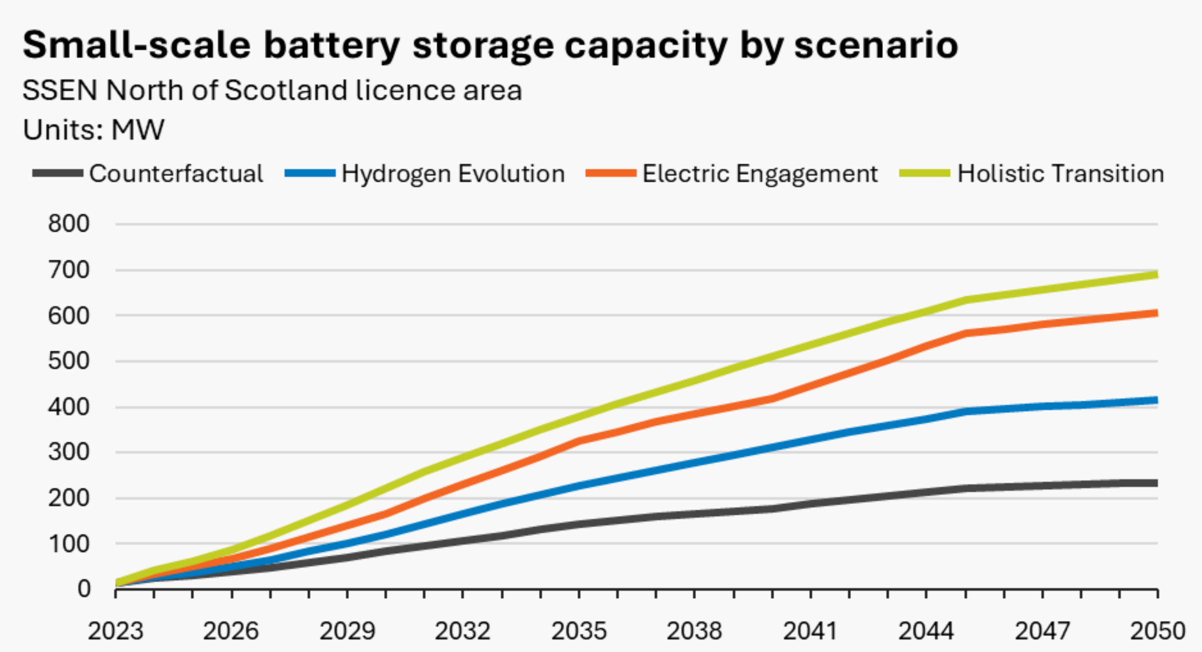
- The assessment and assumptions around the future deployment of the pipeline have been more conservative in DFES 2024, in line with recent stakeholder feedback. This limits the uptake of new battery storage in all four scenarios to only sites with granted planning permission or positive Capacity Market activity.
- As a result, DFES 2024 projections are broadly aligned with DFES 2023 projections, despite the increased scale of the project pipeline.
- Under the more ambitious scenarios, **Holistic Transition** and **Electric Engagement**, DFES 2024 projects less near-term deployment of large-scale battery storage capacity than DFES 2023. This is due to updated pipeline assumptions, reflecting the current barriers to the near-term deployment of such a large number of sites.

4.2. Battery storage (small-scale)

Technical specification	Building Blocks
Small-scale battery storage (<1 MW), comprising Domestic Batteries (G98) and High Energy Users.	Srg_BB001 Srg_BB002

4.2.1. Summary

- Small-scale battery storage, in the form of domestic batteries and batteries installed at commercial and industrial properties with high energy demand, has a relatively small baseline in the North of Scotland licence area but a potential to grow under every scenario.
- Domestic battery uptake is closely tied to the uptake of domestic rooftop solar PV. In the past two years, over half of domestic PV installations have been installed alongside a domestic battery. This trend is modelled to continue in the near term under all four scenarios. In the longer term, adoption of domestic batteries reduces, as other forms of demand flexibility are favoured.
- Installations of behind-the-meter batteries at 'high energy user' sites, such as factories, hospitals, water company sites and universities, are projected to increase under all four scenarios. This is a reflection of businesses seeking to maximise the consumption of renewable energy generated onsite, as well as using batteries for onsite energy management and participating in commercial balancing services.
- There is some uncertainty around how prevalent domestic and non-domestic batteries will be in the future, compared to alternative sources of flexibility such as smart charging, V2X and thermal storage. As a result, there are a range of outcomes modelled for small-scale battery storage in the licence area, from 0.2 GW under the **Counterfactual** to 0.7 GW under **Holistic Transition**.



4.2.2. Modelling and outcomes

Baseline

Source: SSEN connections data

Scale	Capacity (MW)	Sites	Description
Domestic (<10 kW)	2	470	The lack of available data for domestic battery storage installations means that the true baseline capacity in the North of Scotland licence area is not well understood. This is due to the majority of home batteries being installed alongside solar PV installations and only one of the technology types typically being recorded. There is currently no complete national database for domestic battery installations. Engagement with domestic solar and battery installers suggests that over half of domestic solar PV installed in 2023 and 2024 were installed alongside a home battery. This aligns with a market outlook report by SolarPower Europe, which suggests a UK-wide

			residential battery storage capacity of approx. 1.1 GWh.[15] The domestic battery baseline has, therefore, been modelled based on a disaggregation of this market outlook to licence areas based on domestic solar PV uptake, since the two technologies are very often installed in tandem.
High energy user (10 kW – 1 MW)	0.31	9	There are 9 'high energy user' battery storage sites in the baseline, these were identified through analysis of battery storage sites in the SSEN connections data that were smaller scale and located at commercial business sites.

Pipeline

Source: SSEN connections data

Status	Capacity (MW)	Description
Total	0.2	Number of sites: 2 These two pipeline sites are modelled to connect in 2024 under all scenarios due to their small scale.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Holistic Transition	225	695	Under these scenarios, the proportion of domestic solar installations being commissioned with an accompanying domestic battery starts at 55% in the near term, reflecting current market reports, and decreases to 20-25% by 2050.[16] This reflects the uptake of EVs (potentially with V2X capability) and thermal storage reducing the case for standalone domestic storage. Overall uptake still remains high due to the number of highly engaged consumers.
Electric Engagement	166	606	

			Deployment at high energy user sites increases over the scenario timeframe as more businesses seek to manage their onsite energy use and costs through flexibility technologies, as well as leveraging the potential to participate in commercial flexibility markets and balancing services. Small-scale battery storage capacity reaches 0.7 GW under **Holistic Transition**.
Hydrogen Evolution	121	415	Under this scenario, the proportion of domestic solar installations being commissioned with an accompanying domestic battery starts at 55% in the near term, reflecting current market reports, and decreases to 12% by 2050. This reflects the uptake of EVs (potentially with V2X capability) and thermal storage reducing the case for standalone domestic storage, as well as consumers not being strongly engaged in demand side flexibility. Deployment at high energy user sites increases moderately over the scenario timeframe, as a limited number of businesses seek to manage their onsite energy use and costs through flexibility technologies and participation in commercial flexibility markets is also limited. Small-scale battery storage capacity reaches 0.4 GW under **Hydrogen Evolution**.
Counter-factual	83	235	Under this scenario, the proportion of domestic solar installations being commissioned with an accompanying domestic battery starts at 55% in the near term, reflecting current market reports, and decreases to 10% by 2050. This reflects the uptake of EVs (potentially with V2X capability) and thermal storage reducing the case for standalone domestic storage, as well as very limited engagement in demand side flexibility by consumers. Deployment at high energy user sites increases slowly over the scenario timeframe, as only a small number of businesses seek to manage onsite energy use and costs through flexibility technologies and participation in commercial flexibility markets is low. Small-scale battery storage capacity reaches 0.2 GW under the **Counterfactual**.

Spatial factors

Factor	Description
Domestic rooftop solar PV uptake	The uptake and location of domestic battery storage installations is directly tied to the uptake of domestic solar PV.
Number and location of 'high energy user' commercial and industrial sites	High energy user battery storage uptake and distribution is based on the number and location of existing energy-intensive non-domestic properties, such as industrial estates, hospitals, universities and factories.

Stakeholder input

Stakeholder feedback	Impact on DFES analysis
SolarPower Europe market outlook report	The baseline and near-term uptake of domestic battery storage as a proportion of domestic solar PV installations, has been based predominantly on SolarPower Europe market outlook report data, augmented and verified by engagement with domestic battery installers.
Direct developer engagement	Several domestic battery installers were engaged to confirm that the modelled baseline numbers were in-line with their installation experience over the past two years. In addition, modelling assumptions around the typical size and capacity of domestic battery installations, and the proportion of domestic solar PV installations currently coming with a domestic battery, were checked and updated based on this direct engagement.

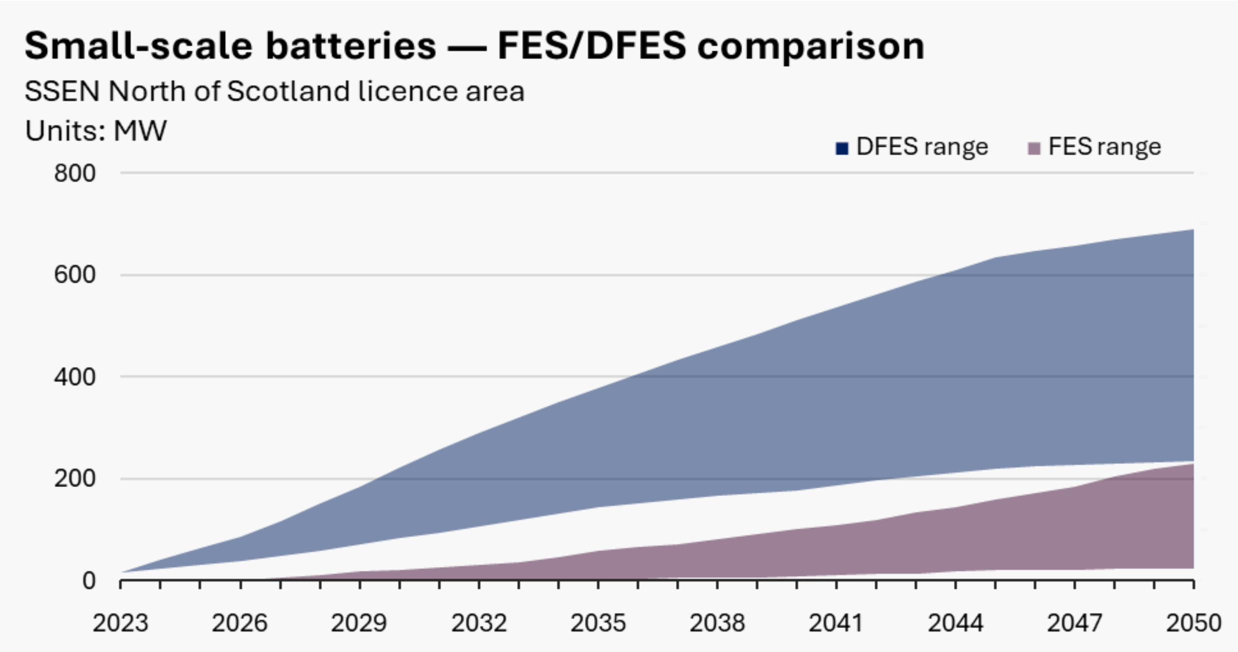
4.2.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The DFES 2024 domestic battery baseline and projections out to 2050 are significantly higher than the FES 2024 outcomes. This is likely driven by differences in the modelling approach regarding domestic batteries:

- The DFES small-scale battery storage baseline is significantly above the FES. This is due to market data and stakeholder engagement with domestic solar and battery installers indicating that higher levels of domestic battery installations have been seen over the past two years.
- In the near-term, engagement suggests that the uptake of domestic battery storage systems is set to continue, in-line with the uptake seen through joint domestic solar and battery installations seen over the past few years.
- The DFES projections are then modelled to level out in the longer term as other domestic flexibility options, such as smart charging, V2X and thermal storage become more prevalent. This is opposite to the FES trend, where domestic battery uptake continues to accelerate over the scenario timeframe out to 2050.



Comparison to DFES 2023

- The small-scale battery projections have changed significantly compared to DFES 2023 for domestic batteries, in both the baseline and the magnitude of projections over the scenario timeframe. This is based on recent market report data and direct engagement with domestic battery installers, which suggests that the current domestic battery baseline and near-term growth is under recorded and likely to be much higher than only those domestic battery installations registered with (or notified to) the DNOs or the Microgeneration Certification Scheme (MCS).
- Previous DFES small-scale battery projections were closely tied to the FES projections. As such, the changes detailed in the reconciliation to FES above also apply to this comparison, with greater levels of growth in the near-term in line with current uptake trends rather than uptake accelerating in the longer term.
- High energy user batteries at commercial sites have been modelled similarly to DFES 2023 and have similar 2050 outcomes.

4.3. Liquid Air Energy Storage

Technical specification	Building Blocks
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.

