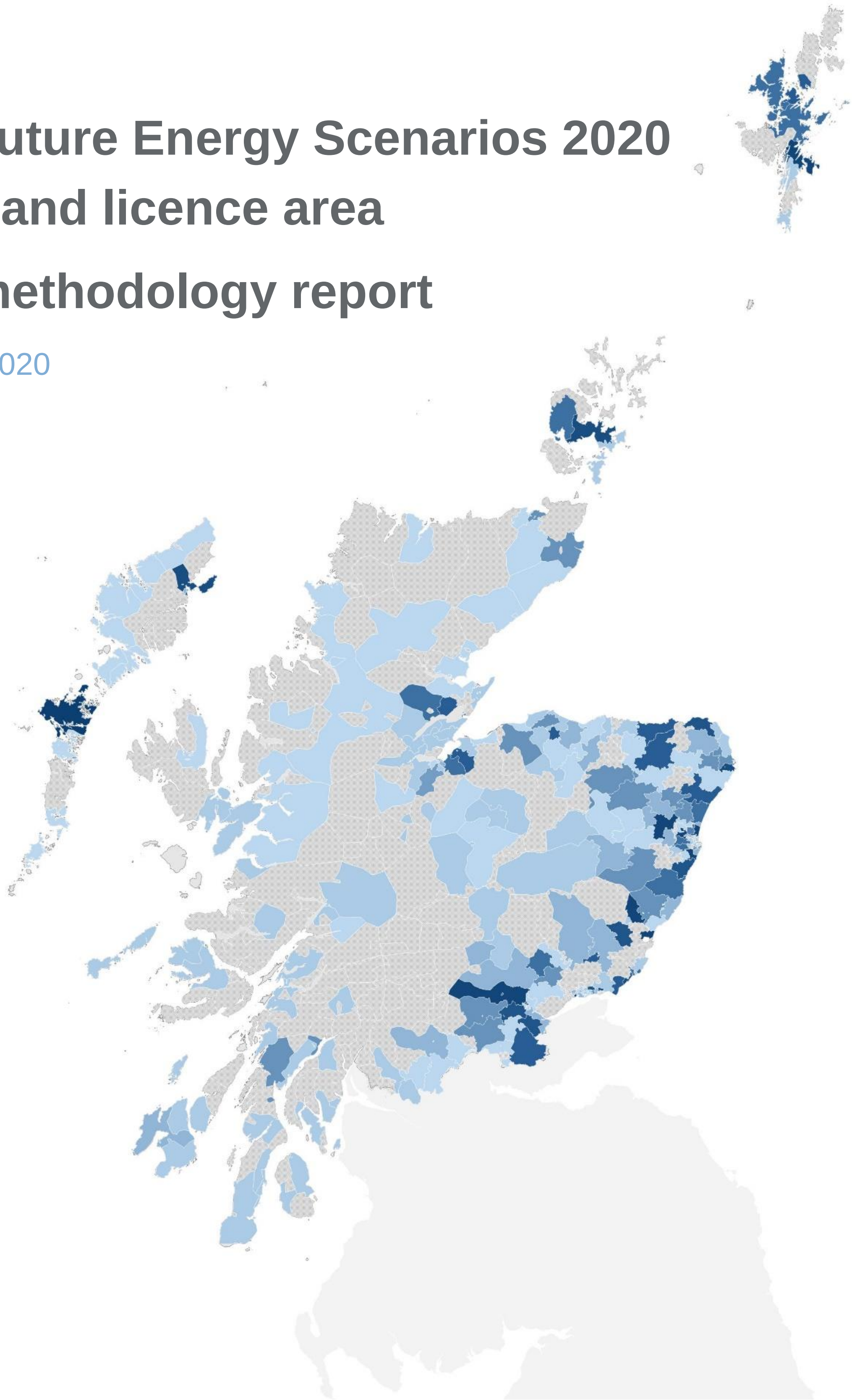
Distribution Future Energy Scenarios 2020
North of Scotland licence area
Results and methodology report

Produced: December 2020

Version: Final



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Analysis and report by:	Ray Arrell, Jonty Haynes, Frankie Mayo, Grace Millman, Ben Robertson, Joel Venn, and Sophie Whinney
Approved by:	 Johnny Gowdy, Project Director
	Regen, Bradninch Court, Castle St, Exeter EX4 3PL Regen is a trading name of the company Regen SW registered number: 04554636

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Foreword

Scottish and Southern Electricity Networks (SSEN) is responsible for the safe supply of electricity to over 8 million people in 3.8 million homes in the north of Scotland and central southern England.

As part of SSE Group, SSEN is a principle partner of the UK Government's hosting of COP26 the international climate change summit scheduled to take place in 2021, that will have a key role in focusing and driving international decarbonisation efforts.

Climate change is an international problem that requires local solutions. The transition to net zero will tangibly change how our customers experience and engage with the energy system that serves them. The UK and Scottish Governments have demonstrated the leadership that this challenge demands with respective 2050 and 2045 net zero targets. SSEN is committed to supporting these ambitions and enabling the action that is required.

According to the Climate Change Committee's 6th Carbon Budget, electricity demand could treble by 2050. The work REGEN has undertaken in this and previous reports for SSEN has been invaluable in supporting informed decision making and targeting investment. The data gathered and set out here highlights the action that the net zero ambition requires and the pace of change we can expect.

The ban of the sale of new diesel and petrol vehicles by 2030 and the target of installing 600,000 heat pumps a year by 2028 will make a significant impact in reducing the carbon impact of two of the UK's largest emitting sectors.

The next regulatory price control period for distribution networks (RIIO-ED2 2023-28) will have a crucial role in enabling the changes this report sets out. We are constructively engaging with Ofgem to support a settlement that empowers local communities, enables strategic investment and supports a cost-effective transition to net zero.

The sharing of data will be critical on this journey. Open data can be a catalyst to securing change, empowering customers and service providers that enables informed decision making across the energy ecosystem. We will be seeking to use this report to direct and inform conversations with our customers and key stakeholders.

SSEN is working with local communities and local authorities in understanding their net zero ambitions and how we can support and enable the realisation of their goals. This report has a key role in informing and directing those conversations. It sets the path that we, and the communities we serve, need to take to play our role in meeting the UK's net zero ambitions.

For SSEN net zero means: accommodating substantial numbers of electric vehicles, heat pumps and a range of other smart and low-carbon technologies; supporting the development of new markets that provide flexibility solutions that enables a cost-effective transition; and working collaboratively with our customers to ensure their needs are accounted for and met to deliver an equitable net zero future.

I'd like to thank Regen for their work on this illuminating and timely report, and to thank all our stakeholders, including local and regional authorities, who have contributed to the research. We hope it will add to the body of knowledge and evidence needed to turn net zero ambitions into action.

Andrew Roper, DSO Director, SSEN

Introduction

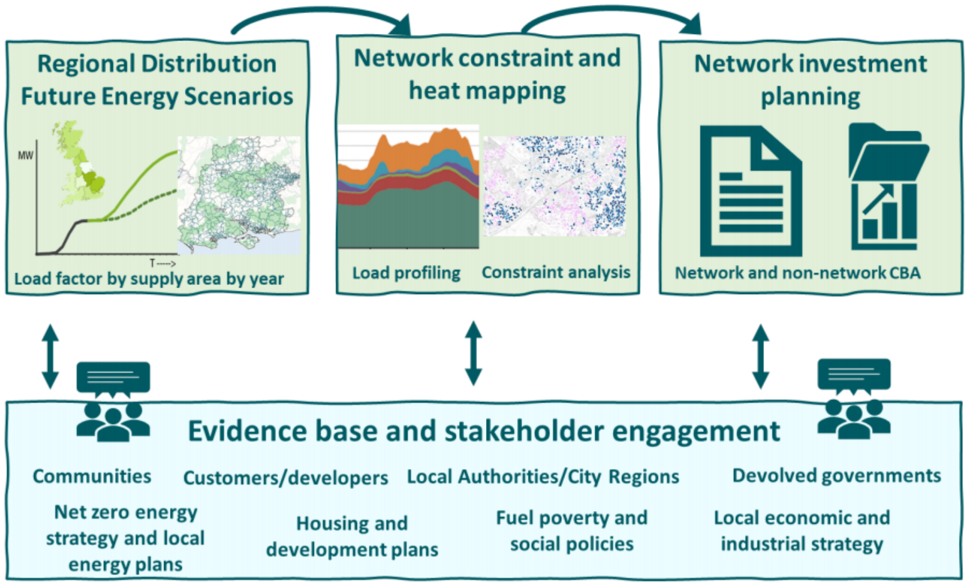
This report provides a summary of the methodology and results of the 2020 edition of the Distribution Future Energy Scenarios (DFES) for the North of Scotland electricity distribution network licence area[1], operated by Scottish and Southern Electricity Networks (SSEN).

DFES analysis produces granular scenario projections for the increase (or reduction) of the electricity distribution network connected capacity of electricity generation, storage and low carbon demand technologies. The SSEN DFES 2020 analysis also includes projections for new housing growth and new commercial and industrial developments.

As its framework, the DFES uses a set of four national energy scenarios based on the National Grid ESO Future Energy Scenarios (ESO FES) 2020 publication. The DFES projections are however heavily influenced by input by local and regional stakeholders, including local authorities and the Scottish Government, regional growth factors and a detailed analysis of the pipeline of projects and developments within SSEN's North of Scotland licence area. The DFES therefore provides a more granular and "bottom-up" assessment of the impact of changes to the energy system and the transition to net zero.

For SSEN, the DFES analysis supports network development planning[2], network constraint analysis and future investment appraisal. DFES data sets allow network planners to model and analyse a range of potential future load scenarios. They also provide an evidence base to enable network strategy teams to appraise different investment options, including the use of flexibility services. The 2020 DFES analysis is being used to provide an evidence base and set of scenarios to engage with local authorities, key stakeholders and customers in the development of SSEN's RIIO[3] ED2 business plan submission to Ofgem.

DFES scenario projections represent a range of potential outcomes which, subject to a number of uncertainties, can be expected to change over time. However by completing annual reviews of the DFES, and through extensive stakeholder engagement, energy networks can build up a picture of how energy consumption, generation, and the uptake of new low carbon technologies is changing as the UK transitions to a net zero energy system.



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[1] Also referred to as the Scottish Hydro Electricity Power Distribution (SHEPD) licence area
[2] Network Development Planning is a statutory responsibility for the networks under EU Electricity Directive 2019/944.
[3] RIIO "Revenue = Incentives+Innovation+Outputs" regulatory review process that determines energy network expenditure and investment in GB. The next RII0 ED2 period runs from 2023-2028

Reflecting uncertainty in the DFES analysis

During the stakeholder engagement process that has supported the development of the SSEN 2020 DFES analysis, several questions were raised regarding the degree of uncertainty and risk that accompanies the DFES projections. The question of projection uncertainty has become particularly pertinent in relation to how the DFES scenario projections might feed into the development of SSEN's business case for the RIIO-ED2 business plan submission and the use of budget uncertainty mechanisms.

Over the near term the DFES projections are heavily influenced by the pipeline of projects and new developments that can be identified in; the planning system, SSEN's connection database and by direct discussion with developers and stakeholders. Over the medium and longer term the projections will tend to reflect the underlying scenario assumptions and degrees of certainty supported by regional and national policies.

At a high level DFES projections are subject to a number of areas of uncertainty, including:

1. National Grid ESO FES scenario range of outcomes
2. National and devolved government policy uncertainty
3. Regional policy and local factors
4. Commercial uncertainty
5. Technology development uncertainty
6. Consumer adoption and behaviour uncertainty
7. Local distribution factors
8. Transmission vs distribution network connection uncertainty

Whilst it is important to highlight these areas of uncertainty, it is also important to recognise the counterfactor, that the future of energy in the UK and Scotland is becoming more certain with the adoption of legally binding decarbonisation targets and the emergence of a more coherent energy strategy. For example, during the course of the SSEN DFES analysis the UK government has firmed up its commitment to ban the sale of petrol and diesel engine vehicles by 2030. This has greatly increased the certainty of a higher growth projection for electric vehicles. In Scotland, policy announcements backed by regional decarbonisation programmes, are helping to set a clearer pathway for the energy industry.

When assessing the uncertainty of future energy scenarios, some key underlying assumptions have been made:

- Renewable energy generation capacity is very likely to significantly increase
- Unabated fossil fuel electricity generation is very likely to continue to decline
- The shift to more decentralised energy assets will continue to some degree
- The electrification of transport is already in progress and will accelerate
- Hydrogen has a key role to play for industrial processes and some forms of transport
- Further energy efficiency deployment is vitally needed in both homes and businesses
- The electrification of heat will increase although there remains a key uncertainty over the role that hydrogen boilers could play

At an individual technology level uncertainty is considered as a key part of the analysis and is reflected in the range of scenario outcomes presented. Specific uncertainties, and assumptions that have been made, are identified within each of the technology summary sheets. A summary uncertainty rating of the main generation, storage and demand technologies in the scope of the modelling is shown in Figure 1.

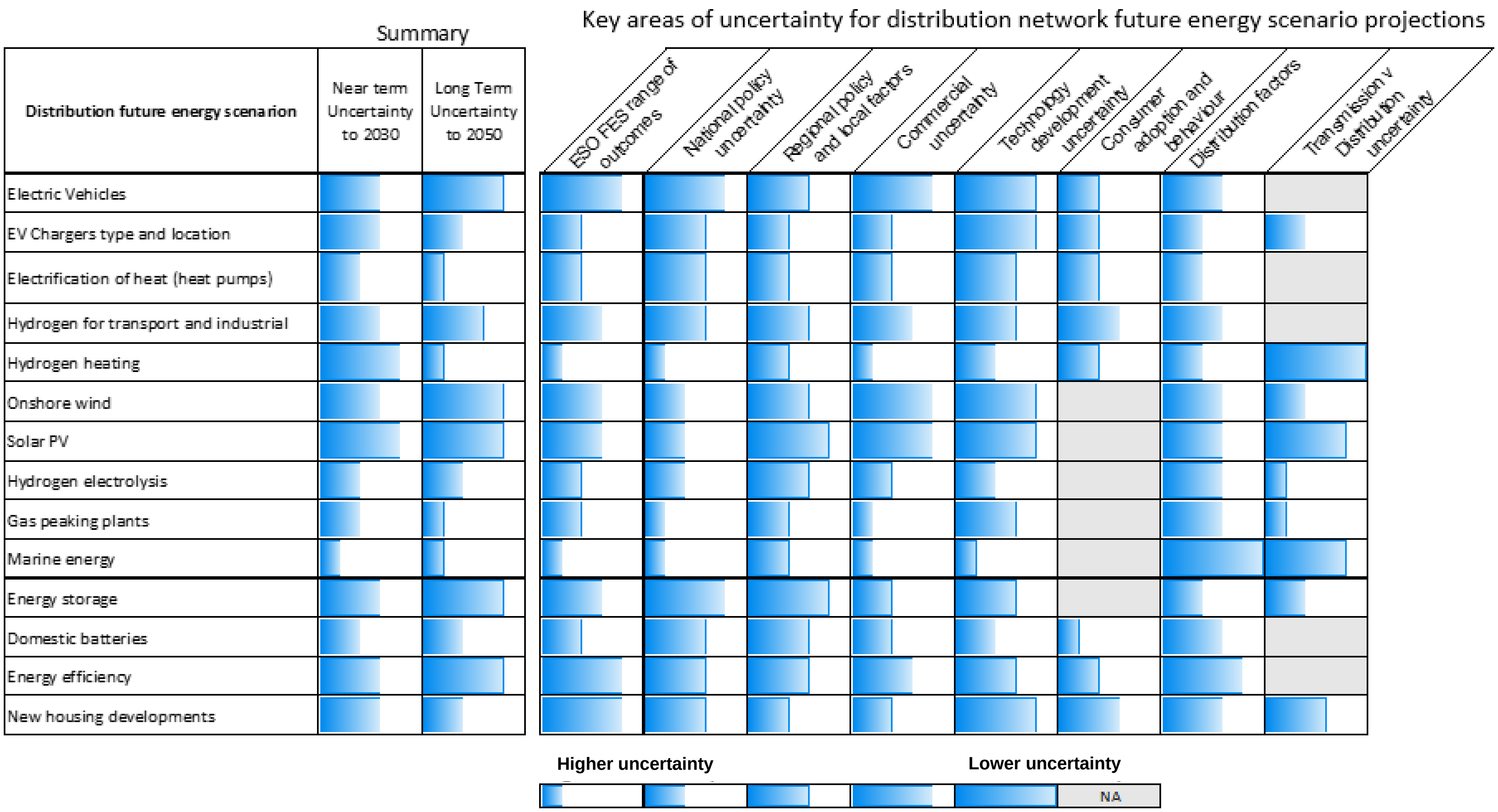


Figure 1 SSEN DFES 2020 technology uncertainty matrix

Distribution Future Energy Scenarios (DFES) methodology

The overall DFES methodology can be summarised under four key headings:

- The **technologies** that are in the scope of the future scenario analysis
- The **scenario framework** that is being used to frame the societal, technological and economic 'worlds' that the projections sit within
- The **analysis stages** that are applied to each technology when modelling scenarios
- The **geographical distribution** of the projections down to sub-regional or local levels

Technologies in-scope

The technology scope of the SSEN DFES includes those technologies and load sources that directly connect to SSEN's electricity distribution network in the North of Scotland as summarised in Table 1. The DFES scope does not include projections for technologies connected to the Scottish transmission networks.

Table 1 DFES Technologies and demand sources

Electricity generation technology classes	Electricity storage technology classes	Key new sources of electricity demand
Renewable energy generation technologies: solar PV, onshore wind, offshore wind, hydropower and marine. **Waste and bio-resource electricity generation** technologies: biomass, sewage gas and anaerobic digestion from other feedstocks. **Fossil-fuel electricity generation** technologies: diesel and natural gas.	**Battery Storage** Commercial and domestic scale battery storage technologies	**Electric vehicles**: cars, vans, motorbikes, LGVs, HGVs and buses **Electric vehicle chargers**: on-street residential, off-street domestic, car parks, destination, workplace, fleet/depot, en-route local and en-route national **Electricity fueled heating technologies:** air source and ground source heat pumps, hybrid heating and direct electric heaters. **Hydrogen electrolysis** **New property developments:** strategic housing developments and commercial and industrial developments.

The National Grid FES 2020 framework

The SSEN DFES 2020 has used the National Grid ESO Future Energy Scenarios 2020[4] (FES 2020) as the overarching framework to base the analysis upon. As well as providing a scenario framework the FES 2020 has been used to provide a basis for national level assumptions and growth projections, and for the technology definitions using the industry standard "Building Block" definitions.