4.3.1. Summary

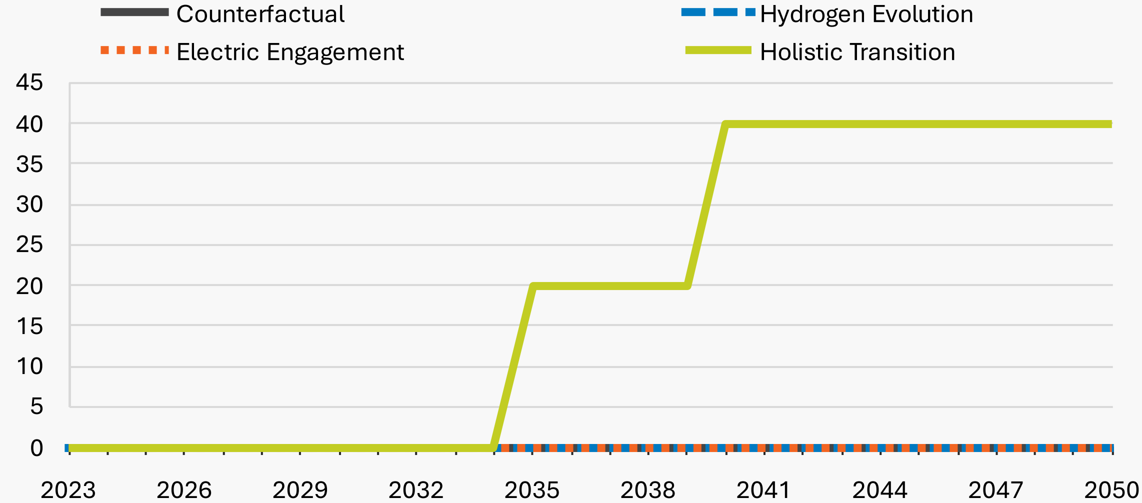
- LAES uses electricity to power compression and refrigeration equipment to cool air until it liquefies. This liquid air is then stored in cryogenic energy storage tanks for the duration required. When electricity is needed, the liquid air is exposed to ambient temperature air (or waste heat from industrial processes) to convert it back to a gaseous state. This resultant expanded gas is used to turn a turbine to generate electricity.
- Battery storage technologies dominate the UK storage pipeline (see the battery storage chapter of this report), but LAES is considered one of the technologies that could provide longer-duration storage and other support services to the electricity system.
- Highview Power is one of the leading UK developers of this technology, due to deliver the first commercial scale LAES plants with funding through the National Wealth Fund (formally UK Infrastructure Bank) and the private sector. These projects are as follows:
    - The upscaling of an existing pilot site in Carrington, Manchester, to an 800 MWh commercial scale plant, due to commission in 2026.
    - A new 2.5GWh facility in Hunterston, south of Glasgow, has been announced.
    - A new 2.5 GWh site in Aberdeenshire is in development, designed to support the onshoring of North Sea wind power and provide grid stability.[17]
    - An additional 2.5GWh facility in England is indicated as an ambition.
- These 2.5 GWh sites will be connected to the electricity transmission network and are likely aiming to make use of a proposed Cap and Floor revenue guarantee mechanism for commercially deployable LDES projects.[18] Ofgem and DESNZ are due to consult on the detailed design of this scheme in 2025 and the first contract allocations are proposed to be awarded in 2026.

- The scale of the Highview projects indicates that the future of the technology lies in direct connection to the transmission network for the provision of grid services. However, previous engagement with Highview had indicated the consideration of co-location with renewables and large-scale data centres. This is reflected in the modelling of two 20 MW sites co-located with onshore wind farms from the mid-2030s under **Holistic Transition** in the North of Scotland licence area. This is the same approach that was taken for DFES 2023.
- A wide range of long duration storage technologies is being developed with potential applications on the distribution network.
- In addition to the proposed cap and floor mechanism, there have been two rounds of innovation grant funding to support pre-commercial Longer Duration Energy Storage (LODES) technologies, with the majority of the successful projects located in Scotland.[19]
- These successful projects include redox flow batteries, thermal energy storage, gravitational energy storage, as well as power-to-X projects making use of surplus energy. Successful development of these trial projects and continued policy support could see these technologies significantly impacting the distribution network in the future. This may also mean the non-battery storage technology analysis in the DFES may adapt to allow for a more diverse range of technologies in future assessments.

Liquid air energy storage capacity by scenario

SSEN North of Scotland licence area

Units: MW



Section 5: Future sources of disruptive electricity demand

Results and methodology

This section includes the results and assumptions for the following technologies:

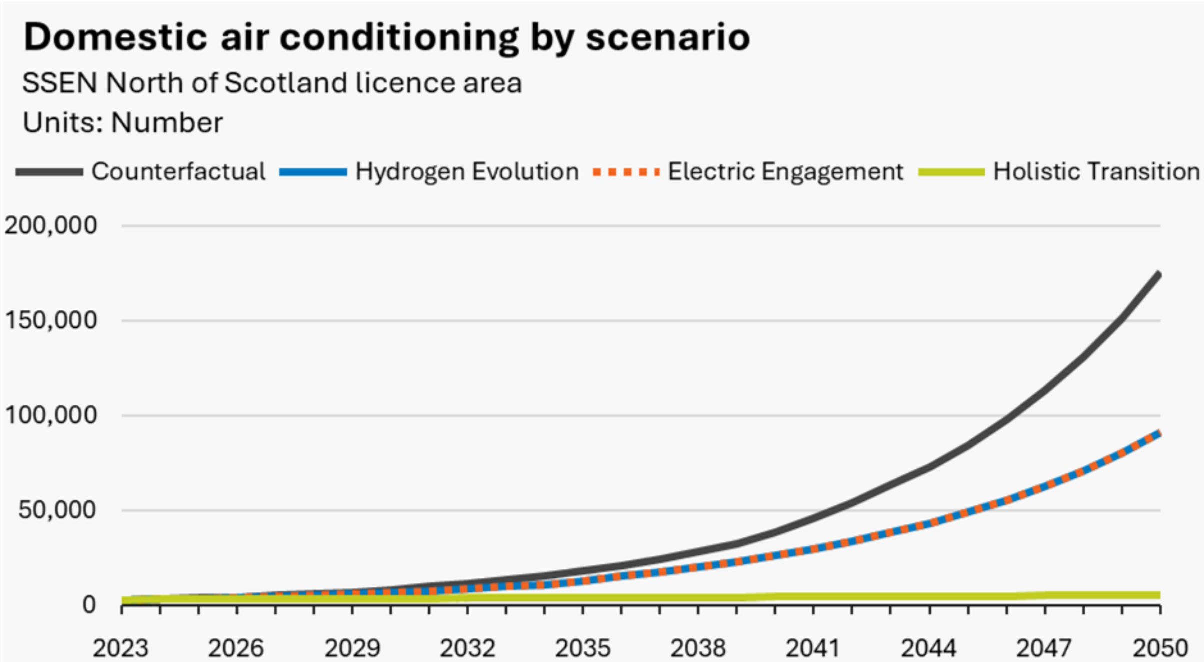
- Domestic air conditioning
- Electric vehicles and EV chargers
- Heat pumps and resistive electric heating
- Hydrogen electrolysis
- New property developments

5.1. Domestic air conditioning

Technical specification	Building Blocks
Number of domestic air conditioning units, based on a typical portable or window-mounted air conditioner. Note that a single home has potential to own multiple units.	Lct_BB014

5.1.1. Summary

- Domestic air conditioning (A/C) is not currently common in the UK - an estimated 1% of UK homes are thought to have an installed domestic A/C unit. As no public or network register of domestic A/C installations has been found, the regional baseline has been modelled as a proportion of the FES 2024 figures for current domestic A/C across GB.
- Increased summer temperatures and extended heat waves are likely to result in an increased uptake of domestic A/C in the future. The UK building stock is not optimised for passive cooling, which could see the uptake of A/C increase more significantly under scenarios with limited retrofit.
- Given the limited visibility of the baseline and high level of uncertainty around how homes in the UK will be cooled in the future, there is a broad range of scenario outcomes. The North of Scotland licence area has lower summer temperatures than the majority of the UK, resulting in lower domestic A/C uptake overall.
- By 2050, up to 175,000 domestic A/C units are installed under the **Counterfactual** scenario. Minimal domestic A/C units are installed under **Holistic Transition** by 2050, which assumes effective passive cooling measures are more prevalent across homes.



5.1.2. Modelling and outcomes

Baseline

Source: FES 2024

Scale	Units (000)	Description
All	3	There is limited baseline data on domestic A/C levels in the UK. The DFES modelling aligns with FES 2024's estimate of 370,000 domestic air conditioners in the UK in 2024.

Scenario projections

Scenario	Total units (000)		Description
	2030	2050	
Holistic Transition	4	6	Uptake is minimal, with households opting for passive cooling methods such as shading, ventilation and insulation. This results in the equivalent of just 1% of homes having A/C in 2050.
Electric Engagement	7	91	Uptake accelerates, particularly in urban areas due to heat island effects and the prevalence of smaller dwellings such as flats that may be more susceptible to overheating. However, uptake and awareness of passive cooling methods means that active cooling via A/C remains relatively uncommon. This results in the equivalent of 15% of homes having A/C in 2050 under this scenario, including some homes with multiple A/C units.
Hydrogen Evolution	7	91	
Counter-factual	8	175	Increasing frequency of heat waves and low uptake and awareness of passive cooling methods leads to high uptake of A/C to achieve comfortable internal temperatures in homes. This results in the equivalent of 29% of homes having A/C in 2050 under this scenario, including some homes with multiple A/C units.

Spatial factors

Factor	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. Although domestic A/C uptake occurs in all types of households, it is distributed towards denser urban areas in towns and cities to account for this.

5.1.3. Comparisons

Reconciliation to FES 2024

- FES 2024 does not detail A/C projections by region, so no direct comparison could be made.

Comparison to DFES 2023

- There are no major differences between DFES 2023 and DFES 2024 outcomes.

5.2. Electric vehicles and EV chargers

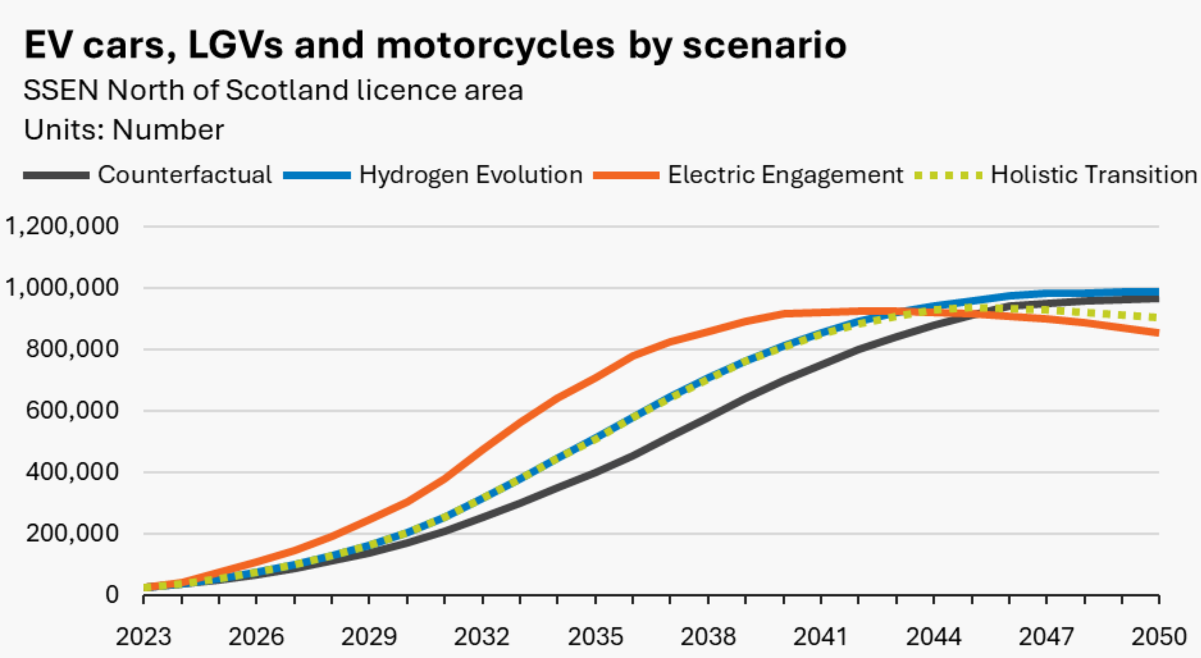
Technical specification	Building blocks
Electric vehicles (EVs) – including cars, buses and coaches, HGVSs, LGVs and motorcycles, covering both battery EVs and plug-in hybrid EVs	Lct_BB001 Lct_BB002 Lct_BB003 Lct_BB004
Electric vehicle chargers (EV chargers)	No FES building blocks are available for EV chargers.

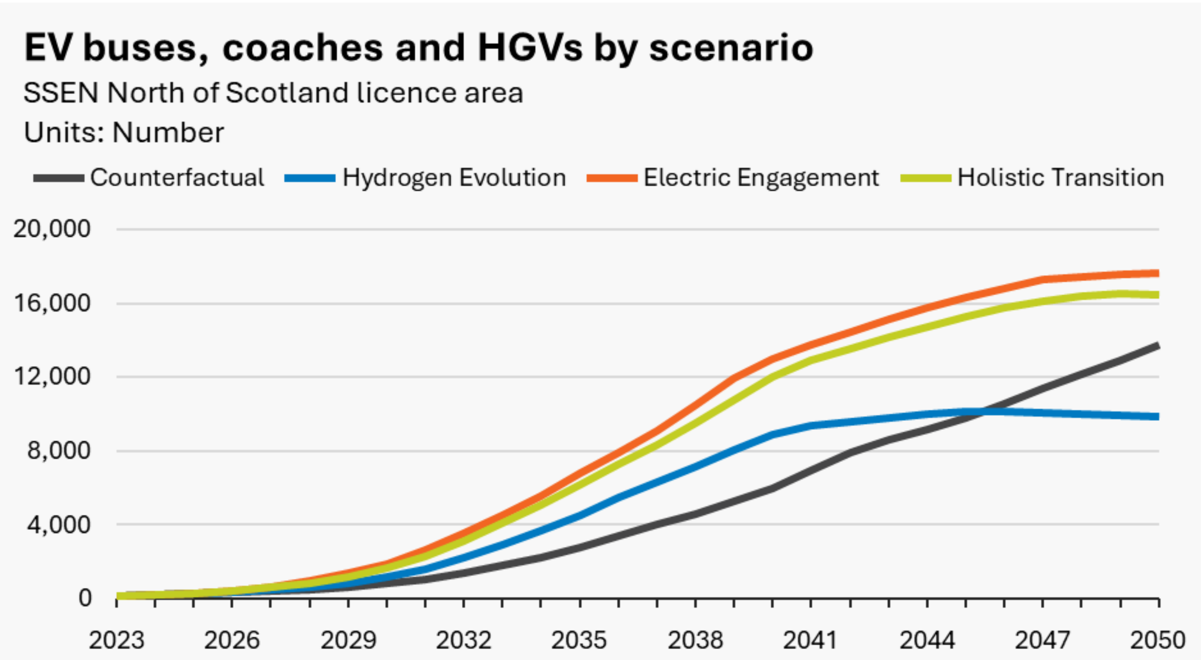
Regen transport model EV charger archetypes		
Domestic EV chargers	Off-street domestic	Homes with somewhere to park a private vehicle off-street
Non-domestic EV chargers	On-street residential	Charging at roadside car parking spaces
	Car parks	Charging at areas provided for parking only, hence excludes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