Where available FES 2020 regional, grid supply point (GSP), projections have been used to inform the SSEN DFES, and provide a SSEN DFES to FES 2020 reconciliation for each of the technology building blocks.

The FES 2020 scenario framework is based on two key axis; the speed of decarbonisation and the level of societal change as outlined in Figure 2 and Table 2.

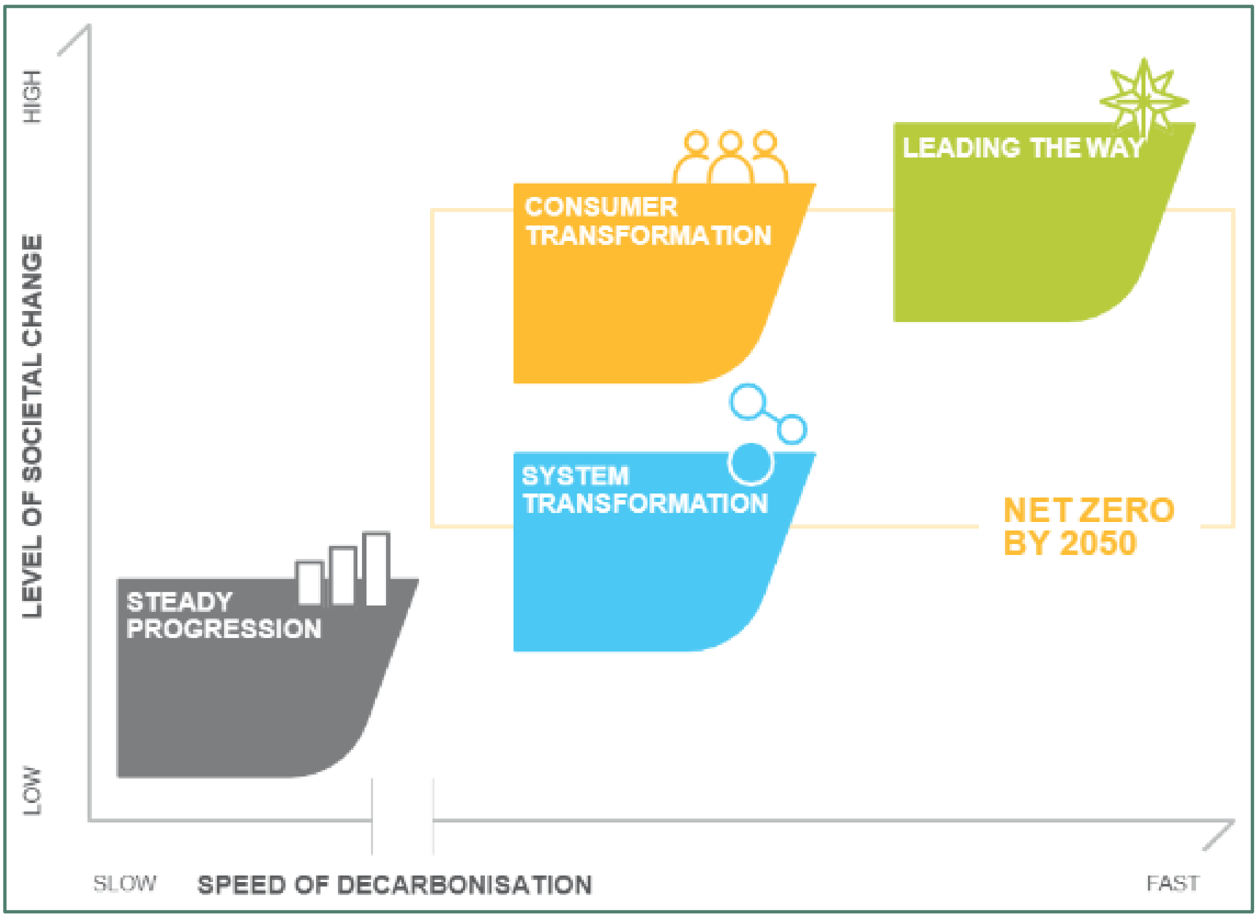


Figure 2 National Grid ESO Future Energy Scenarios 2020 scenario framework

[4] FES 2020 https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

Table 2 National Grid ESO FES 2020 high level scenario descriptions

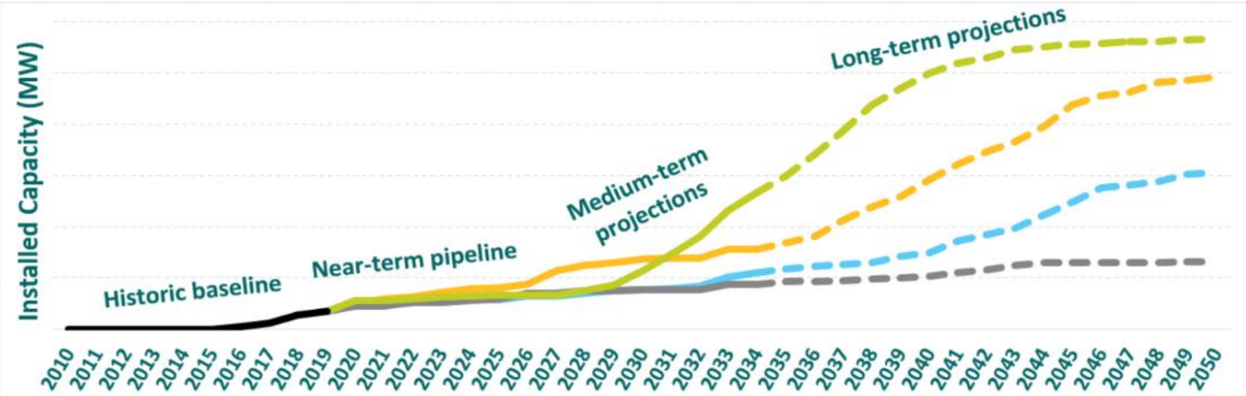
National Grid ESO FES 2020 Scenario	High level scenario description
Steady Progression Does not meets GB net zero targets by 2050	Overall low levels of decarbonisation and societal change. • Uptake of low carbon/renewable generation along current trends • Slower uptake of EVs and heat pumps • Some continued use of unabated fossil fuels • A lower uptake of electricity storage
System Transformation Meets GB net zero targets by 2050	High level of decarbonisation with lower societal change. Larger, more centralised solutions are developed. • Highest levels of hydrogen deployment for heating as well as transport and industrial use • Most hydrogen is produced via Steam Methane Reformation (SMR) with Carbon Capture Utilisation and Storage (CCUS) • Focus on transmission-scale low carbon generation such as offshore wind and nuclear • Practically no uptake of domestic batteries
Consumer Transformation Meets GB net zero targets by 2050	High levels of decarbonisation and societal change. Consumers adopt new technologies rapidly, and more decentralised solutions are developed. • Rapid uptake of EVs, low carbon technologies and energy efficiency • Significant electrification of domestic heat and commercial heat • Low carbon electricity generation more distributed, with high amounts of onshore wind and solar PV
Leading the Way Meets GB net zero targets by 2048	Very high levels of decarbonisation and societal change. Consumers adopt new technologies rapidly, and a mix of solutions is developed. This scenario aims for the “fastest credible” decarbonisation pathway. • Combines some of the features of both Consumer Transformation and System Transformation for low carbon generation and electric vehicles • Large volumes of hydrogen produced purely through electrolysis • Ambitious energy outcomes such as the widespread uptake of autonomous vehicles, hybrid heat pumps and also domestic energy storage

DFES analysis stages

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

1. Determines the **historic deployment** and establishes the **existing baseline** of operational or connected projects
2. Assesses the **near-term development pipeline**, recording and reviewing projects with connection offers or planning applications. For technologies with a high degree of pipeline evidence the range of outcomes between the scenarios may be quite narrow
3. Develops **medium and long term projections** out to 2050, with depending on the technology a much higher level of variation across the four scenario results.
4. **Geographically distributes** these annual, scenario-specific projections across the licence areas.

There is a potentially notable level of scenario variation, which increases as time moves on, again depending on the technology. This results in a widening of total projected outcomes (in MW or number) across the four scenario results.



Granularity and geographical distribution of the DFES

Larger scale generation and storage technologies have been distributed down to Electricity Supply Areas (ESAs) which have in the main been defined at the 11 kV primary substation level.

In the North of Scotland licence area this has led to a distribution to approximately 500 individual ESAs, which in urban areas such as Dundee or Aberdeen would equate to a group of post codes or small borough, while in rural areas, this could equate to a wider area covering part of a county. ESA level data can then be aggregated up to support network analysis at higher voltage levels, or to provide data aggregated to local authorities or other regional boundaries. See Figure 3.

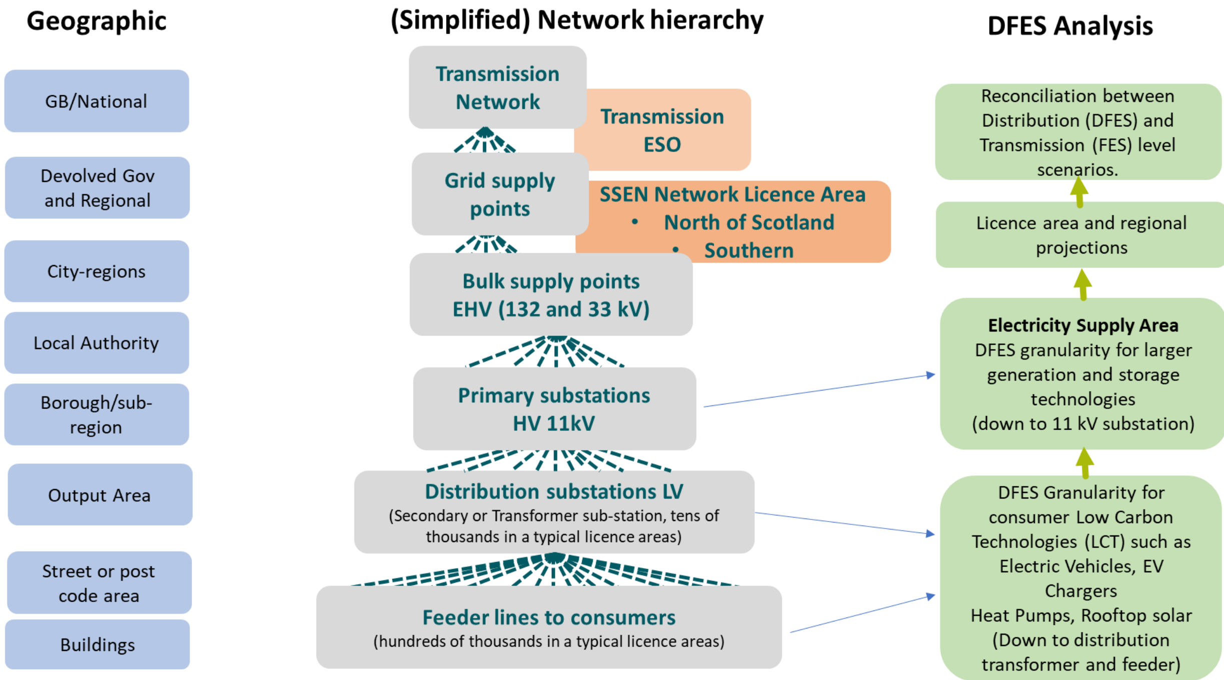


Figure 3 DFES granularity at different network hierarchy levels and corresponding regional & geographic areas

Low carbon technologies at the low voltage distribution sub-station and feeder level

For SSEN DFES 2020, the scenario projections for a number of Low Carbon Technologies (LCTs) have been distributed with much more granularity down to the level of secondary distribution “transformer” sub-station, or to individual LV feeder lines which serve individual or small groups of consumers. This level of granularity corresponds roughly to a post code or street level analysis.

The SSEN DFES LCTs have been distributed to secondary sub-station and feeder line level. The distribution of scenario forecasts, with annualised projections to 2050, to this low level of granularity required the handling of data files with hundreds of millions of individual records. Scenario projections at this low level of detail have also been aggregated within the ESA level datasets.

The apparent preciseness of this very granular analysis should be treated with caution, especially looking out to 2050. The distribution of technology deployments are still based on some high level scenario assumptions and distribution factors. The detailed SSEN DFES datasets do however allow SSEN network planners to begin to model the potential impact of demand and technology changes on the low voltage network and to understand the scale and range of network reinforcement that might be needed.

The distribution factors that underpin the spatial analysis, which are described in more detail within each of the technology summary sheets, were based on data gathered from a wide range of datasets including Ordnance Survey Addressbase, DfT road traffic flow data, Census Output Area data including affluence and demographic data, postcode statistical data, and individual property EPC data.

Use of affluence as a key distribution factor and implications for the equitable access to low carbon technology

The distribution analysis uses affluence as one of the key factors driving the uptake of low carbon technologies. This is based on previous new technology deployment trends and empirical evidence that the uptake of low carbon technology has, to date, tended towards more affluent areas. For EVs, it is also based on the very practical consideration that, in the near term at least, the availability of off-road parking is a key driver for EV adoption.

The assumption that affluence will be a key driver for LCT adoption does, however, need to be applied with caution, especially in relation to network investment. There is a risk that, if affluence is given too much significance, network investment will be channelled to more affluent areas which would then create inequitable access to LCT for the future. There is also a risk that networks may underestimate the impacts of other factors which may actively counter balance affluence, for example the actions of local authorities and social housing providers to encourage LCT uptake in less affluent areas, as is already seen in relation to public charge point provision in Scotland. In the case of EVs, there is also a strong argument that the initial cost barrier will be superseded as EV capital costs reduce and EV driving (with lower running costs) becomes the cheaper transport solution.

To provide a degree of balance in the analysis the following approach has been taken.

- Affluence is considered a key distribution factor in the short term for **Consumer Transformation** and **Leading the Way**. For the **Steady Progression** and **System Transformation** scenarios, which have lower social interventions, affluence remains a stronger driver in the medium term.
- Over the medium and longer term, for the higher ambition scenarios, the impact of the affluence distribution factor is reduced and an assumption is made that the deployment of LCT technologies will become more ubiquitous and will follow the underlying factors.
- For solar PV and heat pumps, the scenarios specifically include a social housing weighting factor to counter purely affluent areas. This social housing impact has previously been documented in Regen's DFES studies.
- For the more ambitious scenarios, from mid to late 2020s, the underlying assumption is that EVs will become ubiquitous. Therefore, the growth in demand for EVs in both on-street and off-street areas begins to increase at equivalent rates.

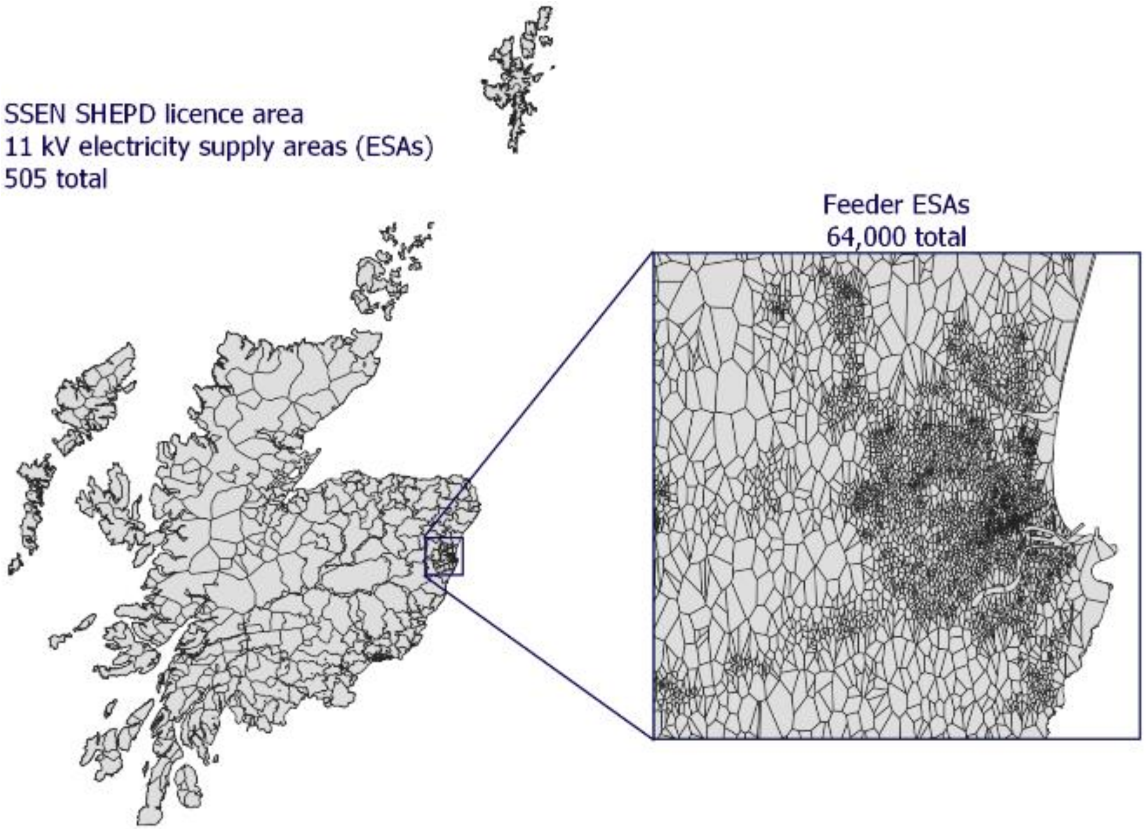
The impact of affluence on LCT uptake, and how the networks respond through network investment to ensure equitable access to new technology, is a key area for further research and should be considered as part of each network's stakeholder engagement, local area plans and RIIO-ED2 business planning. There may be a case for higher levels of network provision in less affluent areas, which is outside the scope of this study.

Table 3 SSEN DFES building blocks granularity of distribution

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

Technologies that are projected to 11kV ESAs

- Onshore wind
- Offshore wind
- Large-scale solar PV
- Hydropower
- Biomass generation
- Anaerobic digestion
- Sewage gas
- Landfill gas
- Energy from Waste
- ACT
- Gas generation
- Diesel generation
- Hydrogen generation
- Battery storage
- Hydrogen electrolysis
- Data centres
- Air conditioning



Technologies that are projected to LV Secondary substations and feeder lines

- Electric vehicles
- Electric vehicle chargers
- Heat pumps
- Direct electric heaters
- Rooftop solar PV

The SSEN North of Scotland Licence Area

The North of Scotland electricity distribution licence area covers the area served by the low voltage, 11kV and 33kV network in northern Scotland and the Scottish isles.

This area spans the southern borders of Perth and Kinross, Dunblane and Loch Lomand, to the Northern coast of Scotland and all of the Scottish Islands such as Shetland, Orkney, the Outer Hebrides and the Small Isles.

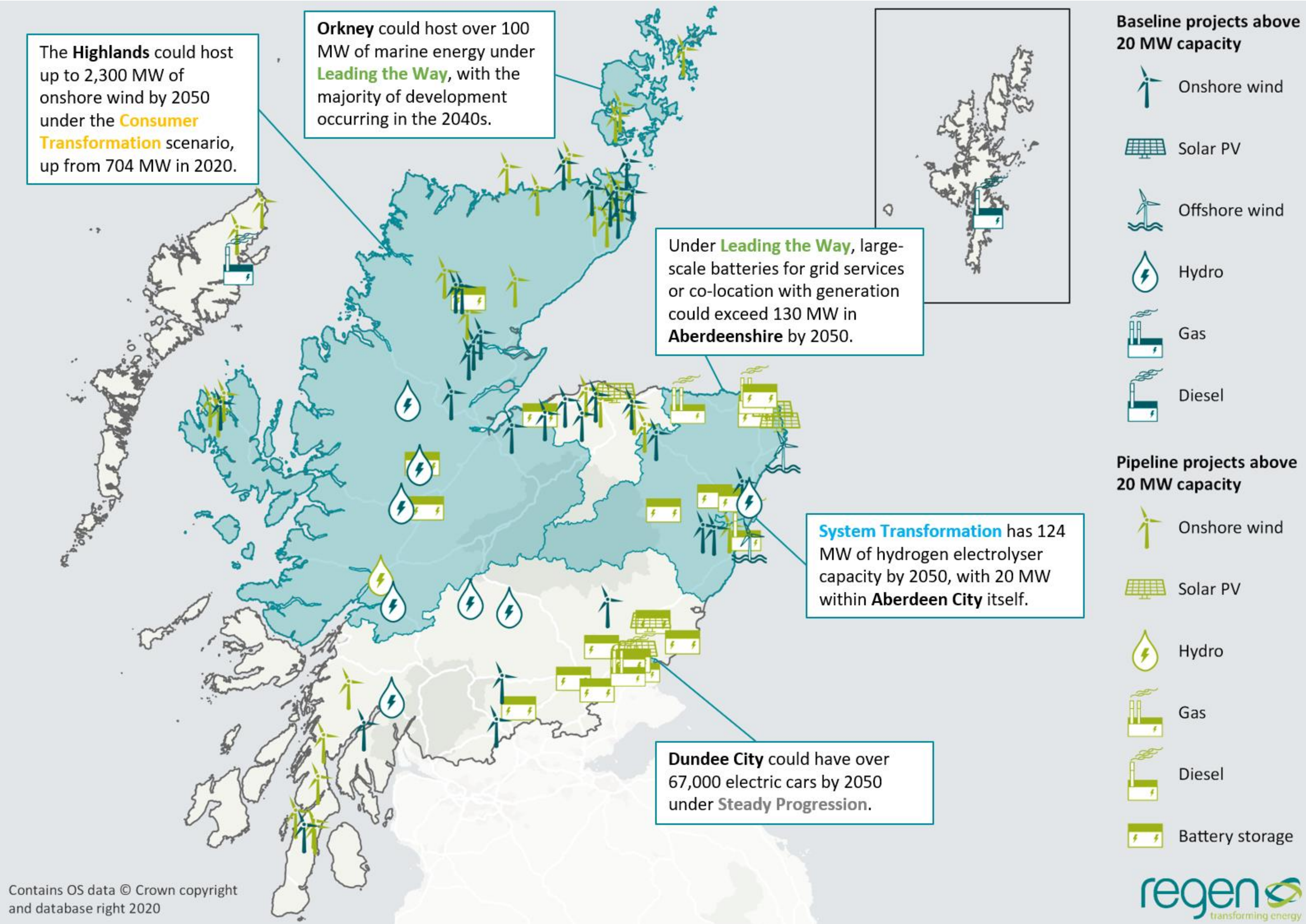
The licence area includes a significant number remote and rural areas, such as the Highlands, national parks such as the Cairngorms and the Trossachs, as well as a number of more urbanised areas such as Aberdeen, Dundee, Inverness and Fort William.

The licence area includes 14 local authority areas.

The total capacity of distributed electricity generation has steadily increased in the past 10 years to over 3.1 GW. This growth has been led by onshore wind development, with connected capacity increasing from 1 GW in 2011 to just over 2 GW of in 2019.

The licence area also hosts 32 MW of offshore wind connected to the distribution network and a notable amount of hydropower, with 807 MW connected in 2019 (an increase from 600 MW in 2011). The remaining capacity is made up from a number of back-up diesel generators (126 MW) supporting the Scottish islands, waste-drive generation variants (93 MW) and natural gas CHPs (53 MW). The largest generation site in the licence area is the 77 MW Clashindarroch onshore wind farm.

Electricity demand in the licence area can be considered atypical, with a disproportionately higher number of homes with electrically fuelled heating, due to significant regions of the licence area not connected to the gas network. The licence area is however beginning to reflect some of the potential energy transitions and low carbon technology adoptions, with just under 6,000 battery electric vehicles and plug-in hybrids registered in the licence area and c.12,000 homes and businesses with a type of heat pump installed.



The **Highlands** could host up to 2,300 MW of onshore wind by 2050 under the Consumer Transformation scenario, up from 704 MW in 2020.
Orkney could host over 100 MW of marine energy under Leading the Way, with the majority of development occurring in the 2040s.
Under Leading the Way, large-scale batteries for grid services or co-location with generation could exceed 130 MW in **Aberdeenshire** by 2050.
System Transformation has 124 MW of hydrogen electrolyser capacity by 2050, with 20 MW within **Aberdeen City** itself.
Dundee City could have over 67,000 electric cars by 2050 under Steady Progression.
Baseline projects above 20 MW capacity
Onshore wind
Solar PV
Offshore wind
Hydro
Gas
Diesel
Pipeline projects above 20 MW capacity
Onshore wind
Solar PV
Hydro
Gas
Diesel
Battery storage
regen
transforming energy

The North of Scotland DFES - 2050 projection headlines

By 2050, the scale and variety of technologies connected to the distribution network is significantly different than today:

Collectively distribution network connected solar, wind, hydro and marine generation capacity in the licence area increases by over 285% from just over 3 GW in 2019 to **c.8.8 GW** in 2050 in **Consumer Transformation**. This is predominantly onshore wind generation, which accounts for c.6.2 GW of connected capacity in 2050.
The capacity of distribution network waste-driven electricity generation in North Scotland evolves significantly by 2050. With all landfill gas generation decommissioning and **c.56 MW** of anaerobic digestion (from various feedstocks) is in operation by 2050 under the scenario **Leading the Way**.
Excluding the diesel generators that support the Scottish islands, the **74 MW** of fossil fuel generation disappears from the distribution network in all scenarios by 2050, bar some natural gas reciprocating engines in **Steady Progression**. Some **24 MW** of hydrogen fuelled generation is operating by 2050 in the **System Transformation** scenario.
Battery storage projects connecting to the distribution network hugely increases in all scenarios by 2050, reaching **c.1,200 MW** in the **Leading the Way** scenario, from a small baseline of 1.2 MW.
A huge number of electric vehicles will be on the road in the North of Scotland licence area, reaching between **800,000-900,000** in all scenarios within the 2040s. In the **Leading the Way** scenario, this equates to **c.560 MW** of electric vehicle charging capacity by 2050.
A huge number of domestic properties switch their heating technologies to low carbon alternatives by 2050. With **c.603,000 domestic properties** and **c.47,000 non-domestic properties** operating a type of heat pump under the **Consumer Transformation** scenario.
Under the **System Transformation** scenario, the capacity of hydrogen electrolysers connected to the distribution network in the North of Scotland licence area reaches **124 MW**.
c.112,000 new houses could be built and **11,200,000 m^2** of non-domestic floorspace could be developed by 2050 in all scenarios.

Three examples of low carbon technology projections at a local level

1) Electric Vehicles in Aberdeen

Aberdeen shows a good example of the potential distribution of domestic electric cars in a city and urban area. Low voltage feeder lines in inner city areas have a lower number of EV cars per household, reflecting a greater use of public transport and lower car ownership found in inner city areas. The proportion of electric cars per household is projected to increase as we move out to more residential and commuter areas with a higher proportion of homes with off-street parking. The **Steady Progression** scenario shown in Figure 4 actually has the slowest electric vehicle uptake, but even under this scenario by 2050 virtually all vehicles are zero carbon.

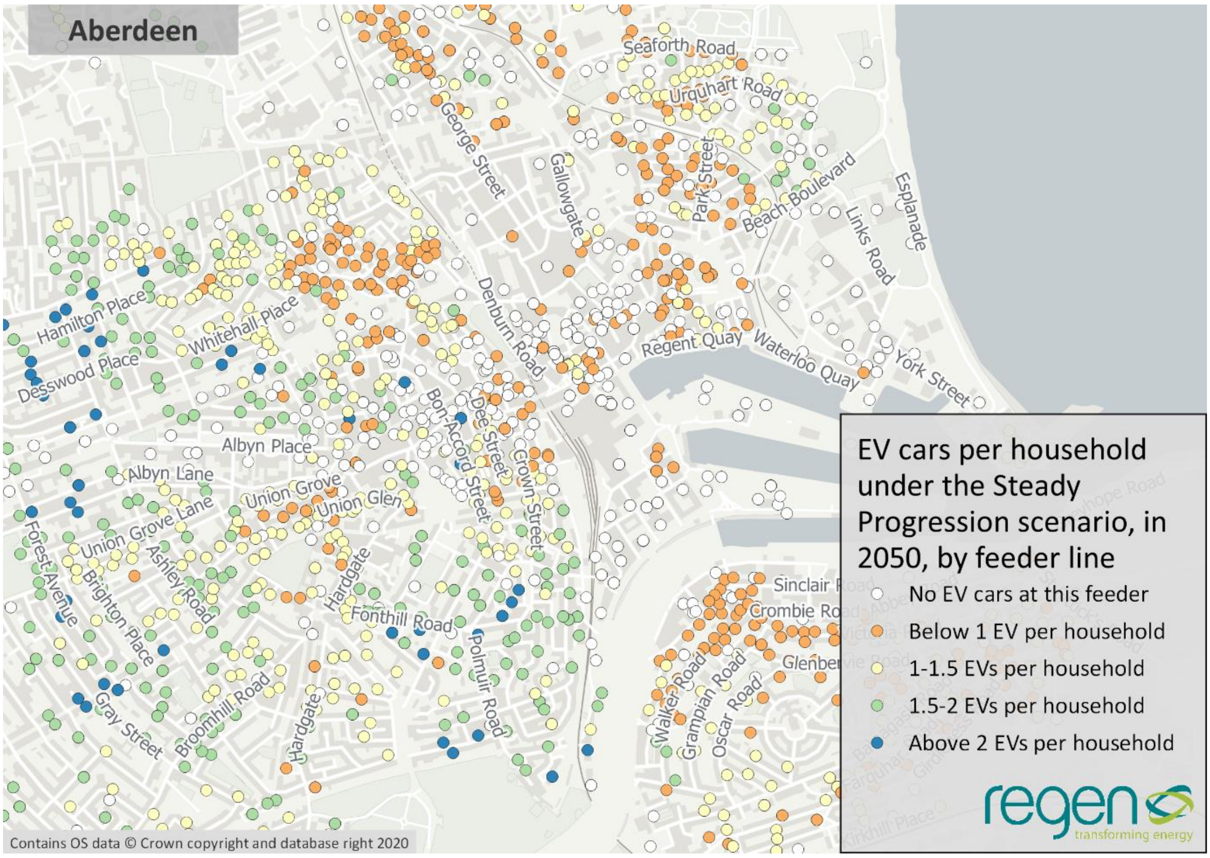


Figure 4 Electric Car distribution at feeder level in Aberdeen under a Steady Progression scenario

2) Heat pumps in Dundee

The **System Transformation** scenario assumes that a large number of existing on-gas consumers will switch to hydrogen as a main heating fuel, and that there will also be a higher number of hybrid heat pumps (using hydrogen as a back-up fuel).

This is reflected in the SSEN DFES distribution analysis which shows, for example, in Dundee, a higher rate of heat pump uptake in areas outside the city which are off-gas grid. Within the city there are however also some hotspot feeders with a high potential for heat pump deployment. These are typically properties which are off-gas and may be reliant on electric heating. They may also be multi occupancy and social housing properties that could be suitable for shared loop heat pump systems.

This level of high granularity projection analysis should be treated as illustrative and is subject to some uncertainty. Without doing a very detailed building stock analysis and also a heat plan for the city, it would be wrong to say with complete certainty which areas are likely to be decarbonised by heat pumps or hydrogen in 2050. The SSEN DFES analysis does however give network planners an initial dataset to begin to model the potential impacts of heat electrification across the low voltage network, and to quantify the likely scale of investment that would be needed.

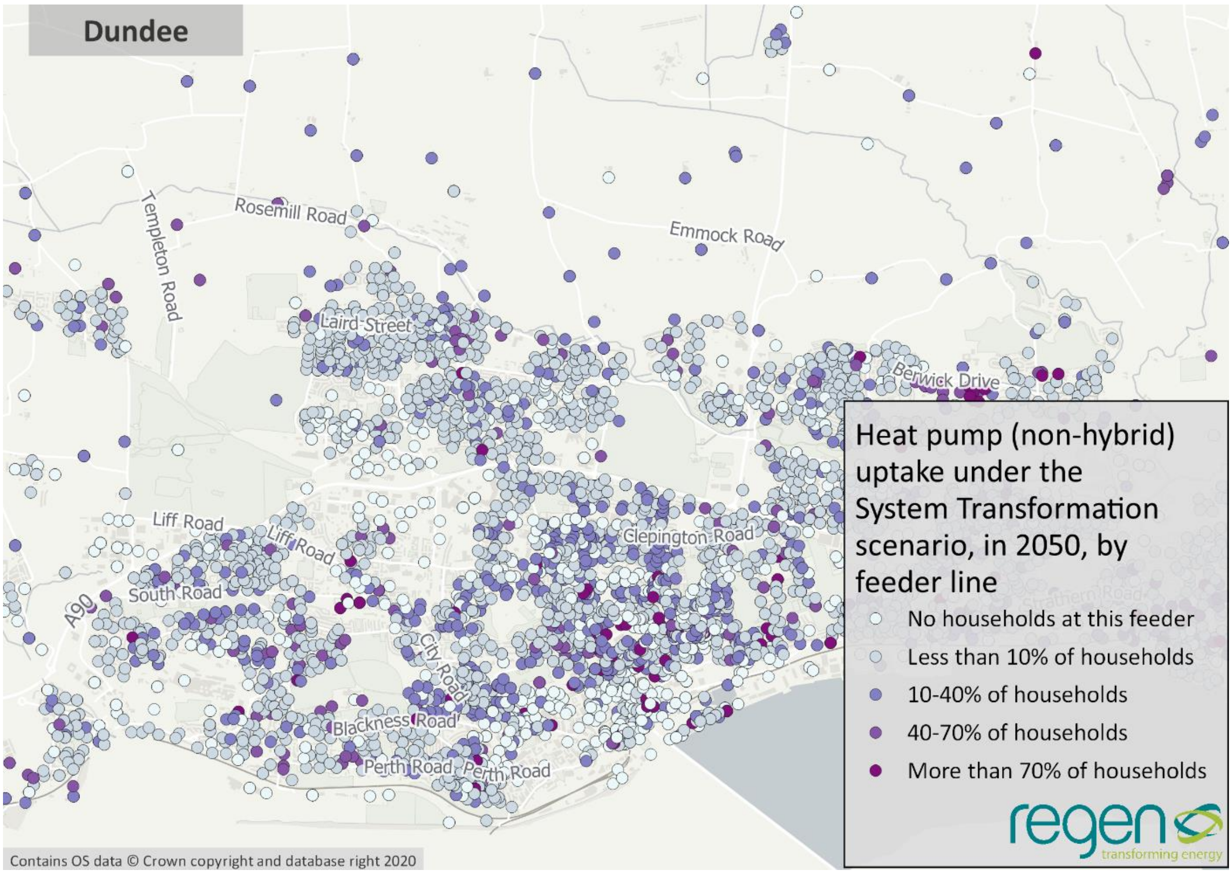


Figure 5 Heat Pump (non-hybrid) distribution in Dundee in 2050 under a System Transformation Scenario

3) Solar PV in Orkney

The **Consumer Transformation** scenario assumes a very high degree of decentralised and local energy generation. This includes a high level of deployment of rooftop solar, driven in part by falling solar prices as well as by a consumer led transformation towards self-generation and smarter local energy systems. While solar energy in the far North of Scotland may not be an obvious option, it is a scenario which could see deployment of rooftop solar in places like Orkney, helping to provide energy in the summertime when perhaps there is less wind power generation to charge electric vehicles and also for conversion to hydrogen.