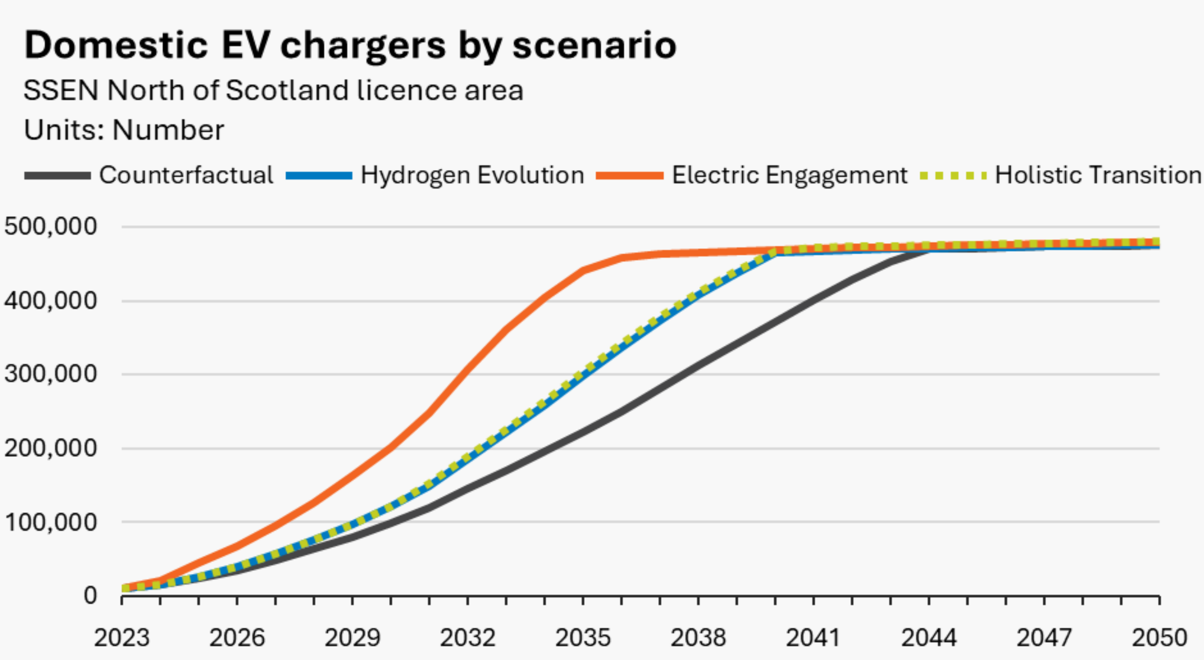
Note: The projection units for domestic and non-domestic EV chargers in the DFES 2024 analysis are different to previous DFES analysis. To illustrate the scale of EV charger uptake, domestic off-street EV chargers are displayed as numbers of chargers, while non-domestic EV chargers are displayed in total 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.

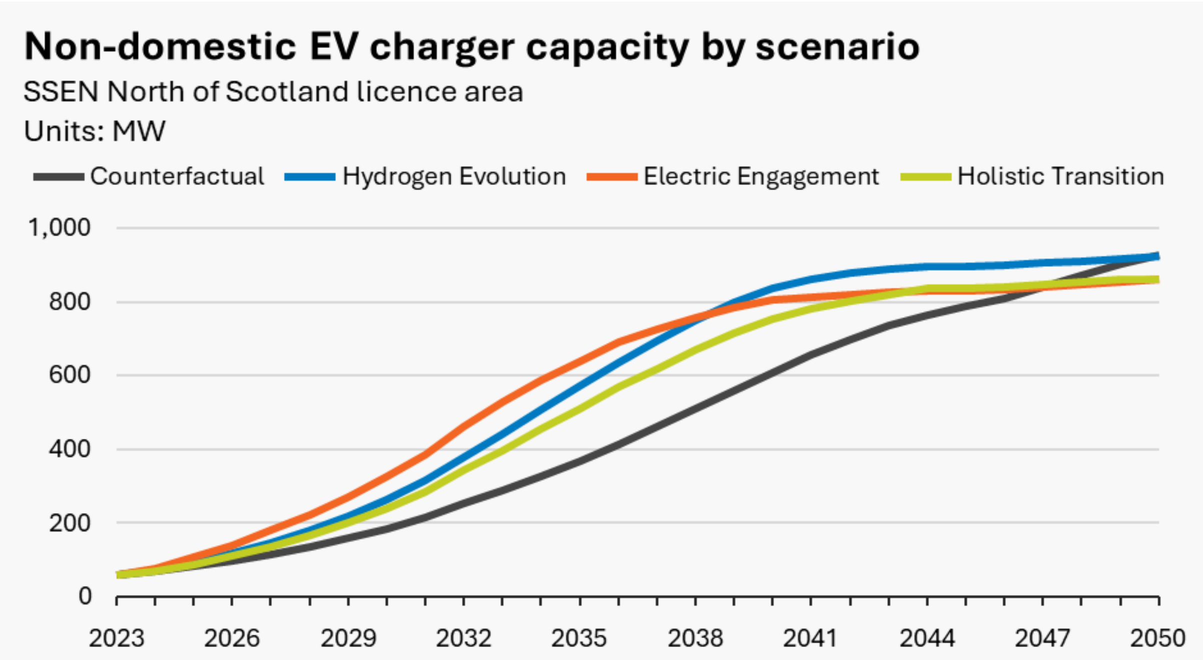
5.2.1. Summary

- Around 3% of vehicles in the North of Scotland licence area are currently battery electric or plug-in hybrid. This is anticipated to increase substantially under every scenario, as the UK looks to decarbonise the transport sector through electrification.
- In the **Hydrogen Evolution** and **Holistic Transition** scenarios, the electrification of vehicles reflects the current Zero Emission Vehicle (ZEV) mandate of no new petrol or diesel cars to be sold after 2035.[20]
- However, under **Electric Engagement**, EV uptake has been modelled to align with an accelerated ZEV mandate, with no new petrol or diesel cars sold after 2030. This has been publicly discussed by the UK Government (with the Scottish Government confirming they will follow the UK Government's lead) but has not yet been legislated.[21] Under this scenario, passenger vehicles such as cars and LGVs are rapidly electrified over the 2020s and the early 2030s. Non-passenger vehicles, such as HGVs and buses, follow suit though over a longer timeframe. By 2050, almost all road vehicles are electrified, with the vast majority of EVs being fully battery electric.
- A greater availability of low-carbon hydrogen, including in cities, under the **Hydrogen Evolution** scenario results in vehicles that are typically harder-to-electrify (such as buses and HGVs) adopting hydrogen-fuelled alternatives which results in a more limited EV uptake.
- The electrification of transport is slowest overall under the **Counterfactual** scenario, however, the vast majority of vehicles are still electrified by 2050.
- **Electric Engagement** and **Holistic Transition** both see a fall in overall vehicle ownership as car sharing, active travel and greater use of public transport reduce the overall need for private vehicles under these scenarios.
- Regen's DFES transport modelling determines the charger capacity that is required for the number of vehicles projected under each of the four DFES scenarios. This future charger requirement is split across a number of different domestic and non-domestic charger types as seen in the table above and includes domestic off-street chargers, rapid en-route chargers and chargers in public car parks etc.
- Domestic off-street chargers are modelled and presented in numbers of chargers. It is assumed that homes with multiple EVs do not purchase a second charger at the same rate as their first, leading to a levelling out of domestic EV charger capacity under all scenarios.
- The **Counterfactual** and **Electric Engagement** scenarios see the greatest variation in the medium term, with between 369 MW and 641 MW of non-domestic EV charging capacity connected in the licence area in 2035, respectively. These scenarios converge in the longer term as road transport electrification progresses, resulting in a minimal range of projected outcomes around 900 MW by 2050.


EV cars, LGVs and motorcycles by scenario
SSEN North of Scotland licence area
Units: Number
Counterfactual
Hydrogen Evolution
Electric Engagement
Holistic Transition
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050


EV buses, coaches and HGVs by scenario
SSEN North of Scotland licence area
Units: Number
Counterfactual
Hydrogen Evolution
Electric Engagement
Holistic Transition
20,000
16,000
12,000
8,000
4,000
0
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050


Domestic EV chargers by scenario
SSEN North of Scotland licence area
Units: Number
Counterfactual
Hydrogen Evolution
Electric Engagement
Holistic Transition
500,000
400,000
300,000
200,000
100,000
0
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050


Non-domestic EV charger capacity by scenario
SSEN North of Scotland licence area
Units: MW
Counterfactual
Hydrogen Evolution
Electric Engagement
Holistic Transition
1,000
800
600
400
200
0
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050

5.2.2. Modelling and outcomes

Baseline

Source: DfT data, OpenChargeMap data, SSEN connections data

<table>
<tr><th>Type</th><th>Vehicles (000s)/ Capacity (MW)</th><th>Description</th></tr>
<tr><td colspan="3">Electric Vehicles</td></tr>
<tr><td>Pure electric car</td><td>15</td><td rowspan="3">Although EV uptake in the North of Scotland licence area is behind the national average, the uptake of battery EVs is increasing rapidly, increasing from approximately 7,000 in DFES 2022, to over 10,000 in DFES 2023 and over 15,000 in DFES 2024. This is due to several factors, including:
• Favourable tax benefits for ultra-low emissions vehicles
• Increasing consumer confidence and awareness of EVs
• Electrification of commercial vehicle fleets
• Financial benefits of high mileage EV, compared to petrol or diesel vehicles.</td></tr>
<tr><td>Plug-in hybrid car</td><td>9</td></tr>
<tr><td>Pure electric LGV</td><td>1</td></tr>
<tr><td>Other EVs</td><td>0.4</td><td>While most EV uptake has centred on cars, other electric vehicles such as LGVs and buses are also beginning to see uptake. EV uptake in the licence area is proportionally higher in urban areas and island settings, including Dundee, Aberdeen and the Western Isles. However, evidence suggests that urban and rural uptake rates are beginning to converge.</td></tr>
<tr><td colspan="3">EV chargers</td></tr>
<tr><td>Domestic</td><td>73</td><td rowspan="2">The baseline of domestic EV chargers has increased from just over 40 MW in DFES 2023 to 73 MW in DFES 2024. Recorded non-domestic chargers, such as those seen from interrogating OpenChargeMap data, have remained fairly stable.</td></tr>
<tr><td>Non-domestic</td><td>60</td></tr>
</table>

Scenario projections

<table>
<tr><th rowspan="2">Scenario</th><th colspan="2">EVs (number) and EV charger capacity (MW)</th><th rowspan="2">Description</th></tr>
<tr><th>2030</th><th>2050</th></tr>
<tr><td>Holistic Transition</td><td>207,000 EVs
1,099 MW charger capacity</td><td>919,000 EVs
4,226 MW charger capacity</td><td rowspan="2">A high proportion of new car and LGV sales are EVs in the late 2020s and early 2030s. Harder-to-electrify vehicles, such as buses and HGVs, see some uptake in the medium-term, but hydrogen-fuelled alternatives also begin to be adopted under these scenarios, limiting EV uptake for these heavier vehicles, particularly under Hydrogen Evolution.

Plug-in hybrid vehicles see moderate uptake under both Holistic Transition and Hydrogen Evolution, with battery electric vehicles being the dominant EV technology across all vehicle classes.

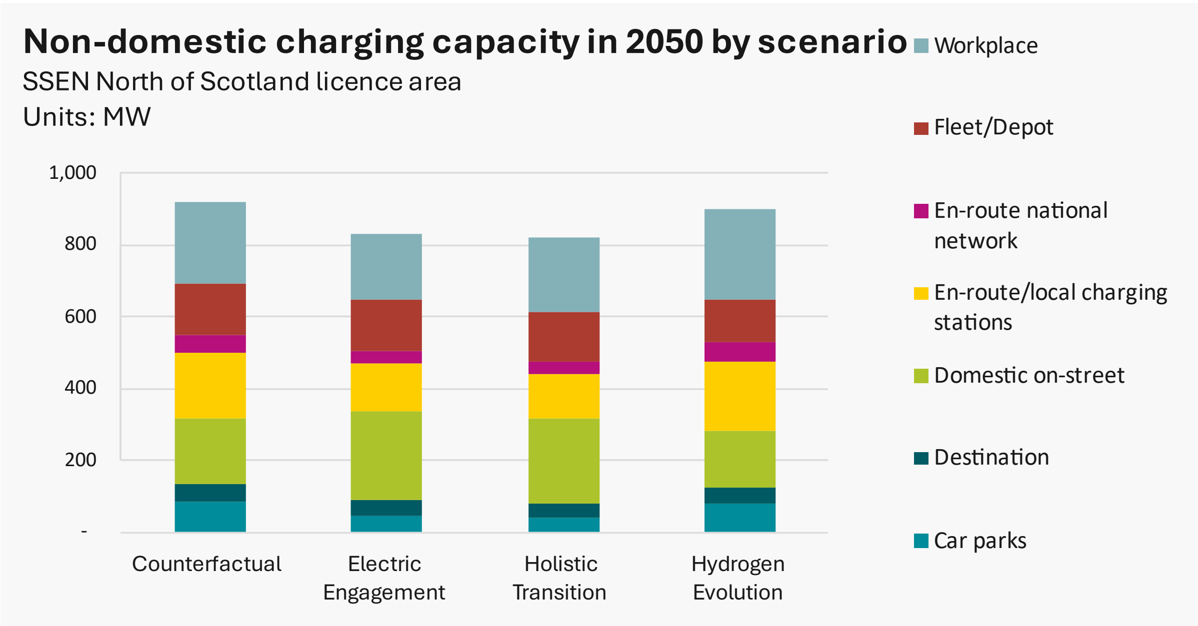
While domestic charging is most common, rapid en-route charging also sees significant uptake under these scenarios.