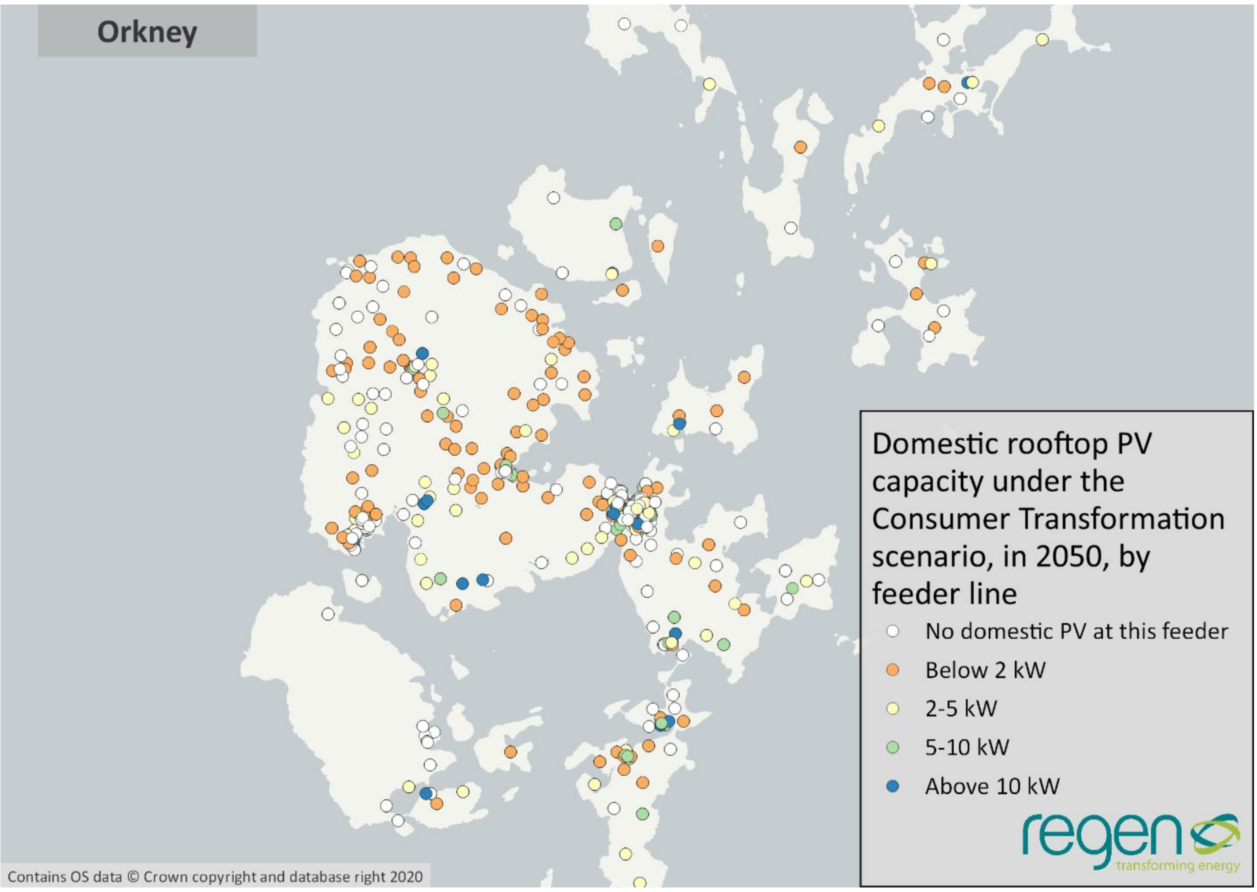


Figure 6 The potential for solar PV in Orkney in 2050 under a Consumer Transformation scenario

Stakeholder engagement

Although based on national energy scenarios, the DFES assessment is intended to be a locally-driven and evidenced-based analysis of the future energy scenario outcomes for a specific region. Stakeholder engagement and consultation is therefore critically important to inform the scenario modelling and test the future assumptions that have been made for the various building block technologies.

To inform the SSEN DFES 2020 analysis the project team has engaged stakeholders through a number of different approaches. These included:

A series of **interactive stakeholder webinars** delivered in August and September, working in collaboration with the SSEN team and the Energy Systems Catapult.

A **data exchange with all of the local authorities** in SSEN's two licence areas, via a SharePoint site, around new strategic housing and commercial developments.

A **local energy strategy survey**, completed by wider environmental teams within a number of the same local authorities.

A number of **technology-specific interviews** and calls with project developers, technology companies, energy sector experts and industry representatives.

For the North of Scotland licence area, a DFES workshop was held with officials from the **Scottish Government**.

Through engaging and consulting with a wide range of organisations and representatives the technology analysis leads were able to seek views and evidence around:

- Individual project development plans and timescales.
- Regional considerations for the potential uptake of specific technologies
- The viability of use cases and business models that would align with assumptions made around increased uptake or reduction of technologies connecting to the network.
- Specific regional policy, regulation and other decision making that could affect both the near-term and long-term trajectories for specific technologies, such as wind planning policy, electric vehicle charger deployment or heat pump uptake.

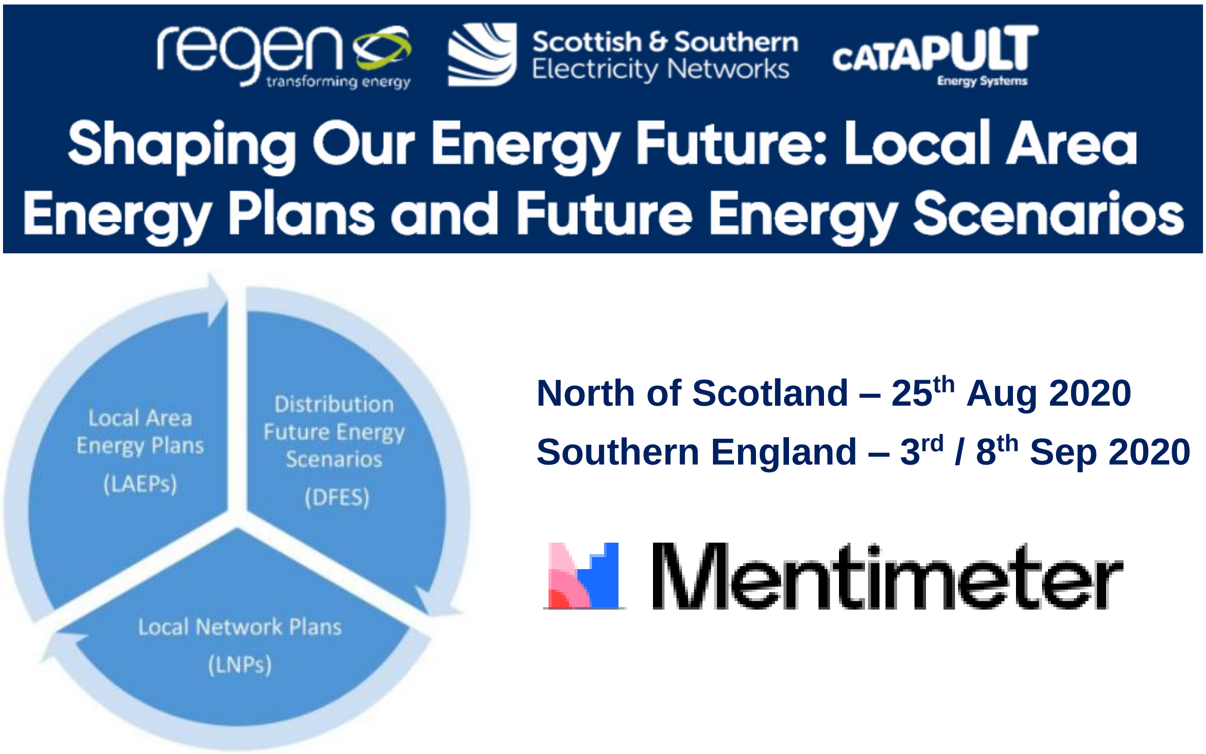
Regional engagement webinars

Regen, SSEN and the Energy Systems Catapult (ESC) delivered three regional engagement webinars across August and September 2020. These interactive and collaborative sessions sought to:

- Tap into stakeholders' local and domain knowledge and insights.
- Increase the understanding of local investment needs for the electricity system, future energy technologies and developments which will influence SSEN's plans for future network developments (including specifically for RIIO-ED2).
- Discuss the potential growth in connected capacity and location of future energy technologies and developments.
- Gauge views on the uptake of new or disruptive technologies, such as hydrogen electrolysis, EVs and heat pumps in the licence areas.

The event brought together a mixture of presentations from the SSEN team around the RIIO-ED2 and local energy plans, the LAEP approach from the ESC team and from Regen, seeking specific views around the key technologies for the 2020 regional DFES and LCT assessments.

As well as an overview of the high level methodology and building blocks that form the scope of the SSEN 2020 DFES and LCT, these events included a number of technology-specific polling sessions, via the online platform Mentimeter.



The North of Scotland webinar was attended by 70 stakeholders, representing a range of organisations across the energy industry. See Figure 7.

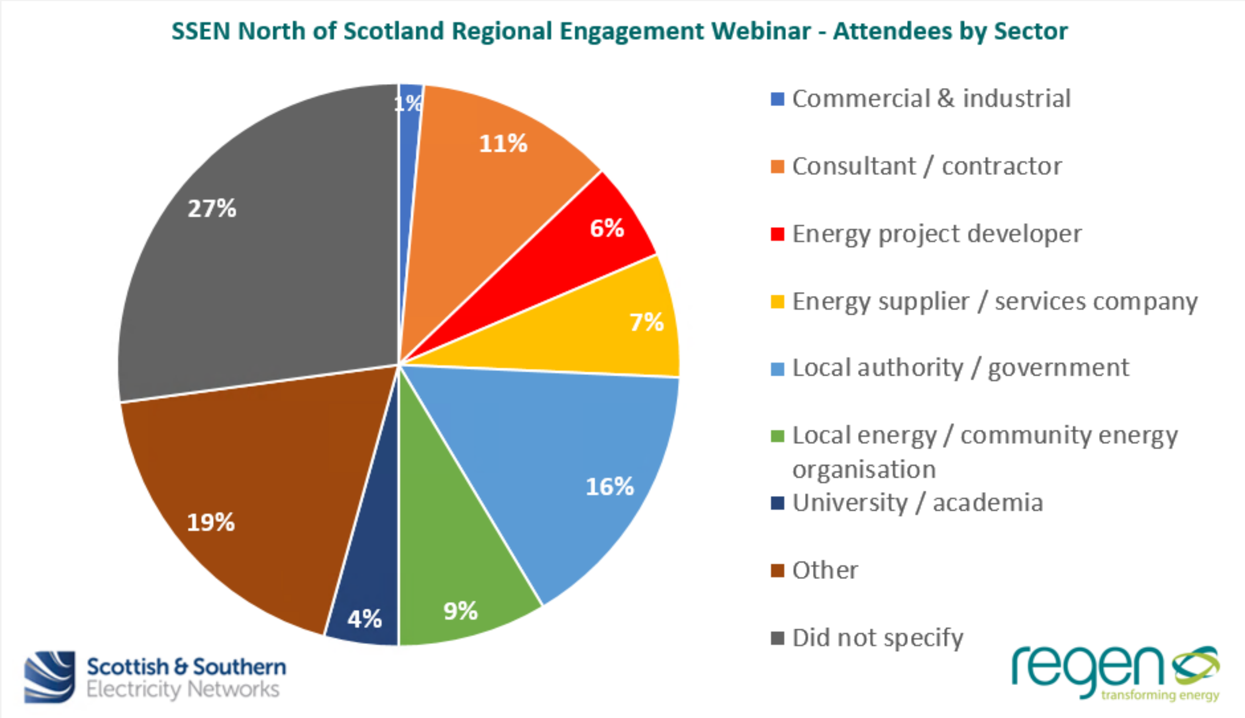


Figure 7 Split of attendees to DFES webinar in Aug 2020 by sector

The webinar attendees were asked a series of polling questions, seeking views on:

- The regional development of distribution network onshore wind generation
- Future battery storage project business models and locational deployment factors
- Future use cases for hydrogen, including hydrogen for heating, industry, electricity generation and hydrogen electrolysers
- The uptake of electric vehicles
- The ownership models for on-street EV charging infrastructure
- The viability of various low-carbon heating technologies for the licence area (e.g. heat pumps, hydrogen heating, hybrid heating systems, bio-fuels, biomethane and district heat networks)

The polling data obtained from Mentimeter, combined with commentary in the online chat function, enabled the analysis team to justify, refine or adjust many of the assumptions that underpinned the individual DFES technology modelling.

Polling results have been included within each technology summary sheet.

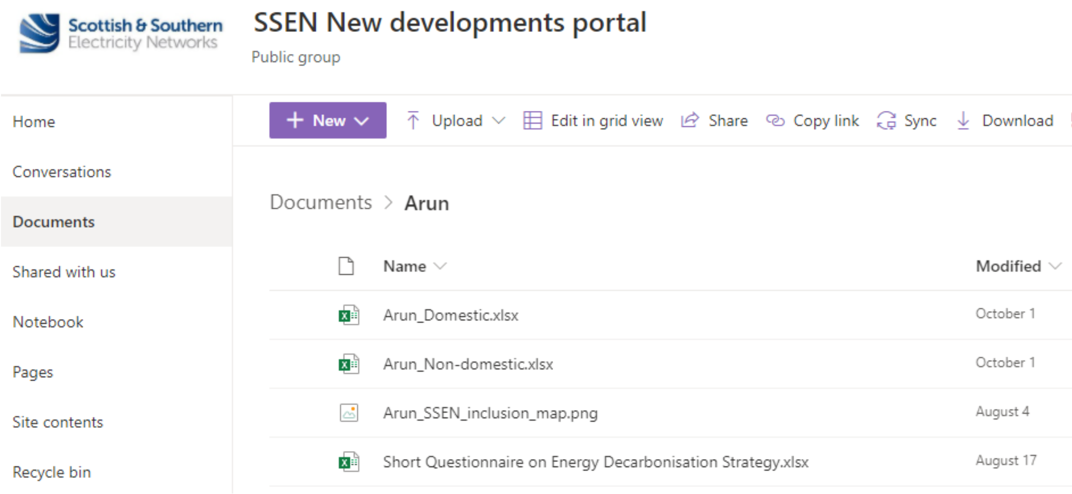
Local authority data exchange and survey

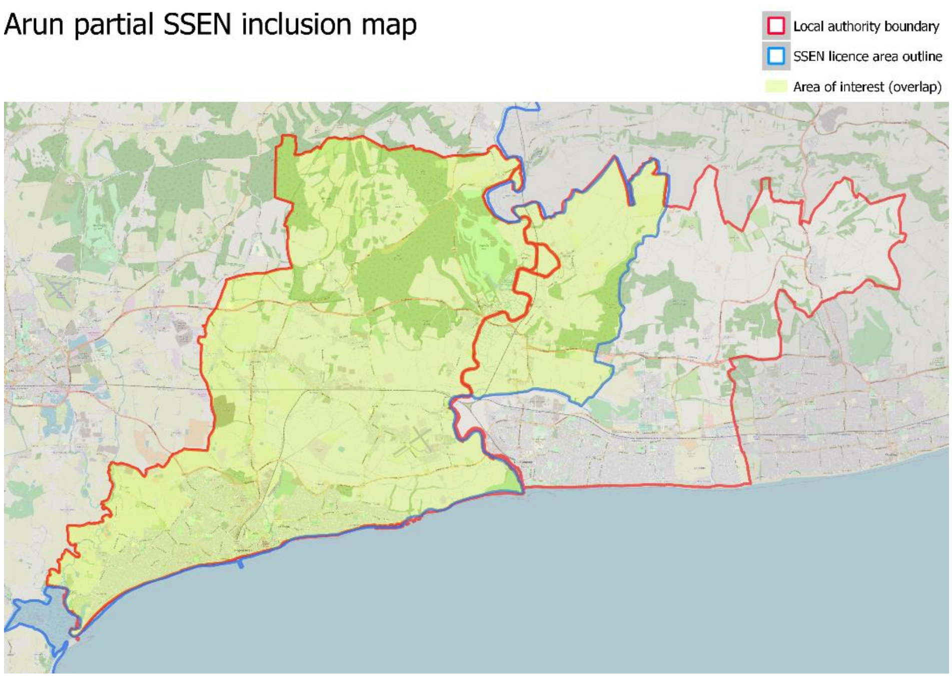
As part of the data gathering process for the 2020 DFES for SSEN, an online portal was established to exchange data related to new housing and commercial developments with all of the local authorities within the North of Scotland licence area.

The portal greatly improved the gathering and validation of local authority plan data and provided localised, granular evidence to support the scenario projections for:

- The number of new houses (based on strategic housing development threshold of 20 homes or more).
- New commercial and industrial developments (measured in m^2 floorspace of development land), categorised into 8 archetypes: Factory and warehouse, Hospital, Hotel, Medical, Office, Restaurant, Retail, School and College, Sport and Leisure, University and Other.

The use of an online exchange site enabled mutual access and updating of the data for new developments in each local authority area between Regen and the local authority planning departments. For the local authorities with borders across licence area, a map was also provided outlining the geographic area where new development data was specifically required. In addition to directly updating the datasets held on exchange portal, many local authorities provided information through Housing Land Audit reports and other supplementary documents.





As part of the evolution of this data exchange process with the local authorities, a short questionnaire was issued to explore the development of local energy and decarbonisation strategies and to inform the distribution of key technologies.

The local authority survey sought specific ‘yes/no’ answers to a set of seven key questions, around local strategies for:

1. **Declaration of a climate emergency**
2. **A transport or low-carbon transport strategy**
3. **A heat or low-carbon heat strategy**
4. **Renewable energy strategy**
5. **Food waste collection strategy**
6. **Net zero strategy**
7. **Net zero target year**

In addition to these questions, open fields for more specific information, notes and links to relevant supporting documents was included.

Although not all local authorities participated the questionnaire provided useful local information for the SSEN DFES, and for the subsequent bilateral engagement that SSEN is undertaking as part of its ED2 business plan development.

The summary results for the councils within the North of Scotland licence area are below.

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

Feeding local ambition into the SSEN DFES

The information gained from conducting this local energy strategy survey, and from direct discussions with regional stakeholders, was used to inform the scenario projections. For example:

- Near-term weighting was placed to the Electricity Supply Area (ESA) distribution of future projections for EVs and heat pumps, where local authority areas have low carbon heat or transport strategies in place.
- Some specific local factors (e.g. low emission zones stated in strategy documents) were also used to augment some ESA factors or uptake rates in the 2020s/30s.
- High levels of ambition, through climate emergency declarations or other strategy was considered when modelling some renewable energy generation projects currently in the planning pipeline.

Sector-specific stakeholder consultations

In addition to the stakeholder engagement webinars, Regen engaged with individual companies and industry representatives to better understand the projections for specific technologies.

An overview of the sector-specific consultations that were held to inform the SSEN DFES 2020 modelling is summarised in Table 4.

Table 4 Sector specific stakeholder interviews

DFES building block technology	Organisation(s)	Feedback received and how it was reflected in the DFES modelling
Solar PV	Elgin Energy Green Cat Renewables Other solar PV developers with pipeline projects in the SSEN connection data.	Informed the capacity, connection year(s) and ESA location of pipeline solar projects Views on general solar development in Scotland, flagging that still only the most optimal site locations will be developed in the near-to-medium term. This was reflected in the connected capacity in the DFES modelling in the 2020s and 2030s.
Onshore wind	Orkney Islands Council McGowan Environmental Engineering Ltd.	Discussed pipeline sites on Orkney and the wind resource potential of the Scottish islands after transmission upgrades. Also discussed wind generation potential in North of Scotland more generally. This acted as a confirmation of our existing modelling method, based on a resource assessment and scenario-specific assumptions and outcomes.
Hydro **Sewage gas AD**	Scottish Water	Discussion around any additional hydro projects in North of Scotland. Confirmed existing scenario projections. Also advised they currently do not have any sewage sludge gas-to-grid injection sites in their portfolio, there were no current plans to increase electricity generation from their biogas or biomethane resources. Whilst Scottish Water are seeking to review their overall biogas strategy, there are no plans to increase biomethane production. Confirmed existing scenario projections.
Solar **Onshore wind** **Hydro**	Gray Associates RWE Balmoral Estates	Confirmation of the development status and future timeline plan of various renewable generation projects. The DFES pipeline projections (mainly in the 2020s) were updated based on feedback received about these individual projects
Hydrogen electrolysis	ITM Power	Clarified the business model of electrolysers supplying hydrogen to fuelling stations. Also confirmed typical electrolyser capacity (MW) scale and use cases we prioritised.

Engagement around the DFES with the Scottish Government

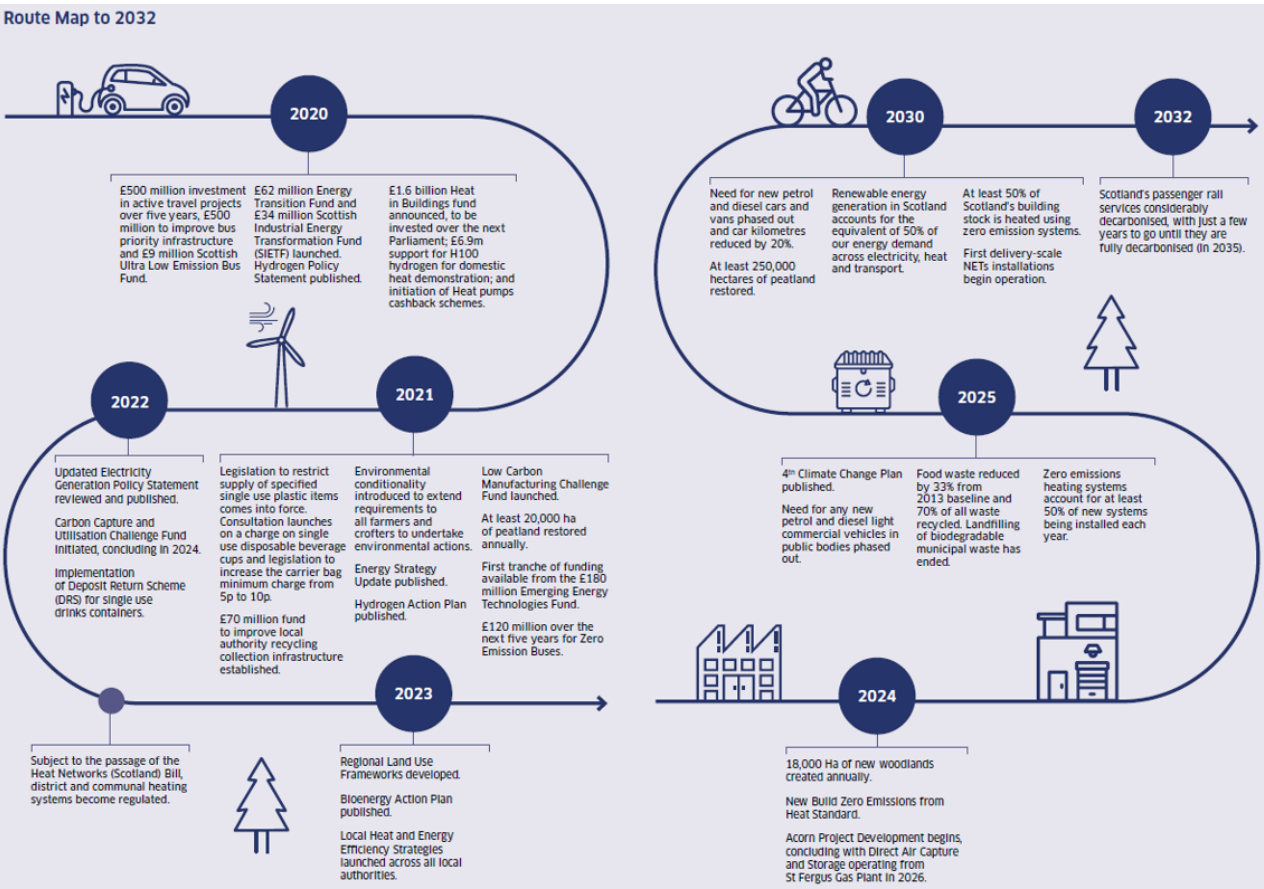
At the end of October 2020, Regen and SSEN met with Scottish Government officials to discuss the assumptions and DFES technology scenario projections for the North of Scotland licence area. The meeting was attended by the following members of Scottish Government:

- Simon Gill – Head of Whole System and Technical Policy, Scottish Government
- Anastasia Charalampidou – Senior Policy Adviser, Scottish Government
- Michael Cairns – Energy & Economics Team, Scottish Government
- Jonathan Bowes – Researcher at University of Strathclyde

The intention of the workshop was to road-test the DFES assumptions and some early modelling results, and to clarify how Scottish Government energy policy targets and decarbonisation strategies should be reflected in the DFES analysis.

In addition to these overarching energy and decarbonisation targets, the Regen team stepped through the modelling of some of the key DFES generation and demand technology assumptions. A summary of the feedback provided from Scottish Government and how this affected the scenario modelling, for each technology, is summarised in Table 5.

In December 2020, the Scottish Government published an update to their climate change plan to 2032, which highlighted a number of energy and decarbonisation targets and ambitions for Scotland and "…*sets out the Scottish Government's pathway to our new and ambitious targets set by the Climate Change Act 2019.*". This plan describes a number of targets, ambitions and future estimated outcomes relating to the decarbonisation of electricity, heat and transport in Scotland, many of which relate to the technologies within the scope of the DFES.



Through this engagement with Scottish Government in both the workshop and from reviewing the Climate Change Plan Update, the DFES scenario analysis has been influenced (either directly or indirectly) by a number of targets, aims and milestones, these include:

- A commitment to reduce carbon emission by 75% compared to 1990 levels (the equivalent UK target announced this week is a 68% reduction)
- A re-statement of the 2017 commitment that 50% of all energy will be from renewable sources by 2030
- £180 million for an Emerging Energy Technologies Fund, supporting the development of hydrogen and providing impetus to the development of Negative Emissions Technologies (NETs)
- £120 million for Zero Emission Buses, driving forward a fully decarbonised future for Scotland's bus fleet and support the Scottish supply chain
- £50 million to create Active Freeways, providing a sustainable link between our towns, cities and some of our most beloved national landmarks
- Scotland's rail services to be decarbonised by 2035
- Offshore Wind Policy Statement published in October which supports the development of between 8 and 11 GW of offshore wind capacity by 2030
- New Build Zero Emissions from Heat standard will be introduced from 2024, by which point all new builds will have to have zero emissions heating systems
- A £1.6 billion Heat in Building fund and a plan to double the installation of low carbon heating with a plan that by 2030, 50% of Scotland's building stock will be heated by low carbon solutions
- Commitment to reduce car kilometres by 20% by 2030, and to phase out the need for new petrol and diesel cars and vans by 2030
- A series of new funds for industry and innovations including; a £180 million Emerging Energy Technologies Fund, a £5 million Carbon Capture and Utilisation Challenge Fund, a £34 million Scottish Industrial Energy Transformation Fund and a £26 million Low Carbon Manufacturing Challenge Fund that will support innovation in low carbon technology, processes and infrastructure.

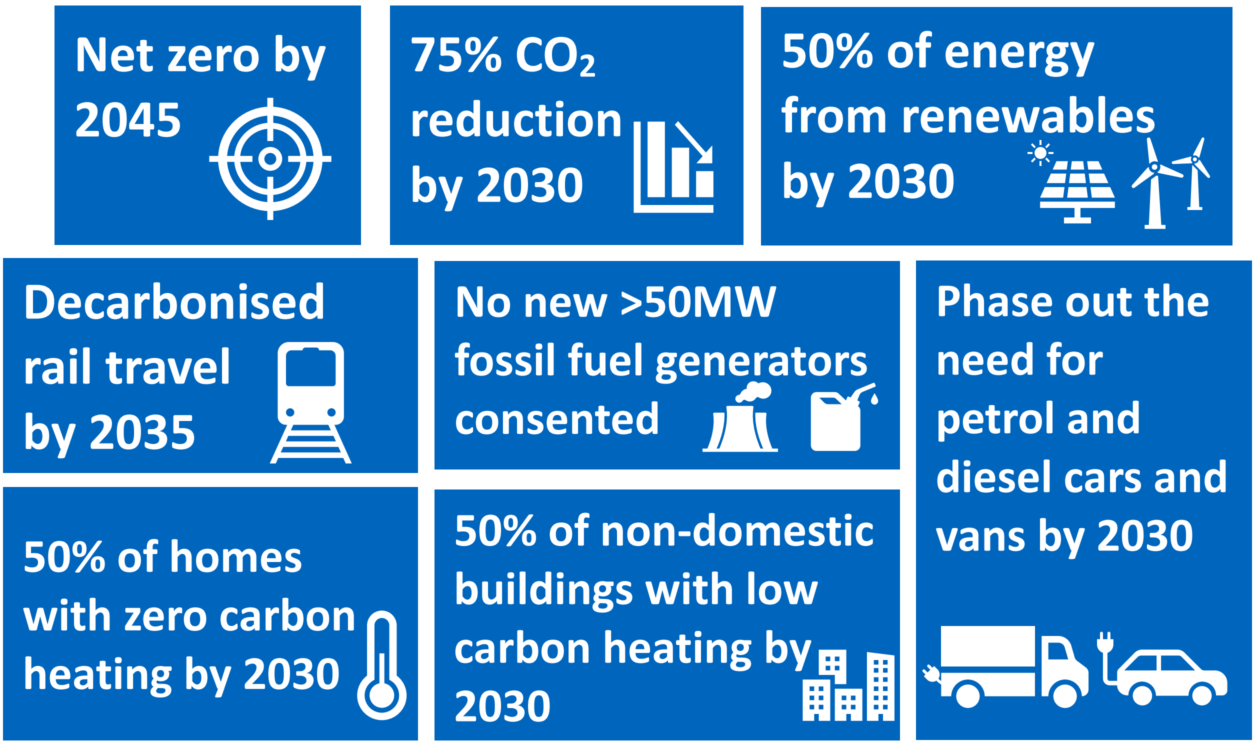


Table 5 Summary of DFES technology feedback from workshop with Scottish Government

DFES building block technology	Topics discussed at workshop or referenced from Climate Change Plan	How DFES modelling was adjusted
Electric vehicles **Electric vehicle chargers**	• Transport Scotland projections for EV uptake in and 2030 target. • Trend of centralised EV charger ownership (e.g. by ChargePlace Scotland) set to continue.	➢ DFES analysis referenced Transport Scotland's scenario projection in **Consumer Transformation**. ➢ Projections for EV charger archetypes confirmed.
Heat pumps **Direct electric heaters**	• Heat electrification as a strong option for the North of Scotland, due to the higher number of off-gas network areas. • Potential to target less affluent homes for deployment of heat pumps. • Direct electric heaters a lower priority, due to looking to tackle other fossil fuel heating technologies first. • Preference for standalone heat pumps over hybrids. Hybrid heating is not a priority. • 50% of homes with zero carbon heating by 2030 highlighted as a key milestone in the Climate Change Plan Update.	➢ Near-term uptake of air source heat pumps were amplified in **Consumer Transformation** and **Leading the Way**. ➢ Minimal adoption of hybrid heating systems reflected. ➢ In **Consumer Transformation** and **Leading the Way**, 77% of homes modelled to have a heat pump variant by 2045. ➢ Direct electric heaters remain connected in the near-term and replaced by more efficient low carbon alternatives by 2045.
Onshore wind	• North of Scotland as a hub for distributed onshore wind generation (1.9 GW connected). • Repowering of existing sites to be higher capacity than the original project. • Capacity being dependent on turbines size, e.g. more turbines or the same number but higher generation capacity. • Climate Change Plan Update highlighted the need for 50% of energy to come from renewable sources in Scotland by 2030.	➢ The repowering aspects of the DFES onshore wind modelling limited the future increased project size/capacity as a result of this feedback. ➢ Overall strong increase of distribution network connected onshore wind aligns with aspirations of 50% renewable energy supply milestone.

Fossil fuel generation	• Scottish island diesel engines likely to remain a special case, due to the role they play to maintain supply to the island communities. Bioenergy Update in 2021 likely to clarify role of biomass as alternative. • National Planning Framework likely to see no new >50MW fossil fuel generators connecting in Scotland. • <50MW sites local authority jurisdiction, planning teams encouraged to consider the real role of gas generation and its value to the electricity system.	➢ Clarified decision to remove the island diesel generators from the scope of the DFES. ➢ Reinforced limited additional gas reciprocating engine capacity connecting in the 2020s in **Consumer Transformation**, **System Transformation** and **Leading the Way**. ➢ Aligned with the DFES decommissioning of all unabated natural gas generation by/before 2045.
Hydrogen electrolysis	• As well as the use cases of HGV/bus refuelling, potential for ferries, shipping and rural train lines to also be potential sectors for hydrogen electrolysis use cases in Scotland.	➢ Reviewed and reflected Transport Scotland Rail Decarbonisation Action Plan and the outcomes of the Hydrogen Assessment Project in electrolysis scenario uptake and geographical distribution.

Technology summary sheets for the North of Scotland licence area

The remaining sections of this document is a compendium of the individual summary sheets covering all of the technology building blocks that form the basis of the SSEN DFES 2020 analysis.

These summary sheets provide:

- A definition and scope of the technology
- A summary of scenario projection results at each projection stage (near, medium and long term)
- An overview of the key assumptions, methodology and logic that has been applied to determine the scenario projections
- An overview of the local and stakeholder evidence obtained and fed into the analysis for that technology/sector
- A reconciliation analysis between the SSEN DFES 2020 and the National Grid ESO FES 2020 (either comparing the DFES results to the ESO's GB level FES projections or the regional grid supply point (GSP) datasets)
- A list of the references and data sources used

This report splits the various technology sheets into three sections, as outlined below:

Technology Category	Technology / sector
Section 1 - Distributed electricity generation	1. Onshore wind
	2. Offshore wind
	3. Large-scale solar PV
	4. Hydropower
	5. Marine energy
	6. Biomass electricity generation
	7. Waste incineration electricity generation
	8. Renewable engines (AD, sewage gas and biogas)
	9. Gas fired generation
	10. Diesel generation
	11. Other generation
Section 2 - Electricity storage	12. Battery electricity storage
Section 3 - Low carbon technologies and new sources of electricity demand	13. Electric vehicles
	14. Electric vehicle chargers
	15. Heat pumps and direct electric heating
	16. Small-scale solar PV
	17. Hydrogen electrolysis
	18. New property developments
	19. Air conditioning

Section 1 – Distributed generation

Renewable energy generation technologies

Fossil fuel generation technologies

Waste-driven energy generation technologies

regen transforming energy

Scottish & Southern Electricity Networks

1. Onshore wind in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers any onshore wind generation connecting to the distribution network in the North of Scotland licence area. This technology is divided into two sub-categories:

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

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

Installed capacity (MW)		Baseline	2020	2025	2030	2035	2040	2045	2050
Large-scale (≥1 MW)	Steady Progression	1,931	1,985	2,218	2,397	2,598	2,748	2,965	3,070
	System Transformation		1,985	2,464	2,835	3,181	3,519	3,706	3,802
	Consumer Transformation		2,002	2,903	3,500	4,343	4,956	5,364	5,737
	Leading the Way		1,998	2,942	3,443	4,120	4,587	4,888	5,165
Small-scale (<1 MW)	Steady Progression	138	138	140	143	148	152	155	157
	System Transformation		139	143	147	157	207	223	225
	Consumer Transformation		139	145	173	301	385	443	500
	Leading the Way		139	144	166	281	329	348	367

Overview of technology projections in the licence area:

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

Scenario projection results:

Baseline (up to end of 2019)

- The large-scale onshore wind baseline, totalling 1,930 MW, is composed of 162 projects with an average capacity of 12 MW.
- This includes eight projects of over 50 MW capacity each, such as Berry Burn and Mid Hill wind farms. These projects were deployed between 2005 and 2016 and were supported via the Renewables Obligation (RO) subsidy mechanism.
- The small-scale baseline of 138 MW comprises 320 projects with an average capacity of 0.4 MW.
- The majority of small-scale onshore wind development occurred as a result of the Feed-in Tariff (aka ROOFIT) subsidy mechanism, with over 100 MW of onshore wind capacity connected between 2011 and 2016 in the licence area.

Near term (2020 – 2025)

- There is over 1,600 MW of accepted onshore wind connection capacity in the pipeline, consisting of 75 projects with an average capacity of 21 MW. This is 75% larger than the average capacity of the baseline, as developers look to economies of scale for future projects that are seeking routes to market.
- Between 103 MW and 142 MW of capacity, depending on the scenario, is deployed by the end of 2021, composed of sites already under construction or those expected to begin construction imminently.
- Several pipeline sites are dependent on electricity distribution network upgrades to connect, such as the proposed Hoy Wind Farm on Orkney, and as such go ahead later in the pipeline period.
- The Access and Forward-Looking Charges Significant Code Review has potential to significantly impact the business models of distributed generation in the North of Scotland. As a distribution network generation-dominated region, projects in the North of Scotland could see high network charges, depending on the code review decision, which is expected imminently. This is a key uncertainty for the future development potential of new onshore wind in the licence area and thus is reflected through the spread of connected capacity seen across the four scenarios in the SSEN DFES.