Car ownership falls under Holistic Transition in the mid-2040s as car sharing via autonomous vehicles, active travel and greater use of public transport reduces the need for private vehicle ownership overall.</td></tr>
<tr><td>Hydrogen Evolution</td><td>207,000 EVs
1,113 MW charger capacity</td><td>999,000 EVs
4,260 MW charger capacity</td></tr>
<tr><td>Electric Engagement</td><td>307,000 EVs
1,743 MW charger capacity</td><td>872,000 EVs
4,228 MW charger capacity</td><td>EVs dominate new car and LGV sales from the late 2020s under the Electric Engagement scenario and from 2030 almost all new cars are electric. Harder-to-electrify vehicles, such as buses and HGVs, also see uptake in the medium-term, with the majority of all road vehicles electrified by 2040.

With such a rapid shift toward battery electric vehicles, plug-in hybrid vehicles see relatively low uptake and the number of hybrid vehicles declines in the late 2030s.

EV uptake is facilitated by a widespread rollout of domestic and non-domestic charging. This includes 350 kW and 1 MW eHGV chargers at major service stations.</td></tr>
</table>

			Overall vehicle ownership falls in the mid-2040s as car sharing via autonomous vehicles, active travel and greater use of public transport moderately reduces private vehicle ownership.
Counter-factual	172,000 EVs 876 MW charger capacity	981,000 EVs 4,259 MW charger capacity	In the **Counterfactual** scenario, there are still a high proportion of new car and LGV sales are EVs by the early 2030s. Harder-to-electrify vehicles, such as buses and HGVs, see limited uptake in the medium-term. Plug-in hybrid vehicles see moderate uptake, yet battery electric vehicles remain the dominant EV technology across all vehicle classes. There is a much lower rate of domestic off-street charging under this scenario, with a higher number of car park, workplace and local charging stations being rolled out in the 2030s. Overall, private vehicle ownership remains higher in the long term under this scenario, reflecting lesser use of both public transport and active travel.



Spatial factors

Factor	Description
Access to off-street and on-street parking, affluence and rurality (source: ONS Census data)	These factors influence the near-term location of EVs and the associated off-street and on-street domestic EV chargers.
Location of petrol/diesel fuelling stations (source: OS Addressbase)	The location of petrol and diesel fuelling stations are used to indicate the location for projected en-route EV chargers.
Location of car parks, workplaces and fleets/depots (source: OS Addressbase)	The location of car parks, workplaces and depots are used to indicate the projected location of car park, workplace and fleet/depot chargers.
Ambition of local authority (source: Regen DFES local authority survey, LAEP publications)	Local authorities who confirmed they had a low-carbon transport plan in place (as part of the DFES 2024 local authority engagement workstream) are assumed to have a slightly accelerated uptake of electric buses and coaches, as well as en-route/local charging stations. Specific LAEP targets for the rollout of EV charger capacity have also been reviewed and incorporated where available and where possible.
SSEN low carbon technology data	The location of EV chargers currently connected to SSEN's network is used to inform the baseline of existing chargers.

Stakeholder input

Stakeholder feedback	Impact on DFES analysis
Local Area Energy Plans	All targets in existing LAEPs that related to EVs and EV chargers were recorded and, where possible, compared to the Regen DFES model outputs. 17 targets relating to EVs and EV chargers were identified in the published LAEPs. However, 15 of these were incomplete and missing key information that prevented

	them from being accurately compared to the DFES projections. The two targets that were able to be compared were from the Perth and Kinross LAEP which included targets for the number of electric vehicles in the area by 2029 as well as the number of rapid chargers installed by 2045. [22]
Scottish Government confirmation of supporting a proposed changed to ZEV mandate	The Scottish Government confirmed they would support, and not diverge from, a proposed change of the ZEV mandate from 2035 to 2030. This has been reflected in **Electric Engagement**.
There is still uncertainty from policy makers as to the split of EVs and hydrogen for HGVs	In **Hydrogen Evolution** there is a much higher market share of hydrogen HGVs compared to the other three scenarios to reflect this uncertainty.
The stakeholders in the North of Scotland regional webinar noted 15 different factors as barriers to the widespread uptake of EVs in the licence area	This validated existing DFES modelling assumptions that already reflects a range of factors that limits EV uptake under some scenarios.

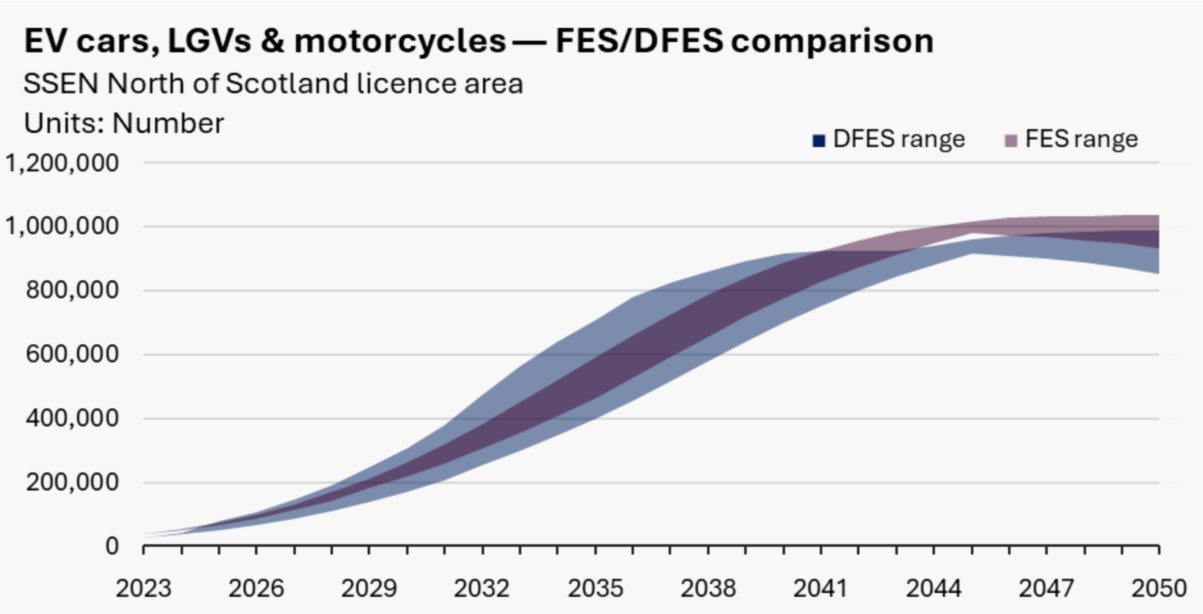
5.2.3. Comparisons

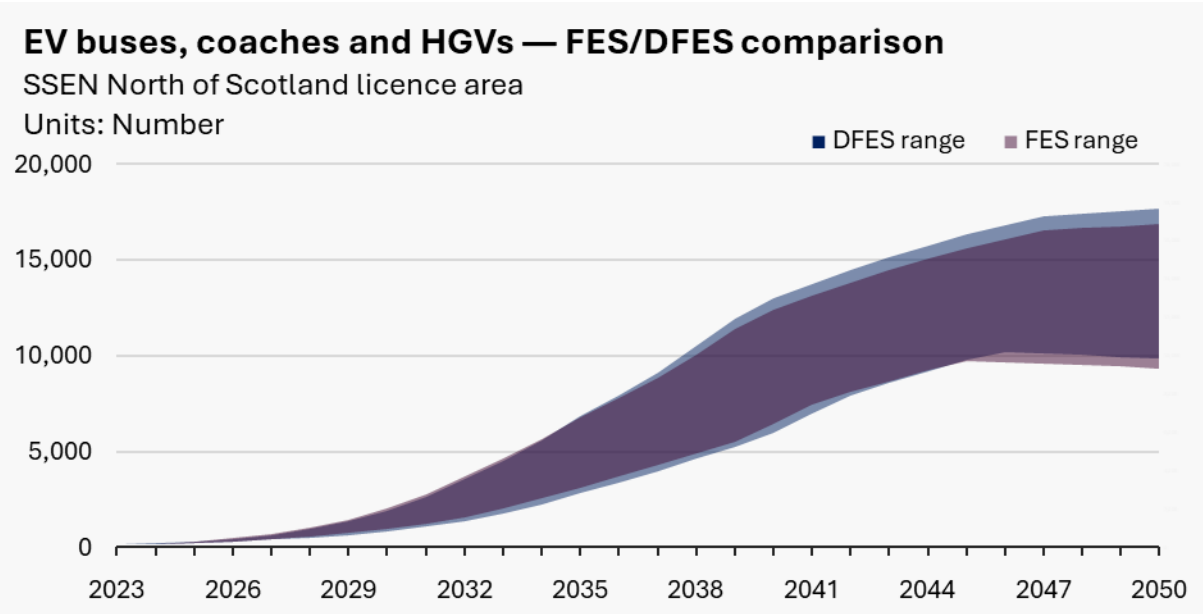
Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- As the uptake of EVs and provision of EV charging infrastructure are heavily driven by national trends and factors, the DFES projections for EVs and EV chargers in the licence area strongly mirror the national FES 2024 outcomes. The exception to this is **Electric Engagement**, which has an accelerated uptake for cars and vans tailored to reflect recent policy uncertainty around the ZEV mandate being applied in 2030 or 2035. This creates a larger envelope of scenario outcomes in the DFES, compared to the FES.
- Overall, vehicle uptake for electric cars, LGVs and motorcycles is marginally higher in the FES compared to the DFES. The reason for this variance is unclear but is likely due to differences in the modelling of the existing vehicle stock. The DFES modelling uses DfT vehicle licencing data to inform the overall number of different vehicle types in the licence area, which subsequently guides the future uptake of EVs.

- Vehicle uptake for electric buses, coaches and HGVs are very closely aligned between the FES and the DFES.
- The different EV charger technologies are not broken down in the FES 2024 data at a GSP, licence area or national level. As such, reconciliation of EV charger capacity in the licence area is not possible. However, FES assumptions on vehicle efficiencies, mileage and vehicle numbers are used to inform the DFES analysis where possible.





Comparison to DFES 2023

- The envelope of values remains broadly similar to DFES 2023, with the overall methodology remaining unchanged. A key difference this year is the divergence of **Electric Engagement** from FES 2024, in order to reflect a proposed (but not yet legislated) change to the ZEV mandate.
- Any other changes reflect the updated projections from FES 2024, which includes a more ambitious uptake of EVs in the **Counterfactual** and greater alignment between **Hydrogen Evolution** and **Holistic Transition**.

5.3. Heat pumps and resistive electric heating

Technical specification	Building Blocks
Domestic and non-domestic non-hybrid heat pumps	Lct_BB005
Domestic and non-domestic hybrid heat pumps	Lct_BB006
Domestic and non-domestic resistive electric heating	Lct_BB007
	Lct_BB008

5.3.1. Summary

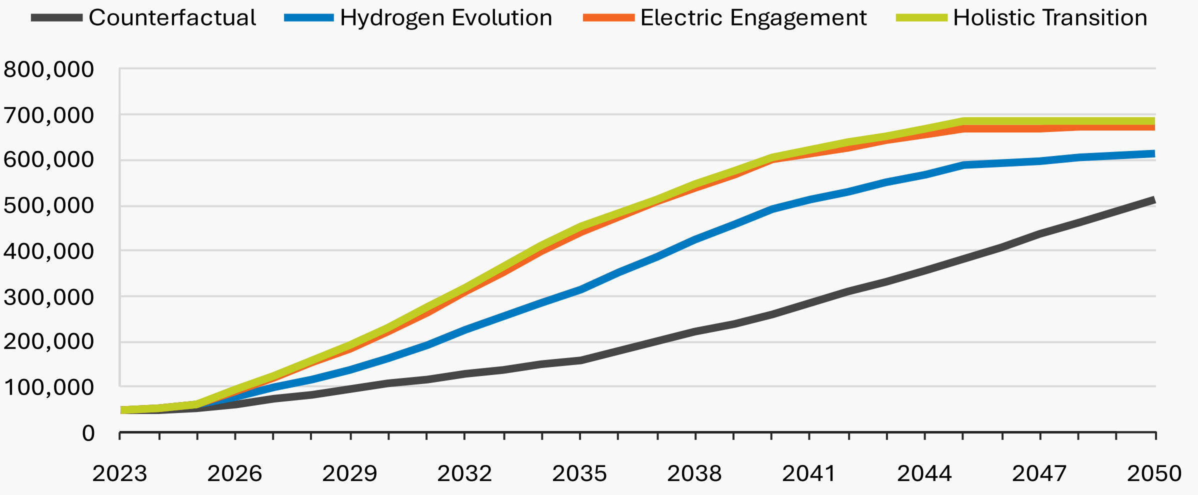
- The North of Scotland licence area has a broad range of housing, from dense areas of on-gas houses and flats in built-up urban areas such as Aberdeen and Dundee, to highly rural, off-gas areas such as the Highlands and Islands. Overall, the licence area has a much higher proportion of off-gas homes than the UK average, resulting in an accelerated uptake of heat pumps in the near term.
- Under the **Holistic Transition** and **Electric Engagement** scenarios, domestic heating is mostly decarbonised through heat pumps in the North of Scotland licence area, in line with national trends. Initial uptake in the 2020s is modelled to occur more commonly in off-gas houses and new-build homes. This is a reflection of anticipated energy performance and new build housing regulations, which will be required to meet the UK Government's target of 600,000 heat pump installations per year by 2028 and reflects engagement with the Scottish Government on low carbon heat policy and support for the adoption of heat pumps in Scotland.
- In the medium and long term, a wider-scale rollout of heat pumps is modelled, with the majority of housing stock having a form of heat pumps by 2050. This results in approx. 0.7 million homes using a form of heat pump by 2050 under the **Holistic Transition** and **Electric Engagement** scenarios.
- Under the **Hydrogen Evolution** scenario, domestic heating is driven primarily by low carbon hydrogen in the form of standalone hydrogen boilers or hydrogen hybrid heat pumps. However, the higher proportion of off-gas homes in the North of Scotland licence area results in a higher uptake of non-hybrid heat pumps, as the availability of hydrogen from domestic heating is assumed to be in line with the current fossil gas heating. This results in approx. 0.6 million homes using a form of heat pump by 2050 under this scenario.
- Under the **Counterfactual** scenario, progress towards heat decarbonisation is slow, despite some uptake of heat pumps in the late 2030s and 2040s. This results in approx. 0.4 million homes using a form of heat pump by 2050.
- The number of households on resistive electric heating decreases in all scenarios, being replaced by more efficient heat pumps and district heating schemes. Direct electric heating, as the most expensive form of resistive electric heating, sees the greatest reduction in the near term. There is a shift from direct electric heating to storage heating in homes where a boiler or heat pump is less suitable.