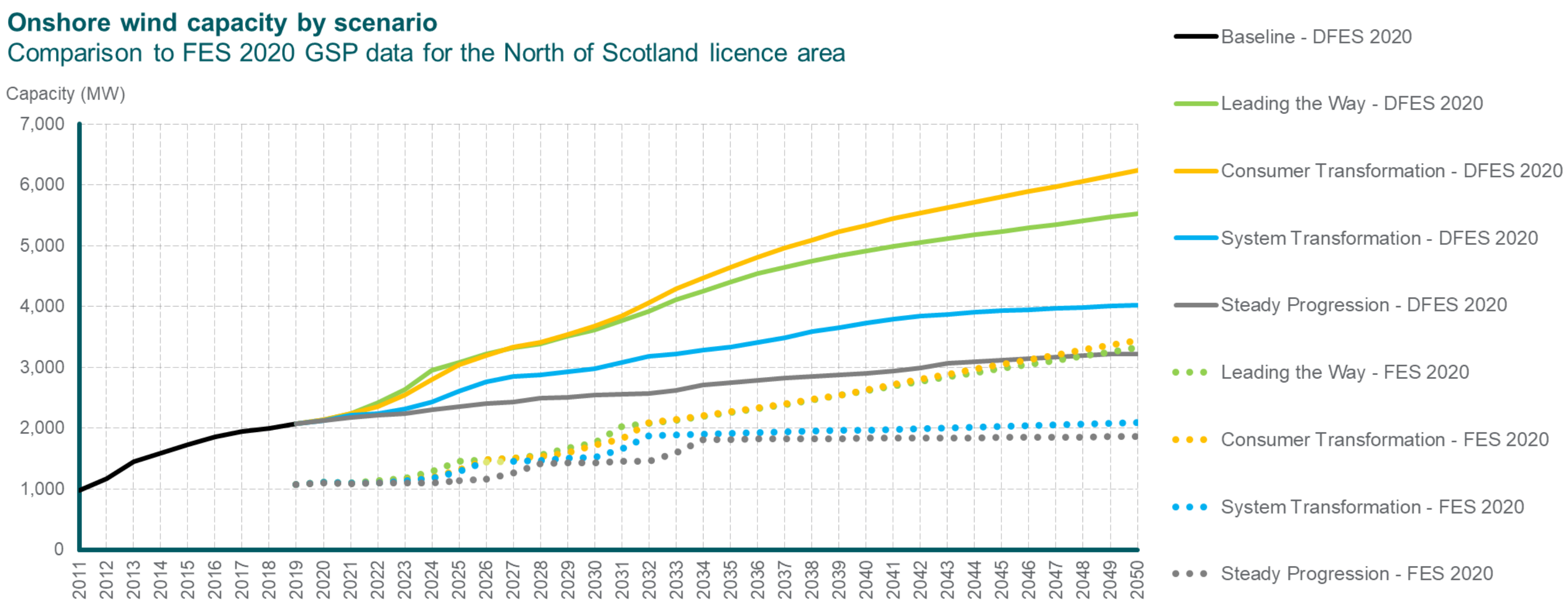
Medium term (2025 – 2035)

- The high level of deployment of onshore wind continues in all net zero scenarios in the medium term, this is driven by some pipeline sites in the early stages of development connecting after 2025, as well as other new projects connecting in areas of high wind resource and fewer planning constraints. Scottish Government targets for renewable energy production[i], and ambitious plans from local authorities in the licence area, means that Scotland continues to host the majority of UK onshore wind development in the medium term and a notable amount of this could fall in the North of Scotland licence area.
- While the fourth round of the Contracts for Difference scheme features onshore wind for potential subsidy support, this is expected to be extremely competitive amongst wind and solar PV across the country, and therefore developers are seeking to new routes to market to progress projects under the assumption of subsidy-free business models.
- Repowering of older baseline sites, specifically those developed in the 2000s and reaching the end of their operational life in the medium-term, drives a further increase in connected capacity. In the net zero scenarios, it is assumed that these sites are powered with more efficient and sometimes larger turbines, as supported in the Scottish Government onshore wind policy statement[ii].

Long term (2035 – 2050)

- Onshore wind capacity continues to increase in the licence area out to 2050, particularly in **Consumer Transformation** and **Leading the Way**, where renewable energy on the distribution network plays a key role in achieving net zero in Scotland and the UK. The highest capacity, seen in **Consumer Transformation**, exceeds 6.2 GW by 2050; this is around three times the baseline capacity. In contrast, connected capacity in **Steady Progression** reaches 3.2 GW by 2050, reflecting a continuation of the trend from 2016, but still representing 1.1 GW of new capacity.
- More recent baseline sites repower during this period, driving a high amount of additional capacity. It is assumed that the scenarios that have greater societal change allow for greater capacity increase upon repowering, reflecting the potential for larger turbines. For example, under **Consumer Transformation** sites repower at 150% of their original capacity, on average. Contrastingly, **Steady Progression** and **System Transformation** only repower to 125%, reflecting more efficient turbines but not much change in turbine height, or possibly fewer total turbines.
- With some of the best wind resource in the country, the North of Scotland licence area continues to be a frontrunner for distributed onshore wind in all scenarios, with long-term projections more dependent on the potential make-up of the whole energy system under each scenario, rather than the North of Scotland licence area in particular. Based on Regen's onshore wind resource assessment, which covers planning constraints, wind resource and network availability, the North of Scotland licence area hosts 22% of GB onshore wind resource area.
- Under **System Transformation** there is still a high level of onshore wind development in North of Scotland, but larger wind farms connecting to the transmission network are preferred by developers and government.

Figure 8: Onshore wind projections (all scales) for the North of Scotland licence area, compared to National Grid FES 2020 regional projections



Reconciliation with National Grid FES 2020:

- The baseline in the National Grid FES 2020 regional GSP data totals 1,077 MW, around half of the SSEN DFES baseline of 2,068 MW. The reason for this discrepancy is unclear. The DFES baseline is constructed directly from SSEN connection data and baseline projects are reconciled against previous SSEN DFES studies and the Renewable Energy Planning Database[iii].
- In the near term, the detailed analysis of pipeline projects has resulted in a higher amount of total connected capacity under **Consumer Transformation** and **Leading the Way**, than occurs in the same scenarios in the FES 2020 regional dataset. This difference comes from projects that are already well into development and targeting commissioning in the next few years, which has been modelled to be achieved in these two higher uptake scenarios.
- In the medium and long term, the rate of increased capacity is similar across all scenarios in FES 2020 and DFES projections.

- However, the FES 2020 regional projections for **System Transformation** and **Steady Progression** sees no further capacity growth from 2032 and 2034, respectively. The SSEN DFES does reflect a relatively small, continued growth in these scenarios, due to some baseline projects repowering in these years.

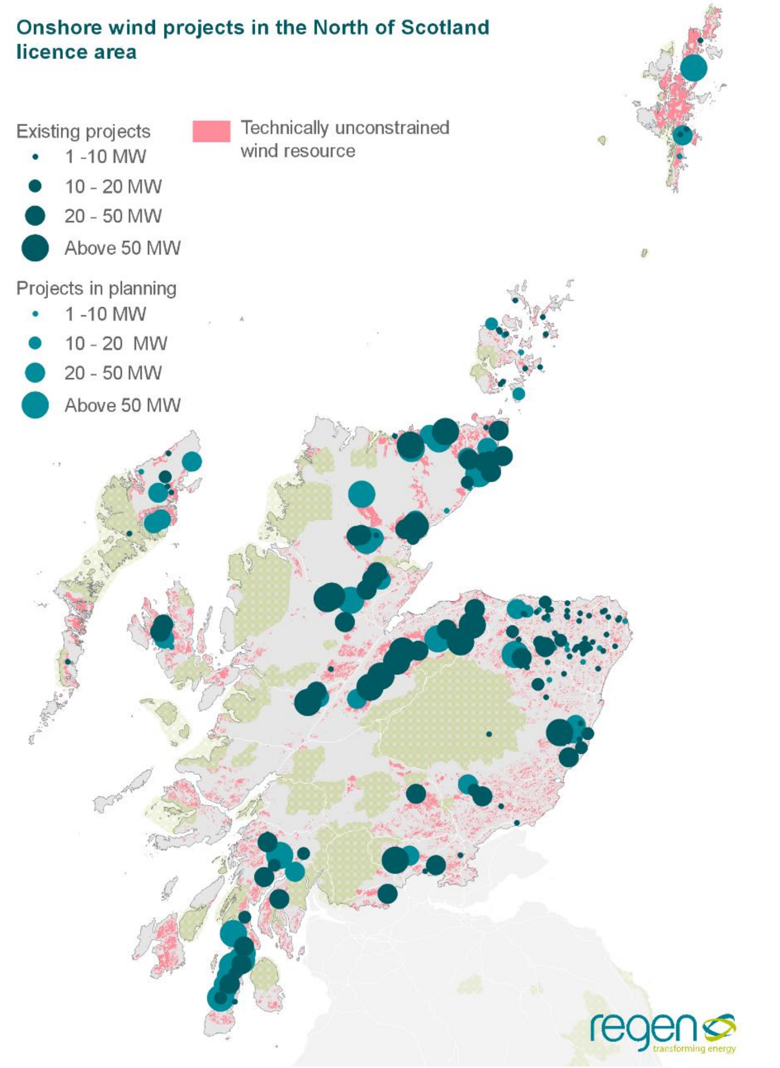
Factors that will affect deployment at a local level:

- New projected onshore wind capacity, not including repowering at existing sites, is based on Regen's onshore wind resource assessment, as seen in Figure 9. This assessment takes into account relevant factors such as wind speed, landscape designations, dwelling proximity, peat land and others.
- Capacity increase due to repowering is located at existing baseline sites.
- The North of Scotland includes many islands that rely on new interconnectors to facilitate new renewable generation projects such as onshore wind. Based on discussion with developers on these islands, and research of the proposed new interconnector cables, the following assumptions have been made:
  - The Orkney to Caithness subsea cable commissions in 2023[iv] with projects able to connect from 2024
  - The Western Isles transmission reinforcement commissions in 2025[v], except under **Steady Progression** where it does not go ahead.
  - The Shetland transmission reinforcement commissions in 2024[vi]

Relevant assumptions from National Grid FES 2020:

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

Figure 9: Onshore wind baseline and pipeline sites, and onshore wind resource area, in the North of Scotland licence area

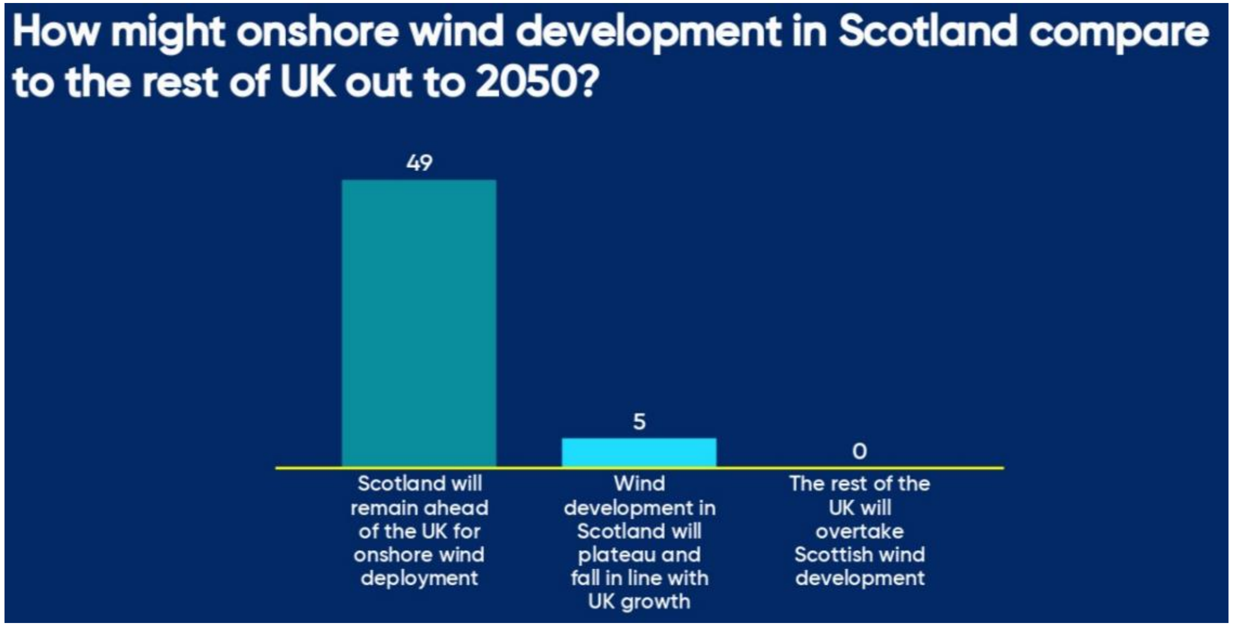


Stakeholder feedback overview:

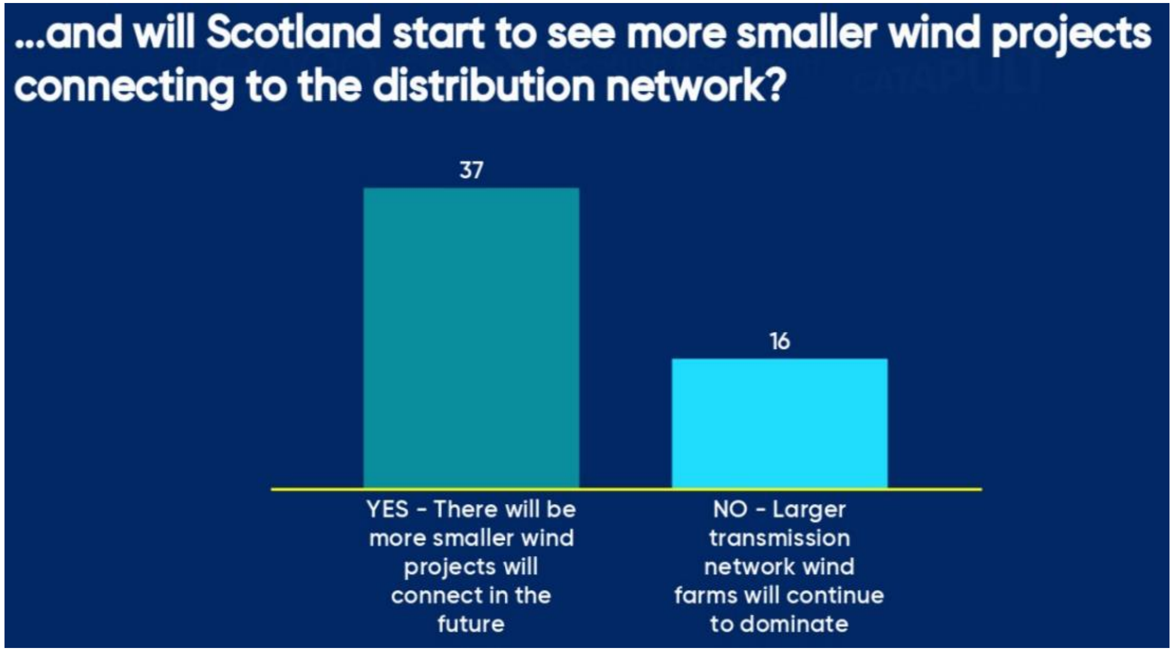
As the biggest technology in terms of capacity in the North of Scotland licence area, multiple instances of stakeholder engagement was undertaken to inform the analysis.

At the North of Scotland stakeholder engagement webinar, over 50 local stakeholders responded to two polls on future onshore wind development in the licence area.

Stakeholders overwhelmingly fed back that Scotland would remain ahead of the UK for onshore wind deployment out to 2050, and this was reflected in all four scenarios.



Stakeholders also generally commented that small-scale wind projects would continue to connect in the future, and wind development would not be exclusively transmission-scale. However, a significant minority believed that most onshore wind development will be at transmission level, and this was reflected in the **Steady Progression** and **System Transformation** scenarios.



Scottish Government were also directly engaged regarding their renewable energy targets and details of the onshore wind policy statement, particularly with regards to repowering.

Developers with projects in the pipeline were contacted on an ad-hoc basis to discuss the likely commissioning dates of their projects, which is directly reflected in the near-term projections. These phone calls also covered the likely trajectory for onshore wind in the medium-term, and the impact of coronavirus on projects currently in development.

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

References:

SSEN connection data, System Wide Resource Registers (GB), the TEC register, the Renewable Energy Planning Database, Climate Emergency declaration data, Feed-in Tariff data, Renewables Obligation data, Contracts for Difference data, Regen resource assessments, Regen consultation with local stakeholders and local authorities.

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[i] Scottish Government aims to generate 50% of energy from renewable sources by 2030: https://www.gov.scot/policies/renewable-and-low-carbon-energy/
[ii] See Scottish government onshore wind policy statement: https://www.gov.scot/publications/onshore-wind-policy-statement-9781788515283/
[iii] See Renewable Energy Planning Database from BEIS: https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract
[iv] See Ofgem Orkney transmission link update: https://www.ofgem.gov.uk/publications-and-updates/ofgem-gives-go-ahead-orkney-transmission-link-subject-conditions
[v] See Ofgem Western Isles transmission link: https://www.ofgem.gov.uk/publications-and-updates/ofgem-encourages-revised-proposals-scottish-isles-transmission-links
[vi] See Ofgem update on Shetland transmission link: https://www.ofgem.gov.uk/publications-and-updates/ofgem-approves-600mw-shetland-transmission-link

2. Offshore wind in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers offshore wind generation, including fixed and floating foundations, connecting to the distribution network in the North of Scotland licence area. **DFES Building block Gen_BB014**

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

Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	32	80	80	80	80	80	80	80
System Transformation		80	80	80	80	80	80	80
Consumer Transformation		80	80	80	80	80	80	80
Leading the Way		80	80	80	80	80	80	80

Overview of technology projections in the licence area:

- The of baseline of distribution network connected offshore wind generation consists of two pioneering floating wind projects.
- It is possible that further demonstration projects will come forward but at the moment there is no visible pipeline of these. Therefore no future capacity increase is projected under any DFES scenario, as future offshore wind in the North of Scotland is likely to be of larger scale and therefore connected to the transmission network.
- It is assumed that existing projects will be repowered at some stage.