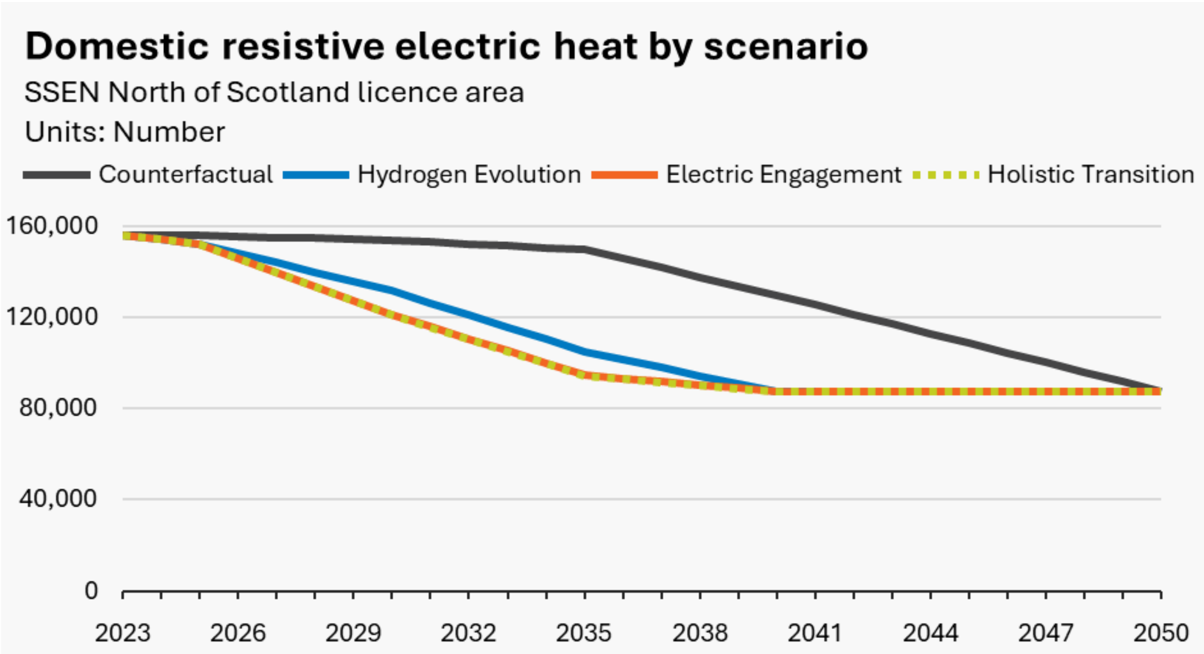
- Heating in non-domestic buildings is currently dominated by gas-fired central heating, resistive electric heating and air conditioning for cooling/temperature control.
- Evidence from DESNZ on low-carbon heating and cooling in non-domestic buildings found that non-domestic building decarbonisation scenarios are strongly influenced by the existing heating system and heating, ventilation and air conditioning (HVAC) environment.[23]
- In all four scenarios, the near-term uptake of heat pumps in non-domestic buildings is focused on buildings heated with off-gas and direct electric heating systems, due to the higher operational costs of these technologies.
- In the medium to long term, buildings currently heated by gas, oil or Liquid Petroleum Gas (LPG) heating systems are modelled to move either to an air-source or ground-source heat pump or connect to a district heat network. Most buildings with resistive electric heating are modelled to move to more efficient air-to-air heat pumps, operating similarly to air conditioners.
- Non-domestic buildings are primarily decarbonised with heat pumps in the three net zero scenarios, resulting in heat pumps heating approx. 10 million sqm of non-domestic floorspace by 2050.
- In all scenarios, resistive heating declines substantially from 2025 through to 2050 in non-domestic buildings, due to the uptake of more efficient heat pumps and district heating. Direct electric heating, as the most expensive heating method, sees a greater reduction in the near term. Under the **Electric Engagement** scenario, a higher proportion of non-domestic buildings remain on resistive electric heating in the long term due to the particularly strong focus on electrification of heat and limited low-carbon alternatives under this scenario.

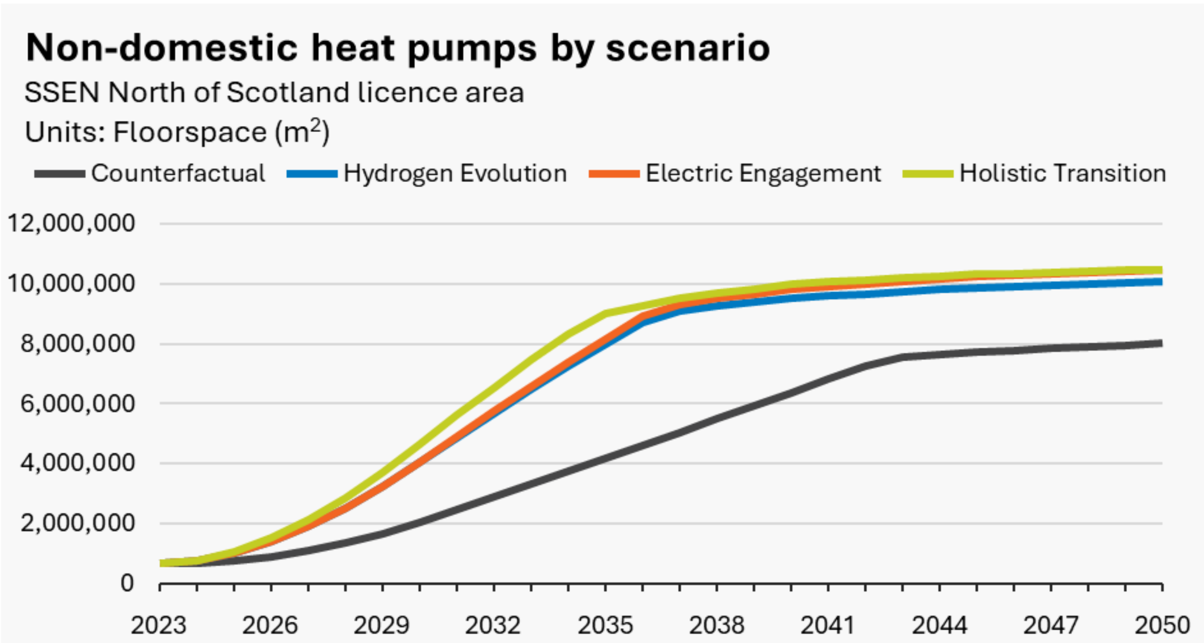
Domestic heat pumps by scenario

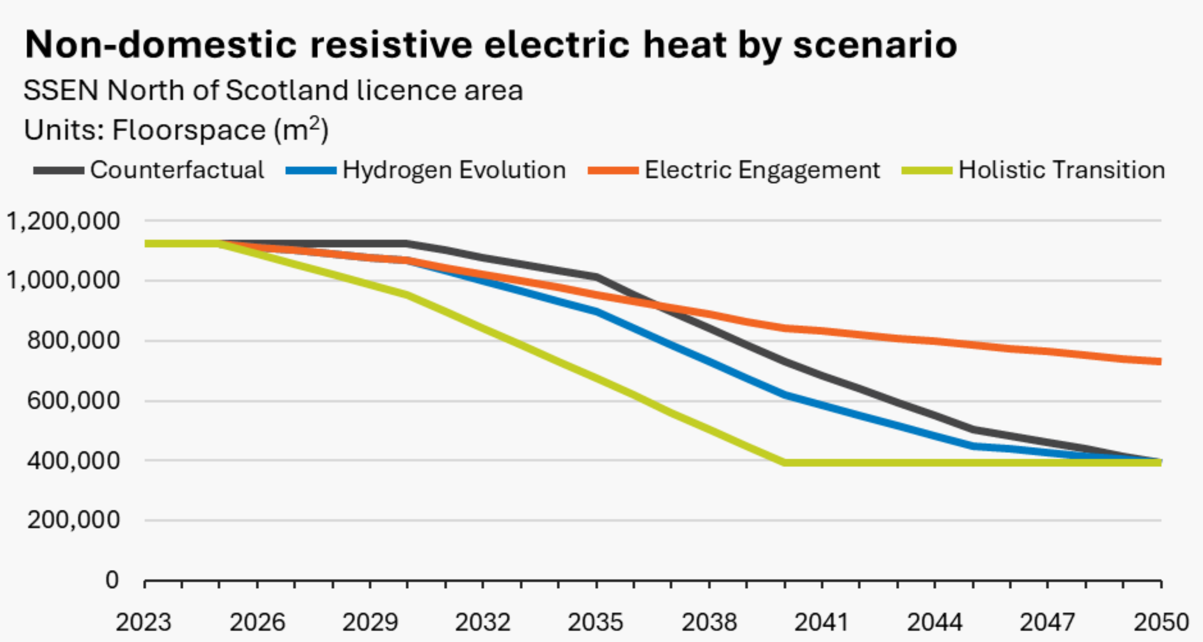
SSEN North of Scotland licence area

Units: Number




Domestic resistive electric heat by scenario
SSEN North of Scotland licence area
Units: Number
Counterfactual
Hydrogen Evolution
Electric Engagement
Holistic Transition
160,000
120,000
80,000
40,000
0
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050


Non-domestic heat pumps by scenario
SSEN North of Scotland licence area
Units: Floorspace (m^2)
Counterfactual
Hydrogen Evolution
Electric Engagement
Holistic Transition
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050



5.3.2. Modelling and outcomes

Baseline

Source: SSEN connections data, EPCs, Census 2011/2022, MCS, DECs

Domestic heating technology	Number (000s)	Description
Non-hybrid heat pumps	48	Most heat pumps in existing homes in the North of Scotland licence area were supported by the Renewable Heat Incentive (RHI) scheme, which ran from 2014 to 2022. This has since been succeeded by the Boiler Upgrade Scheme, which moves support to an upfront grant payment to reduce the capital costs of installing a heat pump.[24]
Hybrid heat pumps	<1	The RHI was popular in the North of Scotland, with around 17% of heat pumps accredited by the RHI in the North of Scotland licence area. This has resulted in approximately 1.22% of homes in the licence area now having a heat pump, which is slightly above the UK average.
Resistive electric heating	156	Resistive electric heating is much more common in the North of Scotland licence area compared to the national

average, heating nearly 12.49% of homes compared to around 10% nationally.

This is due to a combination of rural areas not connected to the fossil gas network and dense urban areas, which features many blocks of flats with electric heating.

Non-domestic heating technology	Floorspace (000 sqm)	Description
Non-hybrid heat pumps	675	EPC and DEC data does not record whether a non-domestic building is heated by a heat pump. As a result, the heat pump baseline is informed by MCS installation data. Relative to the rest of the UK, the North of Scotland licence area has a high proportion of non-domestic buildings currently heated by a heat pump.
Hybrid heat pumps	0	
Resistive electric heating	1,124	Analysis of EPC and DEC data suggests that approx. one million square meters of non-domestic floorspace is currently heated by resistive electric heating. This does not include buildings with air conditioning that are recorded as predominantly providing cooling.

Pipeline

There is no pipeline in the SSEN connections data for domestic or non-domestic heat pumps or resistive electric heating.

Domestic scenario projections

Note that all scenario projections for low carbon heat are slightly accelerated ahead of the overall GB trajectory in each scenario to reflect Scottish Government climate targets.

<table>
<tr><th rowspan="2">Scenario</th><th colspan="2">Heat pumps (000s)</th><th rowspan="2">Description</th></tr>
<tr><th>2030</th><th>2050</th></tr>
<tr><td>Holistic Transition</td><td>229</td><td>685</td><td rowspan="2">Homes are mostly decarbonised with heat pumps in the Holistic Transition scenario. Initial uptake in the 2020s is modelled to occur more commonly in off-gas houses and new-build homes due to anticipated energy performance and new-build housing regulations, before a wider-scale rollout is modelled on the majority of housing stock by 2050.

District heating plays a role in domestic heat decarbonisation within dense population centres across the licence area, especially after 2030. Where a district heat network area has been identified, the majority of flats and terraces, and a substantial proportion of semi-detached and detached homes, in the area are modelled to connect. New-build homes in district heat network areas are also projected to connect to the network in most cases.

Around 671-685,000 domestic heat pumps are modelled to be in operation by 2050 under these scenarios.

The number of households on resistive electric heating decreases in all scenarios, replaced by more efficient heat pumps and district heating. Direct electric heating, as the most expensive form of resistive electric heating, sees the greatest reduction in the near term. There is a shift from direct electric heating to storage heating in homes where a boiler or heat pump is less suitable. However, around 60% of the baseline remains on resistive heating in 2050, particularly in smaller flats where a heat pump may not be suitable or economical.</td></tr>
<tr><td>Electric Engagement</td><td>220</td><td>671</td></tr>
<tr><td>Hydrogen Evolution</td><td>162</td><td>615</td><td>Homes are decarbonised primarily through low-carbon hydrogen options in the Hydrogen Evolution scenario, through the use of standalone hydrogen boilers or hybrid heat pumps. In the North of Scotland licence area, where there is a high proportion of off-gas homes, this results in the vast majority of homes being heated by hydrogen hybrid heat pumps or standalone heat pumps. A minority of homes decarbonise their heating through hydrogen boilers.</td></tr>
</table>

			District heating plays a role in domestic heat decarbonisation within dense population centres across the licence area, especially after 2030. Where a district heat network area has been identified, the majority of flats and terraces, and a substantial proportion of semi-detached and detached homes, in the area are modelled to connect. New-build homes in district heat network areas are also projected to connect to the network in most cases. A little under 616,000 domestic heat pumps are modelled to be in operation by 2050 under this scenario. Resistive heating declines throughout the scenario timeframe due to the uptake of heat pumps and district heating. Direct electric heating, as the most expensive heating method, sees a greater reduction in the near term. There is a shift from direct electric heating to next-generation storage heating in homes where a boiler or heat pump is less suitable. However, around 60% of the baseline remains on resistive heating in 2050, particularly in smaller flats where a heat pump may not be suitable or economical.
Counter-factual	106	513	Under the **Counterfactual** scenario, progress towards heat decarbonisation is slow, despite some uptake of heat pumps in the late 2030s and 2040s. In this scenario, many homes remain heated by fossil gas boilers in 2050, and the UK fails to meet its carbon emissions reduction targets. District heat networks also see lower uptake under this scenario, as progress towards net zero is slower. A little under 515,000 domestic heat pumps are modelled to be in operation by 2050 under this scenario. Resistive heating declines after 2035 due to the uptake of heat pumps and district heating. Direct electric heating, as the most expensive heating method, sees a greater reduction in the near term. There is a shift from direct electric heating to next-generation storage heating in homes where a boiler or heat pump is less suitable. However, around 60% of the baseline remains on resistive heating in 2050, particularly in smaller flats where a heat pump may not be suitable or economical.

Non-domestic scenario projections

Note that non-domestic heating outcomes are projected in square meters of heated floorspace. This is due to the wide range of non-domestic building sizes, making floorspace a more useful unit than number of units for non-domestic heating.

Scenario	Heat pumps (000 sqm)		Description
	2030	2050	
Holistic Transition	4,666	10,482	Non-domestic buildings are primarily decarbonised with heat pumps in the **Holistic Transition** scenario. Similar to heating in domestic buildings, near-term decarbonisation of heat in non-domestic buildings is focused on buildings heated with off-gas and direct electric heating systems due to the higher operational costs of these technologies. Resistive heating declines sharply throughout the scenario timeframe from 2025 to 2040, due to the uptake of heat pumps and district heating.
Electric Engagement	4,042	10,479	
Hydrogen Evolution	4,060	10,104	Non-domestic buildings are primarily decarbonised through the deployment of heat pumps in the **Hydrogen Evolution** scenario. Similar to heating in domestic buildings, near-term decarbonisation of heat in non-domestic buildings is focused on buildings heated with off-gas and direct electric heating systems. Resistive heating declines throughout the scenario timeframe from 2025 to 2050, due to the uptake of heat pumps and district heating. Around 35% of the baseline remains on resistive heating in 2050.
Counter-factual	2,060	8,027	Although to a lesser extent, non-domestic buildings are still primarily decarbonised with heat pumps in the **Counterfactual** scenario. Similar to heating in domestic buildings, near-term decarbonisation of heat in non-domestic buildings is focused on buildings heated with off-gas and direct electric heating systems. This results in the lowest level of heat pump uptake in non-domestic buildings of the four scenarios, with a number of properties likely still remaining on fossil fuel heating systems by 2050. Resistive heating declines throughout the scenario timeframe from 2025 to 2050, due to the uptake of heat

			pumps and district heating. Around 35% of the baseline remains on resistive heating in 2050.

Spatial factors

Factor	Description
Current heating technology	Current heating technology, categorised into on-gas, resistive electric heating and off-gas, affects when the uptake of low carbon heating technology is projected to occur and what type of technology is likely to be installed.
Building type	Building type, categorised into semi-detached, detached, terraced and flats, affects when the uptake of decarbonised heating technology is projected to occur and what type of heating technology is likely to be installed.
Tenure	Tenure, categorised into owner-occupied, privately rented and socially rented, affects when uptake of decarbonised heating technology is projected to occur.
Construction age band	Construction age band, categorised into pre-1930 and post-1930 construction, affects when the uptake of decarbonised heating technology is projected to occur and what type of heating technology is likely to be installed.
Areas with potential for district heat networks, or an existing heat network pipeline project	Areas with potential for district heat networks or an existing heat network pipeline project affects the likelihood of properties connecting to a district heat network as opposed to decarbonising with other heat technologies.
Hydrogen supply for domestic heating	In FES 2024, the **Holistic Transition** scenario features a small proportion of homes heated by hydrogen boilers or hydrogen hybrid heat pumps. The location of these homes is likely to be primarily on the east coast of the UK, in line with the East Coast Hydrogen project from Humber to Teesside, and the north west, in line with the HyNet North West project. [25,26]. Therefore, in this scenario, it is assumed that hydrogen supply for domestic heating does not extend to the North of Scotland licence area. Under **Hydrogen Evolution**, it is assumed that hydrogen supply follows the existing gas distribution network.
Local Area Energy Plans	Data from Local Area Energy Plans has been obtained where available and reconciled against the DFES outcomes. This includes various LHEES for Scottish local authorities, such as Perth and Kinross, which were also used as inputs

	to the overall heat modelling in terms of which building archetypes have the propensity to adopt which low carbon heating technology.

Stakeholder input

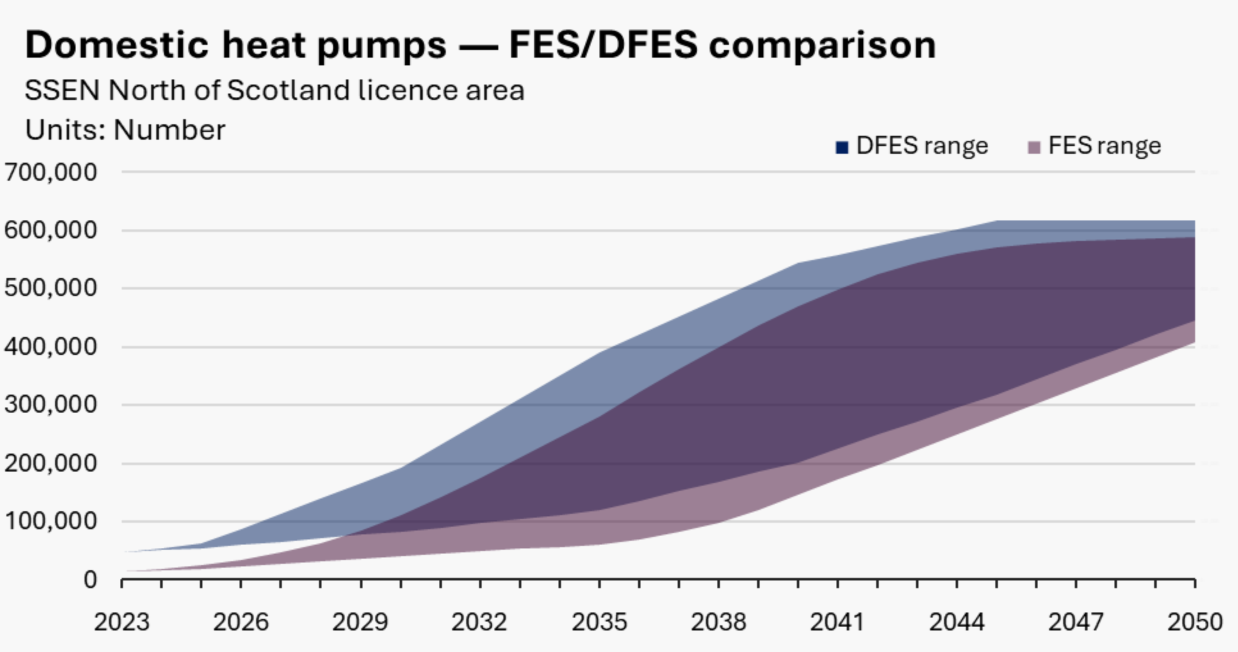
Stakeholder feedback	Impact on DFES analysis
Local Area Energy Plans and Local Heat and Energy Efficiency Strategies	Data and technology specific targets from Local Area Energy Plans and Local Heat and Energy Efficiency Strategies has been obtained where available and reconciled against the DFES outcomes.
Engagement with district heat developers	A leading district heat network developer was engaged to confirm modelling assumptions around the uptake of district heat.
Engagement with DESNZ heat network team	The DESNZ heat network team was engaged to confirm modelling assumptions around the location of district heat and wider assumptions around heat decarbonisation across GB.

5.3.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The trend of DFES 2024 projections is comparable to the FES 2024 outcomes.
- DFES 2024, however, is predicting a higher number of domestic heat pumps from the baseline to 2050 compared to FES 2024, including a higher baseline. This may be in part due to EPC data containing older heat pumps that may not be recorded on MCS or RHI registers. In addition, the DFES reflects a slightly faster uptake of heat pumps in Scotland to reflect Scottish Government heat policy ambition, which has historically had higher and earlier heat decarbonisation targets compared to the rest of the UK.
- The DFES projects non-domestic heat in terms of heated floorspace rather than number of units. As a result, a direct comparison to the FES outcomes is not possible.



Comparison to DFES 2023

- The DFES 2024 domestic heat baseline numbers are higher compared to DFES 2023 baseline numbers. This is primarily due to the uptake of heat pumps over the past year, alongside increased visibility of existing heat pumps in datasets such as EPC records.
- The DFES 2024 scenario projections for **Hydrogen Evolution** differ the most when compared to System Transformation, as the most similar scenario in DFES 2023. This is due to an updated FES 2024 framework, which has increased the number of heat pumps and reduced the amount of hydrogen for domestic heating under this scenario.
- The **Holistic Transition** and **Electric Engagement** scenario projections for heat pumps are mostly comparable to their DFES 2023 equivalent scenarios (Leading the Way and Consumer Transformation). Near-term uptake is lower in DFES 2024 compared to DFES 2023. This is partially due to an updated FES 2024 framework, which has reduced the uptake of heat pumps in the near term, reflecting current national uptake trends.
- Also, variances seen are partially due to Scottish Government policy (following engagement with the Scottish Government), such as an ambition to decarbonise heating in one million homes by 2030, which is not reflected directly in the FES.
- The **Counterfactual** scenario is broadly aligned with the DFES 2023 projections under the equivalent Falling Short scenario. The DFES 2024 projects non-domestic heat in terms of heated floorspace, whereas projections in DFES 2023 was in number of units. This is due to the wide range of non-domestic building sizes, making floorspace a more useful unit than number of units for non-domestic heating. As a result, a comparison with DFES 2023 outcomes is not possible for non-domestic heat.

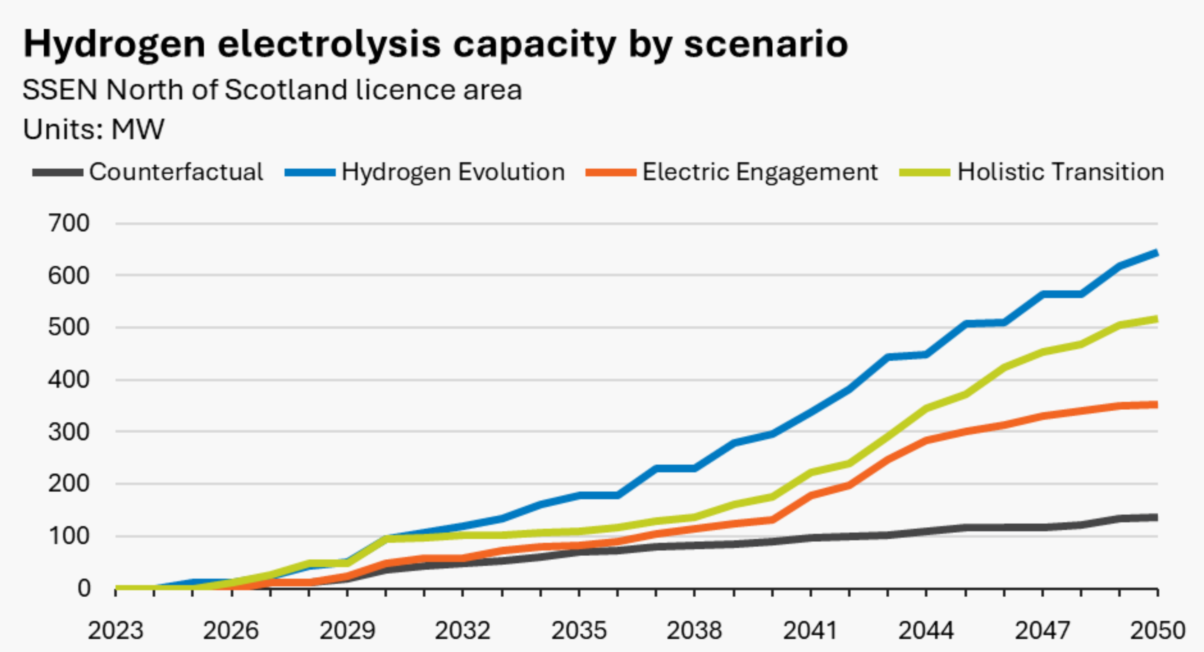
5.4. Hydrogen electrolysis

Technical specification	Building Blocks
Distribution connected hydrogen electrolysis	Dem_BB009

5.4.1. Summary

- The production of low carbon hydrogen through commercial scale hydrogen electrolysis is still an emerging sector, with uncertainty around the scale of its future role in the energy system. The extent to which hydrogen electrolysis will scale-up and seek to connect to the transmission network is one such uncertainty. This results in a wide range of projections for distribution network connected electrolysis in the North of Scotland licence area.
- The 2022 British Energy Security Strategy outlined a target of 10 GW of low-carbon hydrogen production by 2030, of which 5 GW is to be from electrolysis (also known as 'green hydrogen'). In addition, the Scottish Government's Hydrogen Action Plan is targeting 5 GW of electrolysis by 2030 and another 5 GW by 2035.
- Funding has been committed in support of this target:
    - 11 electrolysis projects are receiving funding through the first Hydrogen Allocation Round (HAR 1), totalling 125 MW of green hydrogen production capacity
    - 875 MW of additional hydrogen production capacity will be supported through the second allocation round (HAR 2), with winning projects set to be announced in the first half of 2025
    - An additional 1.5 GW of hydrogen production capacity will be funded across both HAR 3 and HAR 4, launched in 2025 and 2026, respectively
    - Subsequent allocation rounds will be held annually between 2025 and 2030.
- Engagement with electrolyser developers and hydrogen industry groups has highlighted the importance of these allocation rounds in enabling the near-term deployment of commercial-scale projects. The development of commercial electrolysis projects outside of this support mechanism is not considered feasible in the near term. The results of HAR 2, and subsequent allocation rounds, will give greater certainty to the near term development of electrolysis capacity in the licence area and across GB.
- The 'Cromarty distilleries project' is currently the only project with support through HAR 1 in the licence area.[27] Intending to commission a 10.6 MW electrolyser. This site is modelled to build out in all scenarios; with earliest connection modelled in 2025 under **Hydrogen Evolution**.
- Beyond the known pipeline, the potential for additional electrolysis capacity out to 2050 is based on FES 2024 projections for national networked electrolysis, combined with a regional analysis of potential supply and demand drivers for low carbon hydrogen.