Scenario projection results:

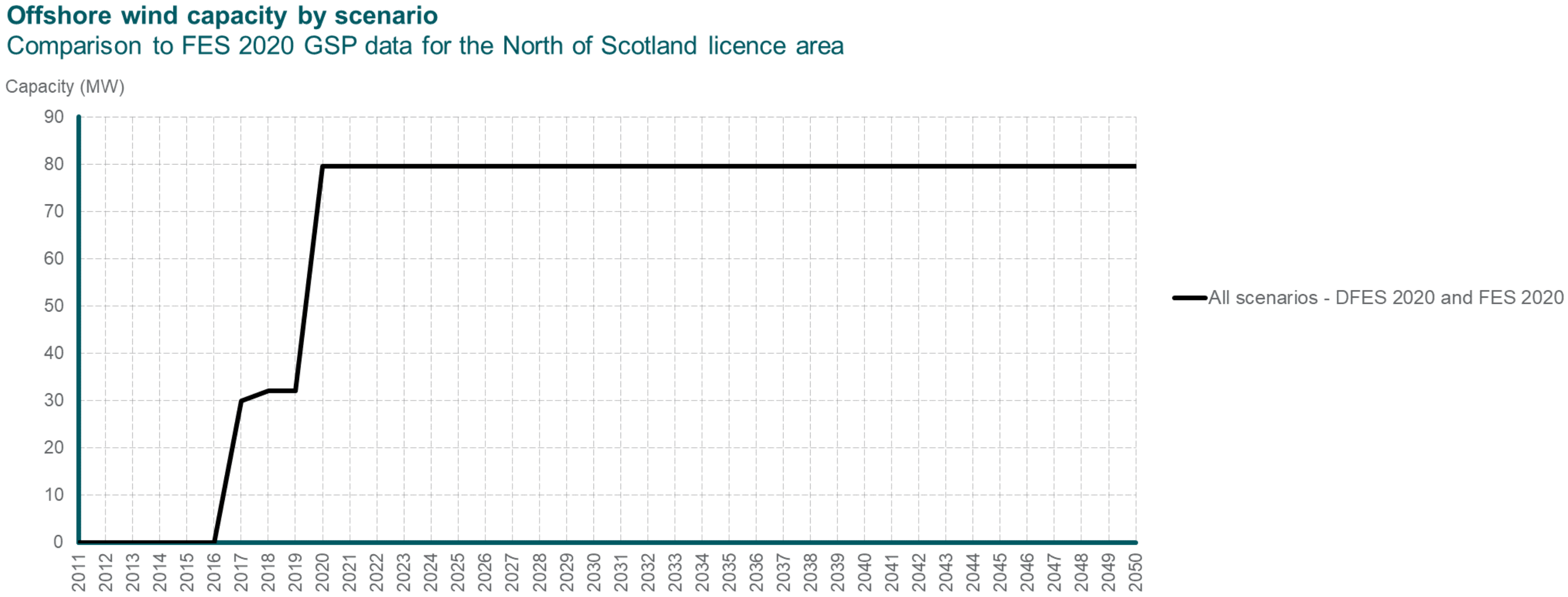
Baseline (up to end of 2019)

- The baseline consists of two projects, both with floating foundations.
- This includes the 30 MW Hywind project, the first commercial floating offshore wind farm, and the Kincardine Floating Offshore Wind Farm, which connected 2 MW of capacity in 2018, and has a further 47.6 MW under construction and expected to connect by the end of 2020.

Projections (2020 – 2050)

- Other than the commissioning of the remainder of the Kincardine project in 2020, there is no further offshore wind capacity projected to connect to the distribution network in the North of Scotland licence area, in any scenario. This is due to there being no accepted connections in the pipeline, and an expectation that any further offshore wind projects off the coast of northern Scotland would be larger-scale projects connecting to the transmission network.

Figure 10: Offshore wind projections for the North of Scotland licence area, compared to National Grid FES 2020 regional projections



Reconciliation with National Grid FES 2020:

The SSEN DFES projections for offshore wind align exactly with the National Grid FES projections for the North of Scotland licence area.

Scottish Government policy context:

Whilst the DFES projections specifically exclude offshore wind capacity connected to the transmission network, it is acknowledged that there are significant targets to connected up to 11 GW of offshore wind in Scotland[vii], and this has been confirmed in the Climate Change Plan Update.

References:

SSEN connection data, the Renewable Energy Planning Database.

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

3. Large-scale solar PV in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers any ground-mounted solar PV - solar generation sites of installed capacity of 1 MW and above – connecting to the distribution network in the North of Scotland licence area. Small-scale solar PV (<1MW) can be found in section 16 of this report.

DFES Building block Gen_BB012.

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

Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	34	39	68	103	191	227	260	283
System Transformation		39	128	211	370	461	544	606
Consumer Transformation		39	107	191	350	441	524	586
Leading the Way		39	157	286	501	676	819	922

Overview of technology projections in the licence area:

- Due to the low levels of irradiance in the North of Scotland relative to the rest of the UK, deployment of solar PV has historically been limited compared to onshore wind.
- This is expected to continue throughout the timeframe of the scenarios out to 2050, as developers focus on sunnier regions of the country.
- Additionally, many developable sites will also have the option of onshore wind, which is currently more viable in most of the licence area.
- In the near term some uncertainty remains around the viability of solar in North Scotland, especially in relation to changes in network charging and the impact of the Access and Forward-Looking Charges Significant Code Review.
- However, as solar PV costs continue to fall, an increase in ground-mounted solar PV capacity is projected in the licence area.

Scenario projection results:

Baseline (up to end of 2019)

- There is currently 34 MW of distribution network connected ground-mounted solar PV capacity, from five projects ranging from 5 to 9.9 MW.
- All five of these baseline sites were developed between 2015 and 2017, during the peak of the Feed-In Tariff programme.

Near term (2020 – 2025)

- There is a pipeline of 326 MW of ground-mounted solar PV projects with accepted connection offers, this is almost ten times the baseline capacity in the licence area.
- This pipeline comprises 18 projects, giving an average capacity of 18 MW. Notably, six of these projects are over 25 MW in size, representing two-thirds of the total pipeline capacity.
- Of this pipeline capacity, 111 MW was found to be either under construction or with planning permission. Most of these sites go ahead in the three scenarios that achieve net zero, as new business models and routes to market become viable for particularly prospective projects.
- The pipeline is very large compared to the current baseline, and represents a key uncertainty in the modelling. This is reflected in the range of near-term outcomes across the four scenarios. It is likely that many of these projects, especially those with less-recent connection agreements, will not go ahead in all but the ideal planning and commercial conditions underpinning the **Leading the Way** scenario.
- Several pipeline sites have held a connection agreement without any evidence of beginning the planning process. These sites do not go through in any scenario. Furthermore, a 49 MW site in Angus has been shelved, as the proposed site is to be used for substation expansion to accommodate the transmission network connected Seagreen offshore wind farm project.
- The Access and Forward-Looking Charges Significant Code Review has potential to significantly impact the business models of distributed generation in the North of Scotland. As a generation-dominated region, projects in the licence area could see high network charges, depending on the code review decision expected imminently. This is a key uncertainty for the future development of large-scale solar PV in the region, in both the near and medium term.

Medium term (2025 – 2035)

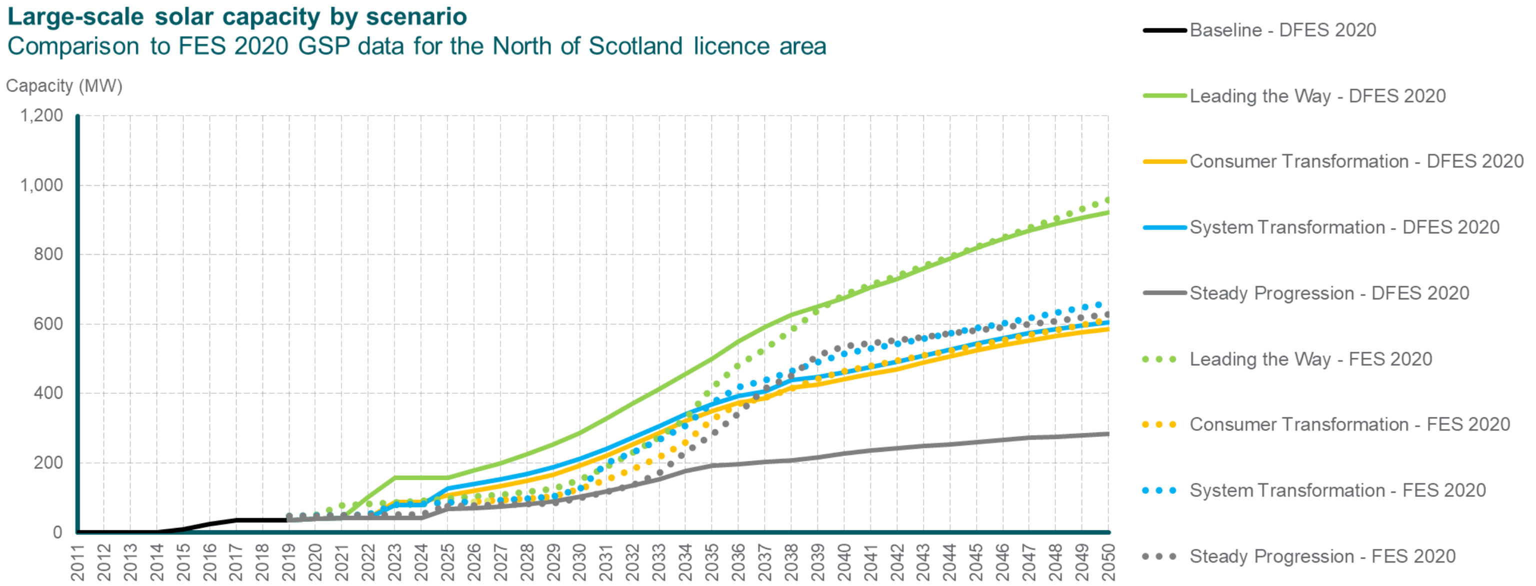
- Despite the strong pipeline of accepted connections, analysis and engagement with stakeholders and developers suggests that the business case for ground-mounted solar PV in the North of Scotland is still likely to be challenging over the near-to-medium term, and thus restricted to only the most suitable sites in most cases. Emerging co-location business models (e.g. with electricity storage) are expected to aid the deployment and revenue potential for ground-mounted solar PV in all scenarios.
- The three net zero scenarios see the highest capacity increase in the North of Scotland licence area, with an average of 25-35 MW deployed per year in each scenario between 2025 and 2035. Though this is a significant increase compared to the existing baseline, this is a small proportion of the 1,100-1,700 MW expected to be deployed annually across GB in these scenarios out to 2050.

- Scottish Government ambition for Scotland to generate at least 50% of its total energy consumption from renewable sources by 2030[viii] results in solar PV development being encouraged in all scenarios. This is despite other renewables, such as onshore and offshore wind, having much greater development potential in the licence area.
- In the scenarios with high levels of solar PV deployment, areas with lower levels of existing solar generation become more attractive to investors, as network costs and the decreasing cost of solar panels favour areas like the North of Scotland.
- Under **Steady Progression**, where new business models and routes to market for solar PV remain challenging not only in the North of Scotland but across the UK as a whole, development of ground-mount solar PV is limited, as developers focus on the sunnier areas of the country.

Long term (2035 – 2050)

- The long-term projections continue in line with the trends seen across the medium-term years, with steady deployment in the three net zero compliant scenarios, as new, commercially viable solar farms become the norm.
- Wholesale price cannibalisation during peak solar periods, has the potential to concern investors at high levels of solar deployment. While solutions such as co-location with storage, production of hydrogen through electrolysis and interconnection, are expected to sustain solar PV business models in the net zero scenarios, development slows from 2040 in line with national trends. It is possible that, under more challenging conditions in these latter years, developers would look to go back to sunnier areas of the country for further large-scale solar development.

Figure 11: Large-scale solar PV projections for the North of Scotland licence area, compared to National Grid FES 2020 regional projections



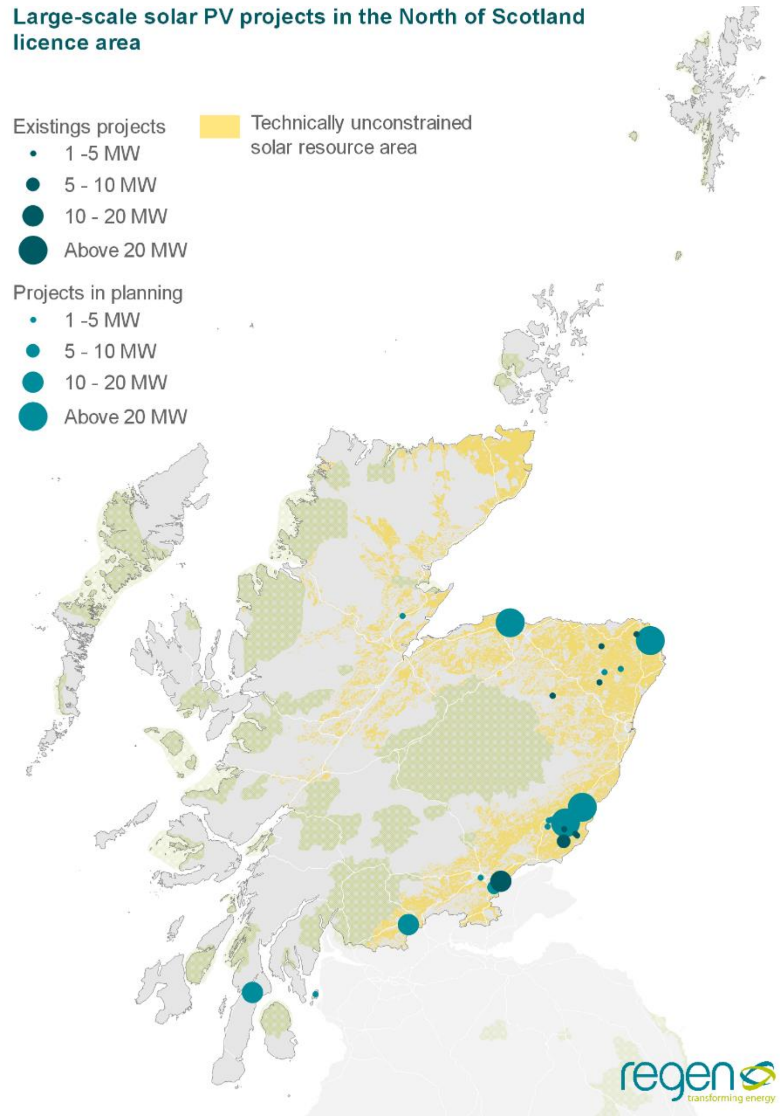
Reconciliation with National Grid FES 2020:

- The SSEN DFES baseline aligns with the FES 2020 regional data.
- In the near term, the FES 2020 data sees little large-scale solar PV deployment in the North of Scotland licence area. The assessment of pipeline sites in the DFES, including direct engagement with project developers, results in a higher level of deployment in the near term under the three net zero scenarios.
- In the medium term, the FES 2020 data sees greater levels of additional capacity connecting than the SSEN DFES, countering the lower near-term growth. By the late 2030s the scenarios are however aligned, with the exception of **Steady Progression** which sees little growth in the DFES, as a result of the lower levels of irradiance present in the licence area.
- After 2040, the connected capacity in the FES 2020 data and the SSEN DFES are directly aligned, as projections hinge on national trajectories for large-scale solar PV in the DFES.

Factors that will affect deployment at a local level:

- New large-scale solar PV capacity is distributed to developable land area based on Regen's large-scale solar PV resource assessment, shown in Figure 12. This considers irradiance, designated land areas, physical constraints, network proximity, ground slope/aspect and proximal buildings.
- Due to the influence of repowering, some of the future large-scale scale PV capacity will be located at existing sites. However, in the North of Scotland licence area this is only a small minority of the projected capacity.

Figure 12: Large-scale solar PV baseline and pipeline sites, and solar resource area, in the North of Scotland licence area



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Relevant assumptions from National Grid FES 2020:

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

Stakeholder feedback overview:

Developers with projects in the pipeline were contacted on an ad-hoc basis to discuss the likely commissioning dates of their projects, which is directly reflected in the near-term projections. These phone calls also covered the likely trajectory for large-scale solar PV in the medium-term, which suggested that developers were mainly considering sites with optimal situations, such as low connection costs due to proximity to network, or availability of developable land. Solar irradiance was cited as the absolute key factor in the near term, and as such North of Scotland would continue to see limited solar PV deployment until solar panel costs decreased significantly as expected. The impact of COVID-19 was also covered, and found to have limited impact on the development of the projects discussed.

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

References:

SSEN connection data, System Wide Resource Registers (GB), the TEC register, the Renewable Energy Planning Database, Climate Emergency declaration data, Feed-in Tariff data, Renewables Obligation data, Contracts for Difference data, Regen resource assessments, Regen consultation with local stakeholders and local authorities.

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

4. Hydropower in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

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

DFES building block Gen_BB018

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

Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	807	874	899	901	903	905	906	907
System Transformation		874	906	918	928	937	946	955
Consumer Transformation		874	922	960	999	1,031	1,055	1,078
Leading the Way		874	914	931	953	974	984	995

Overview of technology projections in the licence area:

- The North of Scotland licence area represents a large proportion of the UK's current and potential future distributed hydropower capacity.
- The majority of the 807 MW baseline consists of large-scale projects, built up to 70 years ago, with no further development of this equivalent scale seen in almost 20 years.
- The future potential for additional capacity is likely to be single-MW or smaller scale projects, as most opportunities for large-scale hydro generation have largely been exploited. The level any additional capacity is uncertain and dependent on whether small-scale renewable generation is supported. The recent Feed-in Tariff has given a good indication of how subsidy has allowed some new hydropower generation to be commissioned, despite being a mature technology.

Therefore, scenario projections for distribution network hydropower capacity in the licence area are highest in **Consumer Transformation** and **Leading the Way**, where small-scale renewables play a vital role in achieving net zero. Under **System Transformation** and **Steady Progression**, hydropower development in limited in the licence area.

Scenario projection results:

Baseline (up to end of 2019)

- There is currently 807 MW of hydropower capacity connected to the North of Scotland distribution network.
- 18 sites, representing 454 MW of capacity, are over 10 MW in size. All of these projects were built before 2002.
- Since 2005, 63 projects with a capacity of 1 MW or greater have been developed. However, the average size of 2.3 MW, with only four sites above 5 MW, shows the clear trend towards much smaller scale hydro sites in recent years.
- Sites below 1 MW in capacity account for 121 MW (15% of the baseline), of which approximately 90 MW has been developed since 2010 as a result of the Feed-in Tariff. Development has slowed in recent years with the reduction in Feed-in Tariff rates and the removal of the Feed-in Tariff programme altogether, with only 33 MW of new distributed hydropower being commissioned in the licence area since 2016.

Near term (2020 – 2025)

- A pipeline of sites with accepted connection offers totals 92 MW in the licence area. However, this is potentially misleading, as a single industrial site in Lochaber accounts for 52 MW of this accepted connection capacity. This site is an existing hydropower plant that directly powers the collocated industrial plant, and the pipeline capacity is only to ensure the potential to export all generated energy in the future.
- Therefore, the pipeline of newly-built hydro projects totals the residual 40 MW, across 55 projects with an average capacity of 0.7 MW.
- Only twelve pipeline projects exceed 1 MW in capacity, totalling 25 MW. The vast majority of these projects have planning permission or are already under construction, and are expected to connect within the next few years in all scenarios.
- In the near-term a continuation of the baseline trend since 2016 is seen, with a few relatively small-scale projects connecting each year.
- The Access and Forward Looking Charges Significant Code Review has potential to significantly impact the business models of distributed generation in the North of Scotland. As a generation-dominated region, projects in the North of Scotland could see high network charges, depending on the code review decision expected imminently. This is a key uncertainty for the future development of hydropower in the region.