- In the North of Scotland, the presence of a significant number of hydrogen innovation projects drives near-term development, as does blending into gas networks under some scenarios. Significantly, the licence area is set to host a significant section of National Gas' proposed future hydrogen backbone transmission network, through Project Union. Its route up the east coast of the licence area is a key locational factor driving medium and long term deployment.[28] Co-location with onshore wind is also a factor impacting long-term projections.
- In addition, as a result of engagement with local stakeholders, the Scottish Islands are highlighted as potentially key locations where distributed electrolysis could have a role in local decarbonisation. This is reflected in the results of this analysis, as is the presence of existing oil and gas infrastructure in the licence area, currently supplying fuel to key local industries such as whiskey distilling.
- By 2050, under **Hydrogen Evolution**, as the scenario that is most supportive of green hydrogen development, 646 MW of hydrogen electrolysis is modelled to be deployed in the licence area.
- Under the least ambitious scenario, the **Counterfactual**, only 136 MW is deployed.



5.4.2. Modelling and outcomes

Baseline

Source: Desktop research

Description
There are a number of small (<1 MW) pilot-scale hydrogen electrolyser projects in the North of Scotland licence area. However, these are not included in the baseline, due to being installed behind the meter using on-site generation. This includes: • The ACHES and Kittybrewster Hydrogen refuelling stations in Aberdeen, produce hydrogen to refuel a fleet of local buses. • EMEC runs a 670 kW electrolyser at the ITEG facility on Orkney, a vanadium flow battery is used onsite to allow the use of tidal energy in hydrogen production. • A 30 kW electrolyser is located at the Creed Integrated Waste Management Facility and is part of the Outer Hebrides Local Energy Hub. As a result, baseline capacity of network connected hydrogen electrolysis capacity is currently modelled at 0 MW in the licence area.

Pipeline

Source: Desktop research

Description
Engagement with the sector has highlighted the importance of UK and Scottish Government support, specifically through the HAR scheme, to the viability of near-term commercial business models. The pipeline assessment has therefore focused on projects with Government support. However, many of these sites fall out-of-scope of the analysis due to deriving hydrogen from on-site generation and/or not seeking a distribution network connection. Some of these sites include: • Aberdeen Hydrogen Hub, a joint venture by BP and Aberdeen city council, with funding through the Net Zero Hydrogen Fund. It aims to produce 800 kg of green hydrogen per day to power fleet vehicles, it will be directly connected to a solar farm as its primary source.[29] • Kintore Hydrogen, a Stratera project with funding through the Net Zero Hydrogen Fund. It aims to deploy 3 GW of electrolyser capacity by 2030, it will be connecting to the Kintore 400kV substation.[30]

- A Front-End Engineering Design (FEED) study has been funded by the UK Government to transition the Sullom Voe Oil and Gas terminal into a hydrogen production facility with 300 MW of electrolyser capacity. The use off excess power from local onshore and offshore wind is being suggested as a power supply.[31]
- The Flotta Hydrogen Hub is a proposed repurposing of the Flotta oil and gas terminal. It would make use of power from the future West of Orkney windfarm.[32]

Currently, only the Cromarty Distilleries Project is modelled to connect to the North of Scotland distribution network. It is a project with support through HAR 1 and it plans to deploy a 10.6 MW electrolyser. This is modelled to commission under all scenarios, between 2025 and 2027.

Scenario projections

Scenario	Capacity (MW)		Description
	2030	2050	
Hydrogen Evolution	96	646	Under this scenario, a main driver for the growth of hydrogen electrolysis capacity in the medium term is the high levels of hydrogen blending through the gas network. This means the coverage of the existing gas network infrastructure is an important regional supply consideration. Demand from industrial decarbonisation in the licence area is also a key medium-term driver. In the long term, a core hydrogen transmission network is built out and links with regional distribution networks, such as those proposed by HyNet and Hyline Cymru.[33,34] This reduces the need for demand and production to be so locally tethered and allows hydrogen production sites to be developed in areas that are most suitable. This results in a balance between the proximity to any future hydrogen gas network, renewable energy projects (including for co-location) and sources of low-carbon hydrogen demand. Hydrogen electrolysis capacity reaches over 0.6 GW by 2050 under this scenario.
Holistic Transition	94	518	Under this scenario, high levels of hydrogen blending means that the coverage of the existing gas network infrastructure is an important regional consideration for the development of

			hydrogen electrolysis projects. Demand from industrial decarbonisation is also a key medium-term driver. A core hydrogen transmission network is developed, but to a lesser extent than seen under **Hydrogen Evolution**, and without regional distribution networks. This makes the route of the core transmission network an important locational factor for electrolysis, alongside existing gas fired electricity generation and industrial activity. Hydrogen electrolysis capacity reaches over 0.5 GW 2050 under this scenario.
Electric Engagement	48	354	With less hydrogen blending, the demand from industrial decarbonisation, heavy transport and existing gas-powered electricity generation are the main medium-term drivers for electrolysis development under this scenario. A core hydrogen transmission network is developed, but to a similarly lesser extent as seen in **Holistic Transition**, including no regional distribution networks. This makes the route of the core transmission network an important locational factor, alongside existing gas fired electricity generation and industrial activity. Hydrogen electrolysis capacity reaches just under 0.4 GW 2050 under this scenario.
Counter-factual	35	136	Hydrogen production and demand are more directly matched at a regional level, as hydrogen networks are not developed. Electrolyser projects are therefore limited and only developed close to hydrogen demand. In the medium and long term, this demand is primarily driven by the industrial sector, heavy road transport and power generation. Hydrogen electrolysis capacity is limited to just under 0.2 GW 2050 under this scenario.

Uptake modelling factors

The below factors are used to inform the overall uptake of hydrogen electrolysis in the North of Scotland licence area.

Factor	Description
Proportion of hydrogen electrolysis projects that connect to the distribution network	A number of anomalies within the FES 2024 GSP level projections for hydrogen electrolysis have led to them being removed as an input to the DFES model. As a result, post-pipeline projections for distribution network connected electrolysis are based upon the FES 2024 GB total networked electrolysis projections, with an assumed ratio of deployment on the distribution network. This ratio is 20% under **Hydrogen Evolution**, **Holistic Transition**, and **Electric Engagement** and 60% under the **Counterfactual**, where the industry does not scale-up and deploy transmission network scale connections.
Hydrogen distribution factors	An assessment of the presence of hydrogen supply and demand factors across all GB licence areas was completed. These factors were used to inform the level of electrolytic hydrogen requirements and thus the projected capacity of hydrogen electrolysis in the licence area, by scenario. These factors include the presence of: o Industrial energy demand o Heavy transport demand o Planned hydrogen network coverage o Gas distribution network coverage o Gas fired electricity generation o Hydrogen innovation projects o Aviation activity o Existing grey hydrogen production o Renewable energy generation

Spatial factors

Factor	Description
Baseline and pipeline sites	The location of known baseline and pipeline sites is used to inform the existing and very near term projected capacity. Post-pipeline capacity is also assigned to areas which host existing hydrogen electrolysis projects or will do so in the future. This is regardless of a project's use of the distribution network.
Route of the proposed hydrogen transmission network	Areas along the route of the proposed Project Union hydrogen transmission network are also identified and considered for the spatial analysis of future hydrogen electrolysis capacity.
Industrial sites	Areas surrounding industrial energy users are identified as hub areas driving the need for localised low carbon hydrogen.
Local authority ambition	Local authorities that have hydrogen strategies or targets in place is also a consideration for the spatial distribution of future hydrogen electrolysis capacity. This information is obtained through the DFES Local Authority Energy Strategies survey.

Stakeholder input

Stakeholder feedback	Impact on DFES analysis
Attendees at the North of Scotland stakeholder webinar were asked what they saw as the future for low carbon hydrogen development in the North of Scotland. They highlighted its potential for decarbonisation on the Scottish Islands, its potential to make use of existing oil and gas infrastructure and its potential for industrial decarbonisation.	These factors are all considered within the modelling of the technology.
Engagement with the wider hydrogen sector has highlighted the importance of HAR funding to the viability of near-term commercial scale electrolysis projects. It also re-affirmed that	The pipeline assessment was focused on these factors.

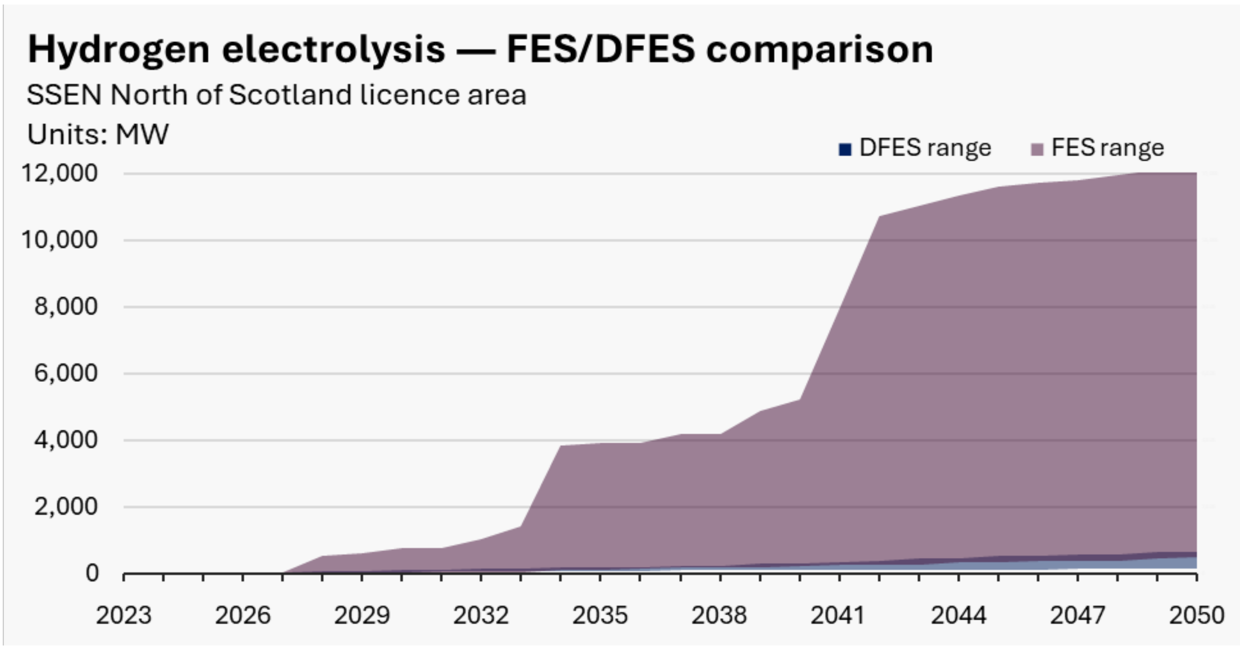
the use of onsite generation would be key in determining impact on the distribution network.	
Engagement with the Scottish Futures Trust re-affirmed a number of modelling assumptions which impacted the modelling. These included: • Small-scale development and securing of supply chains will precede any large-scale development. • Substantial electrolysis development is required before it can serve as an enabler for wind generation by reducing curtailment; this would be needed before the next wave of wind investment. • A hydrogen network infrastructure is critical to enabling hydrogen electrolysis at scale.	These factors are all considered within the modelling of the technology.

5.4.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- FES 2024 projects 12 GW of hydrogen electrolysis connecting to the distribution network in the North of Scotland licence area by 2050 under the most ambitious scenario, **Hydrogen Evolution**, and 500 MW under the **Counterfactual** as the least ambitious scenario. Due to this substantial scale of development and range of outcomes, these projections have been queried with the FES team.
- DFES 2024 projects significantly lower capacities, up to a maximum potential of 646 MW by 2050 under **Hydrogen Evolution**.
- However, DFES 2024 does reflect the overall increase in national electrolysis projections seen across GB in the FES 2024, as well wider updates to how distributed electrolysis is considered under the four scenarios. Resultantly, **Hydrogen Evolution** is now the most ambitions scenario for grid-connected hydrogen electrolysis in the DFES 2024, followed by **Holistic Transition**, **Electric Engagement** and finally the **Counterfactual**, which sees limited development.



Comparison to DFES 2023

- The most ambitious scenario under DFES 2024 projects significantly lower electrolysis capacity before 2030, compared to the most ambitious scenario under DFES 2023. This is a reflection of the current lack of evidence for both a pipeline of commercial scale electrolyser projects that have UK and Scottish Government support, and that some developments will connect to the distribution network as their primary source of electricity supply.
- Relative to DFES 2023, DFES 2024 projects greater capacity beyond 2030 under each scenario, resulting in moderately higher connected electrolysis capacity in the licence area by 2050. This reflects updated FES 2024 projections for national networked electrolysis, alongside regionally specific supply and demand drivers.
- The DFES 2024 projections also reflect changes to how electrolysis is supported in the FES 2024 scenario framework. **Hydrogen Evolution** is now the most ambitions scenario for grid-connected hydrogen electrolysis, followed by **Holistic Transition**, **Electric Engagement** and finally the **Counterfactual**, which sees limited development.

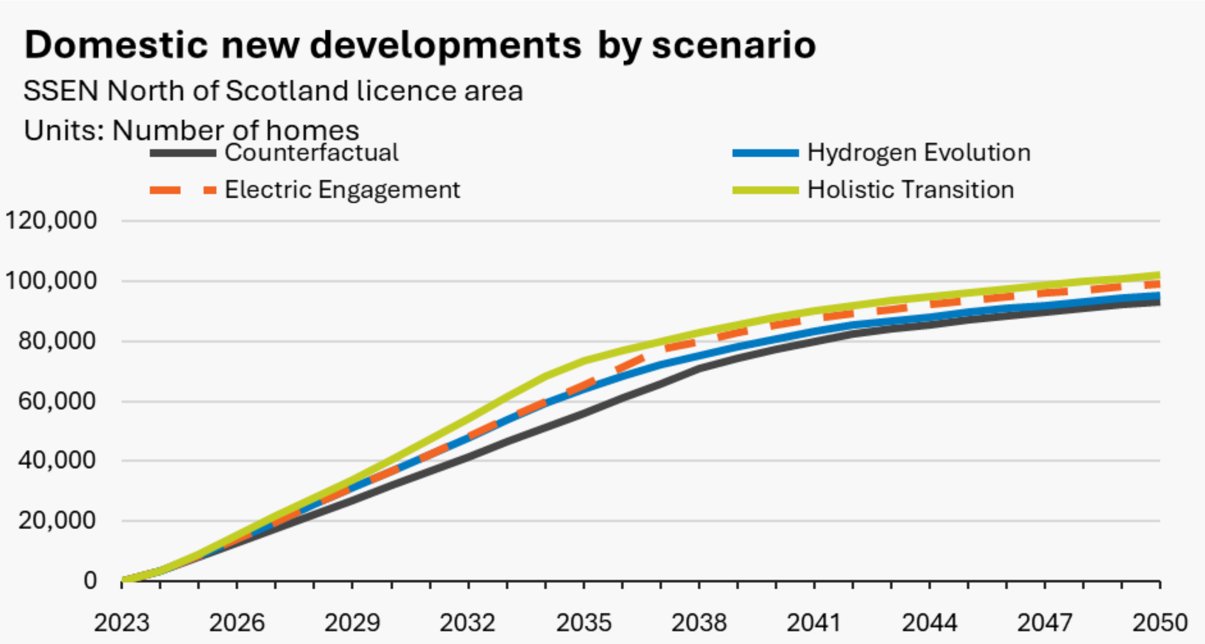
5.5. New property developments

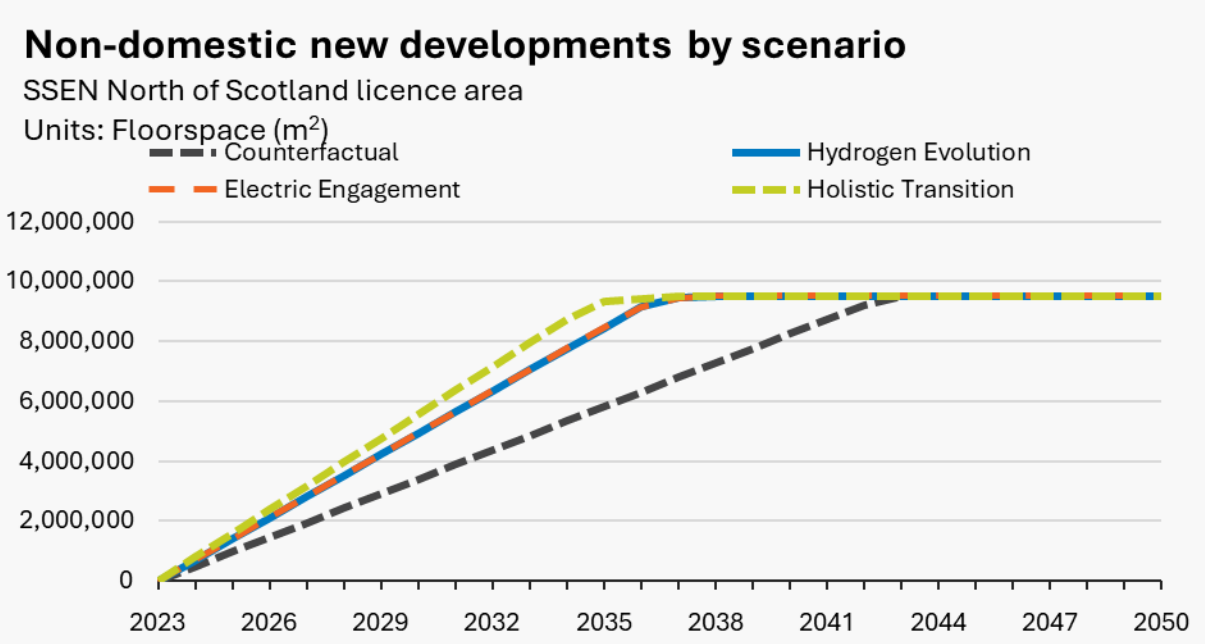
Technical specification	Building Blocks
Number of domestic customers	Gen_BB001a
Meters squared of I&C (industrial and commercial) customers	Gen_BB002b

5.5.1. Summary

- The new developments modelling within the DFES is based on direct engagement with local authority planning departments and an analysis of local planning documents submitted to Regen.
- Of the 15 local authorities in the North of Scotland licence area, seven shared updates for their domestic new development plans and three shared updates for their non-domestic new development plans.
- By 2050, the domestic development modelling results in between 93,200 and 103,000 new homes in the North of Scotland licence area
- By 2050, an **additional** 9.7 million square meters of non-domestic floorspace is also modelled in the licence area under each of the DFES scenarios.
- The Scottish Government has declared a housing emergency on the 15th of May of this year and have published the National Planning Framework 4, that supersedes the previous Scottish Planning Policy.[35] During stakeholder feedback, the team at Scottish Government have stated that they will be adapting to the current UK Governments new ambitious methodology to establish localised housing targets. While the impact that this may have on future new developments is recognised, this has not been directly reflected in the analysis, as it is still in the consultation phase. The DFES modelling does, instead, use the most recently compiled ONS housing projections and historical buildout rates for each scenario.
- In the North of Scotland licence area, the local authorities with the highest number of new homes projected by 2050 are: Aberdeenshire (24,007), Highland (17,712) and Aberdeen City (17,136).
- Notable non-domestic sites projected to be built in each of the DFES scenarios include the deepwater port in Stornoway bay[36], a spaceport in Scolpaig[37] and the expansion of the Barra Airport terminal[38] on the Isle of Barra. Notable non-domestic sites projected in the DFES scenario analysis include the deepwater port in Stornoway bay[39], a spaceport in Scolpaig[40] and the expansion of the Barra Airport terminal[41] on the Isle of Barra.

Note: all new development projection graphs are displayed on a cumulative basis (whereas for DFES 2023 the same projections were displayed as non-cumulative). This is to ensure consistency across the DFES 2024 projections by aligning the format of the projection graphs for each technology so that they are all displayed with cumulative totals.





5.5.2. Modelling and outcomes

Baseline

Scale	Capacity (MW)	Sites	Description
The analysis of new developments in the DFES focuses on additional future domestic and non-domestic buildings. Therefore, no baseline is defined for this technology.			

Pipeline

Source: Local authority engagement and local planning portals

Status	Number of domestic sites (homes)	Number of non-domestic sites (sqm)	Description
Total	618 (86,519)	552 9,671,781)	These sites were identified through direct engagement with local authority planning departments and an analysis of local planning documents submitted to Regen via a SharePoint data exchange. DFES 2024 had updates from 50% of local authorities' domestic data and 29% of local authorities' non-domestic data.
Buildout provided	423 (64,443)	416 (8,446,754)	These sites are modelled according to proposed buildout rates provided by the local authority.
Sites with no buildout information provided by local authorities			
Under construction	7 (293)	2 (61,389)	Sites that have been identified as under construction are modelled to build out in 2025 under all scenarios.
Planning permission granted	19 (2,157)	28 (87,715)	Approved planning permission is strong evidence that a site is moving towards construction. All new development sites which have been granted planning permission are modelled to connect to the distribution network between 2026 and 2028.

Planning application submitted	0	3 (4,925)	A submitted planning application demonstrates a development site has been identified and progressed but is waiting for approval from the local authority. These sites are modelled to connect between 2029 and 2032.
Allocated/ pre-planning	169 (19,626)	103 (906,997)	Allocated and pre-planning sites are those typically identified by local authorities as areas for specific development. As allocated sites are often not yet at the full planning stage, they are the latest sites modelled to connect, doing so between 2030 and 2033.

Scenario projections

Post-pipeline projections are only modelled for domestic new developments due to there being no reliable data sources for non-domestic building targets. The ONS household projections provide a baseline to model future domestic housing numbers for specific localities.

Scenario	2030	2050	Description
Holistic Transition	Domestic (homes)		Under this scenario, domestic and non-domestic sites are modelled to connect at the earliest possible date based on their development stage. In addition to the planned development sites, ONS household projections from 2018 are used to uplift long-term projections out to 2050. A 16% increase over the yearly ONS projections is added to this scenario, based on analysis of building rates over the last 10 years. This reflects the increase in low carbon technologies (including EV chargers, rooftop solar PV and electrified heating technologies) that is expected to occur at new developments under this scenario.
	41,478	103,065	
	Non-domestic (sqm)		
	5,668,195	9,671,781	
Electric Engagement	Domestic (homes)		This scenario is modelled to reflect a moderate range of new builds for both domestic and non-domestic developments. The **Electric**

	37,841	100,157	**Engagement** scenario uses the fastest build-out rate, the same as **Holistic Transition**. In addition to the planned development sites, ONS household projections from 2018 are used to uplift the long-term projections. This scenario is also modelled to reflect less ambitious yearly buildouts, aligned to below the average of historic yearly builds. This reflects the increase in low carbon technologies (including EV chargers, rooftop solar and heating technologies) that are expected to occur at new developments under the **Electric Engagement** scenario.
	Non-domestic (sqm)		
	5,049,299	9,671,781	
Hydrogen Evolution	Domestic (homes)		This scenario also models a moderate range of new builds for both domestic and non-domestic developments. Using the same ONS 2018 long-term uplift and alignment to average historic yearly build as **Electric Engagement**. **Hydrogen Evolution** uses a slower build-out rate, i.e. fewer homes connected per year.
	37,809	96,272	
	Non-domestic (sqm)		
	5,051,945	9,671,781	
Counter-factual	Domestic (homes)		This scenario models sites to build and connect at the slowest buildout rate and in the last year of the connection range in each case. In addition to the planned development sites, ONS household projections from 2018 are used to uplift the long-term projections. A 22% decrease over the yearly ONS projections is applied to this scenario, based on analysis of building rates over the last 10 years. This scenario is the only one that does not connect every home provided by local authorities, with some allocated sites not assumed to be completed by 2050.
	32,806	94,204	
	Non-domestic (sqm)		
	3,526,911	9,671,781	

Spatial factors

The below factors are used to inform the spatial distribution of domestic and non-domestic new developments across the North of Scotland licence area, down to 11 kV substations.

Factor	Description
Planned sites (Local authority SharePoint)	Planned sites are located based on their address or the description of their location.
Housing density (Census 2011/2022)	Modelled sites (domestic properties only) are distributed across all areas, weighted to areas with moderate housing density such as town and city suburbs, as analysis of historic housing development shows these areas see higher levels of housebuilding than denser city centres or highly rural areas.

Stakeholder input

Stakeholder feedback	Impact on DFES analysis
Local authority data exchange	A central part of the new developments analysis relies on ongoing engagement with local authorities in the licence area. Seven local authorities in the North of Scotland licence area provided a domestic new development update and three provided a non-domestic new development update either via the data exchange portal or directly to the DFES project team. For the remaining local authorities, Regen's existing new developments project database was used.

5.5.3. Comparisons

Reconciliation to FES 2024

The outcomes of the DFES modelling have been compared against the FES 2024 outcomes for the same licence area.

- The FES scenarios do not include specific data 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 2024 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.
- As a result of these factors, the new developments outputs cannot be fully reconciled against the FES 2024 data.

Comparison to DFES 2023

- DFES 2024 has changed the method of assigning scenarios to local authority provided data. DFES 2023 did not use a range of connection years, based on site development status, but instead developments were assigned to scenarios based on historical build-out rates to benchmark future development. For sites where no buildout data was provided, the DFES 2024 analysis has used development status to assign the year buildout would commence. This change brings new development modelling in line with other technologies by using planning developments stages to assign connection years.
- The DFES 2024 domestic projections have increased by nearly 15% compared to the DFES 2023 in the licence area. The main driver for this increase is improved engagement and responses from local authorities this year with seven local authorities providing an updated domestic developments data. The resultant increase of 22,500 new homes was provided through direct local authority engagement and has been reflected in the DFES 2024 new housing modelling.
- There is no significant change in the non-domestic projections between DFES 2023 and DFES 2024.

Endnotes and references

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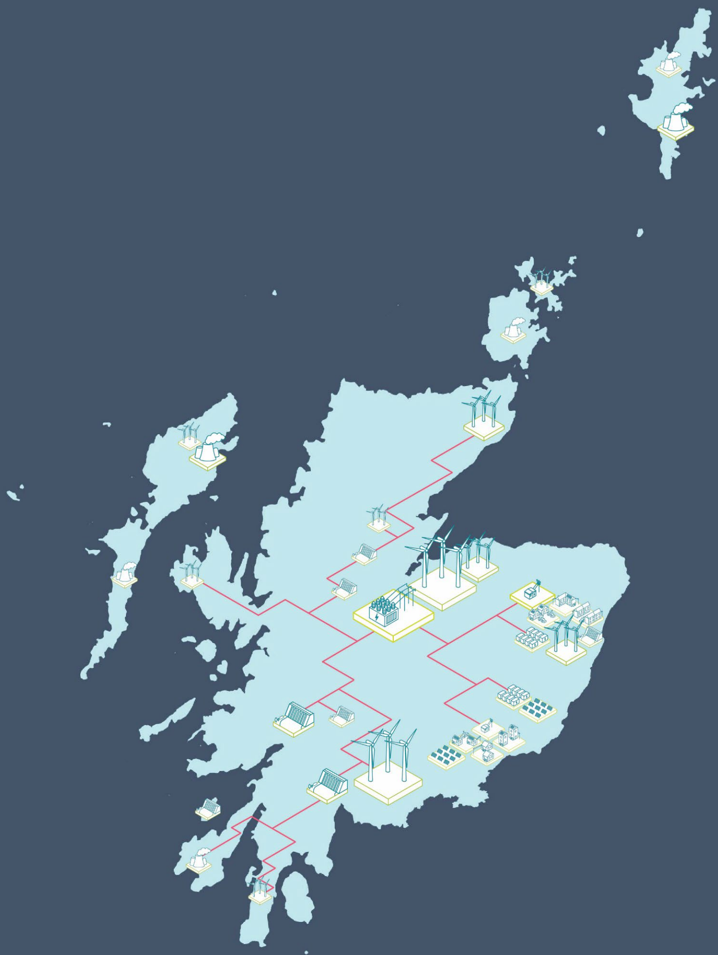

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