Medium term (2025 – 2035)

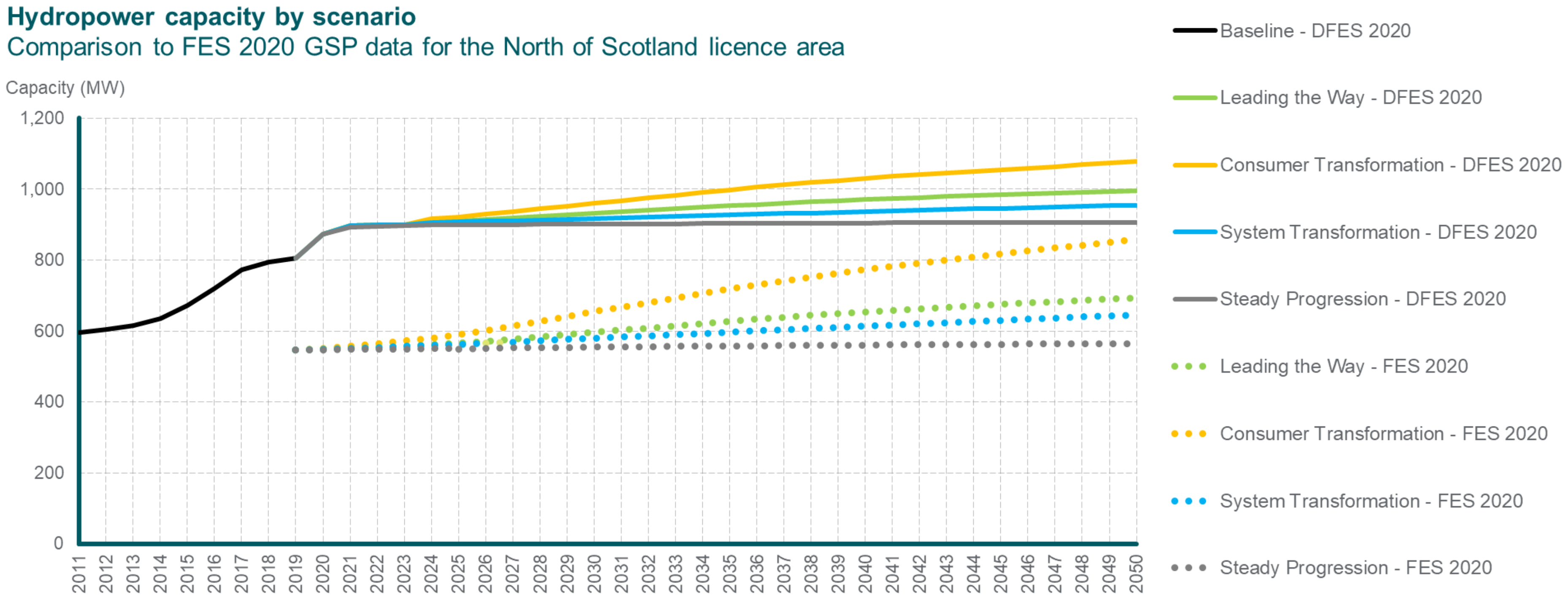
- Beyond the pipeline, the **Consumer Transformation** and **Leading the Way** scenarios see continued deployment of 5-10 MW per year, reflecting trends seen since 2016 and in the pipeline years. These projects are supported primarily by the Smart Export Guarantee with potential value from power purchase agreements or direct colocation with electricity demand, for example at industrial sites.
- The rate of capacity growth in **Consumer Transformation** and **Leading the Way** is aligned broadly to the increased amount of connected hydro capacity since 2018 and in the pipeline, under reduced Feed-in Tariff rates that are comparable to the Smart Export Guarantee.
- Under **System Transformation** and **Steady Progression**, hydropower development is low as preference is given to large-scale generation. This results in more hydropower projects failing to develop. With these scenarios featuring lower levels of societal change, revenue streams such as corporate power purchase agreements are less commonplace than under **Consumer Transformation** and **Leading the Way**, leaving hydropower projects struggling to produce a viable business model in all but the most optimal areas.

Scottish policy continues to support renewable generation technologies such as hydropower, with an aim to generate 50% of Scotland's energy consumption from renewable sources by 2030[ix].

Long term (2035 – 2050)

- The long-term trajectories for hydropower are very similar to those outlined in the medium term, reflecting the national electricity generation assumptions stated under each scenario.
- Despite many hydropower projects being quite old by this point, as a mature technology there is not expected to be significant increase in hydropower because of the repowering of turbines in existing projects.
- **Consumer Transformation** is the only scenario that sees distribution network connected hydropower reach more than 1 GW by 2050, with **Steady Progression** seeing the lowest overall capacity by 2050 of 907 MW.

Figure 13: Hydropower projections for the North of Scotland licence area, compared to National Grid FES 2020 regional projections



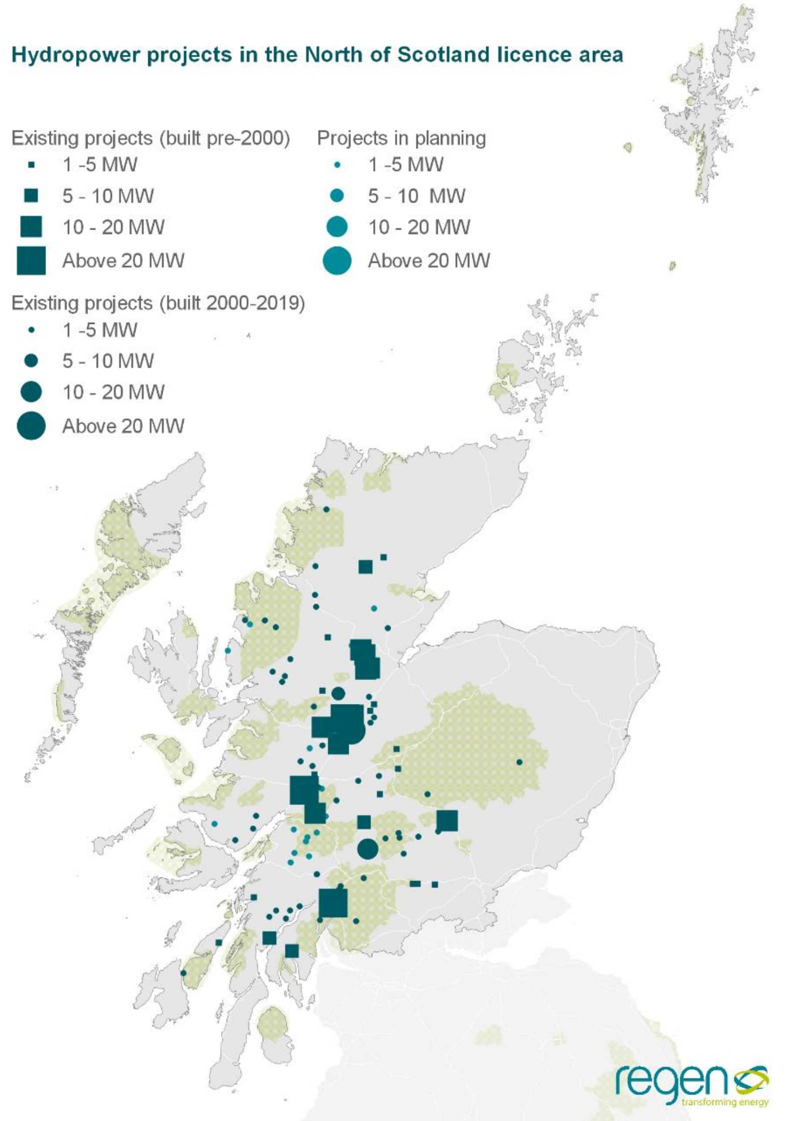
Reconciliation with National Grid FES 2020:

- The FES 2020 regional baseline for hydropower in the North of Scotland licence area amounts to 546 MW, which is 261 MW lower than the baseline determined in the DFES analysis. The reason for this variance is unclear.
- In the near term, the SSEN DFES sees similar levels of increased capacity to the FES 2020 regional data, with the addition of the 52 MW of capacity at the Lochaber industrial site.
- In terms of additional connected capacity projected in the longer term, the FES 2020 regional data and the DFES broadly align at a scenario level.
- The overall capacity is lower in the SSEN DFES, as the evidence from recent years and the near-term pipeline suggests that high levels of additional capacity connecting to the distribution network are unlikely to occur in Scotland without significant subsidy support (at similar levels to the early years of the Feed-in Tariff) which is not expected to happen, even under the most ambitious scenarios, for small-scale renewables.

Factors that will affect deployment at a local level:

- Naturally, hydropower potential is constrained to rivers and or watercourses with vertical change in elevation (head) and flow. The Scottish Highlands, being a mountainous region with high amounts of rainfall, hosts most hydropower in the North of Scotland.
- The distribution of future projects, beyond the known pipeline, is dictated by a combination of a hydropower resource assessment based on river flow and head, and the location of known projects, both existing and those that failed in development, as shown in Figure 14.

Figure 14: Hydropower baseline and pipeline sites in the North of Scotland licence area, noting the age of the largest baseline projects.



Relevant assumptions from National Grid FES 2020:

Assumption number	4.1.1 Hydro generation
Steady Progression	High costs associated with large scale projects. Little ambition or support
System Transformation	High costs associated with large scale projects. Some support is forthcoming for large scale projects, limited societal change from large scale remote generation
Consumer Transformation	Potential for a lot of small scale projects that will have larger societal impact
Leading the Way	Potential for rapid deployment of large and small scale projects; society is more in favour of disruptive projects. Limited by the reduction in energy demand

Stakeholder feedback overview:

Stakeholders were not asked about hydropower in the engagement events, however companies involved in projects with accepted connections were contacted to aid the projections in the near term, including Scottish Water. Future development of hydropower in North of Scotland, including remaining potential, likely scale of future projects, and near-term impact of COVID-19 was discussed and used to inform the scenario projections.

References:

SSEN connection data, System Wide Resource Registers (GB), the TEC register, the Renewable Energy Planning Database, Climate Emergency declaration data, Feed-in Tariff data, Renewables Obligation data, Contracts for Difference data, Regen resource assessments, Regen consultation with local stakeholders and local authorities.

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

5. Marine generation in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

DFES technology building block: Marine - tidal stream and wave energy [Gen_BB017]

The analysis covers any marine generation projects (tidal or wave) that connect to the distribution network in the North of Scotland licence area. The SSEN DFES analysis has focussed predominantly on known small scale project developments, plus insight from Regen's marine lead (Kerry Hayes) and engagement with the Marine Energy Council around other potential pipeline projects that are likely to connect to the distribution network out to 2050.

Whilst the DFES projections specifically focus on marine generation projects connecting to the distribution network, it is acknowledged that a notable more marine generation capacity could connect to the transmission network in Scotland.

The sub technologies included in the DFES marine energy analysis are:

- **Wave energy –** typically connected to the distribution network as small array and demonstration projects
- **Tidal stream energy –** harnessing kinetic tidal flows around headlands and in channels

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

Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	26	26	26	26	26	26	26	26
System Transformation		26	26	26	26	26	26	26
Consumer Transformation		26	26	36	66	80	120	150
Leading the Way		26	26	36	66	100	200	250

Overview of technology projections in the licence area:

- Scotland has significant opportunities to deploy wave and tidal energy technologies.
- The sea areas around the north of Scotland including the Pentland Firth, Western Isles and Orkney have been identified as the best marine energy resources in the UK and indeed in Europe. Orkney is also home to Europe's most active marine energy test facility at EMEC[x]
- Nevertheless the marine energy generation sector as a whole is still at an early stage of technology development and commercialisation and while there a number of small scale projects in Scotland and around the UK the overall scale of development has been limited
- Marine energy projects will be very location specific based on the availability of wave/tidal resources, physical site characteristics and environmental conditions.
- The withdrawal of subsidy support for wave and tidal energy in 2016[xi] has affected industry confidence and has led to the withdrawal and delay of many pre-commercial projects.
- The UK Government is now consulting on a new CfD round to support marine energy and this may unlock marine energy potential[xii]
- If large scale projects do proceed they are likely to connect to the transmission network. Distribution network projects may therefore be limited to smaller commercial projects, demonstration projects, trial sites and testing facilities.
- The North of Scotland licence area does have some operational marine generation sites connected on some of the Scottish Islands and two pipeline projects on Islay, which are both projected to come online in **Leading the Way** and **Consumer Transformation**.
- Beyond this pipeline of known developments, additional project capacity has been modelled to connect to the distribution network in the North of Scotland licence area in the **Leading the Way** and **Consumer Transformation** scenarios. This reflects the licence area the geographical region in the UK that is most suited to hosting wave and tidal demonstration projects and operational generators out to 2050, but also acknowledges the challenging development environment and viability for significant marine generation capacity deployment
- This culminates in 250 MW connected to the distribution network in **Leading the Way** and 150 MW connected in **Consumer Transformation** by 2048. Additional larger marine electricity generation projects could be connected to the transmission network.

Scenario projection results:

Baseline (up to end of 2019)

- There is a total of 26 MW of marine generation capacity with energised connection agreements in the North of Scotland licence area, across 7 projects. Note: not all of this capacity is being currently utilised and some is related to test facilities which may host several technology projects.
- Current projects are located on the northern coast (Canisbay) or the Scottish islands (Islay, Shetland and Orkney).

The largest project, Meygen, has a 15 MW connection agreement and came online in 2016, although currently 6 MW (4 Turbines) of this generation capacity is being utilised.

Near/medium term (2020 – 2035)

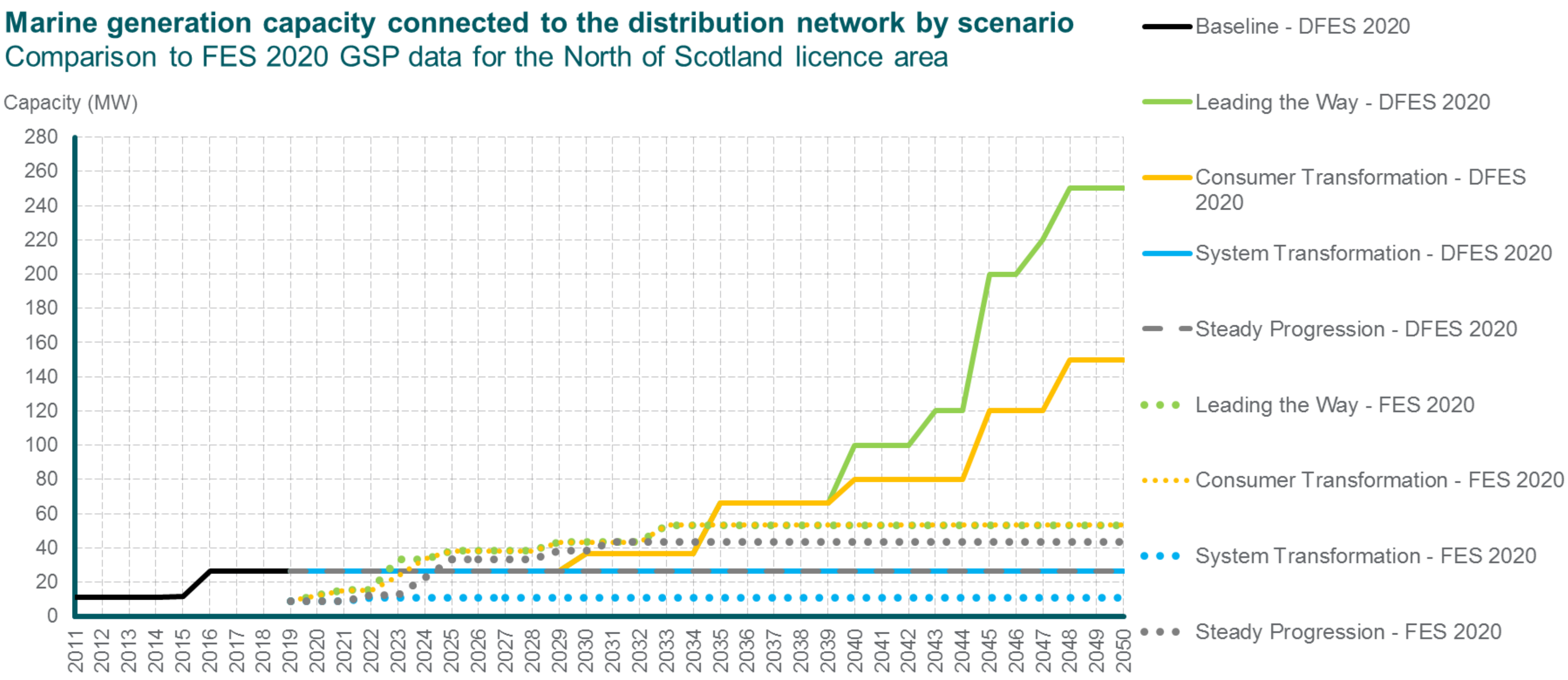
- There are two projects known to be in development on the island of Islay:
    - **Sound of Islay Demonstration Tidal Array** - A 10 MW scheme proposed to be located in the Sound of Islay (East side of the island) that was granted a marine licence by Marine Scotland in April 2016. This also has an accepted connection offer in Jan 2020.
    - **West Islay Tidal Energy Park** - A 30 MW scheme proposed to be located 6 km South West of the Rinns of Islay on the West side of the island, which was granted permission by Scottish Ministers in June 2017.
- These projects have been modelled to come online within the 2030s in only the **Consumer Transformation** and **Leading the Way** scenarios, as whilst some milestones have been achieved, these projects are still challenging, require a lot of work to bring them to physical development and thus should still be considered as fairly speculative.
- The Meygen project is being built out in phases, and while Phase 1A is connected to the distribution network, Phase 1B is likely to connect at transmission level.

Long term (2035 – 2050)

- Larger scale marine projects are likely to connect to the transmission network.
- There may however be opportunities for additional, smaller scale distribution connected projects especially on the Scottish islands.
- The SSEN DFES has therefore modelled all known pipeline projects connecting within the timeframe of the DFES assessment in **Consumer Transformation** and **Leading the Way** between 2035 and 2050.
- In addition to this, the FES GB projections for distribution network connected marine generation reaches 345 MW in **Leading the Way** in 2050. Being that a significant proportion of the potential tidal and wave projects – at all scales – will likely be located in the North of Scotland, the DFES has modelled a further increase in connected marine generation capacity out to 2050.

This peaks at 250 MW by 2048 in **Leading the Way** (c.72% of all GB distribution network marine capacity in this scenario in 2050) and 150 MW by 2048 **Consumer Transformation**.

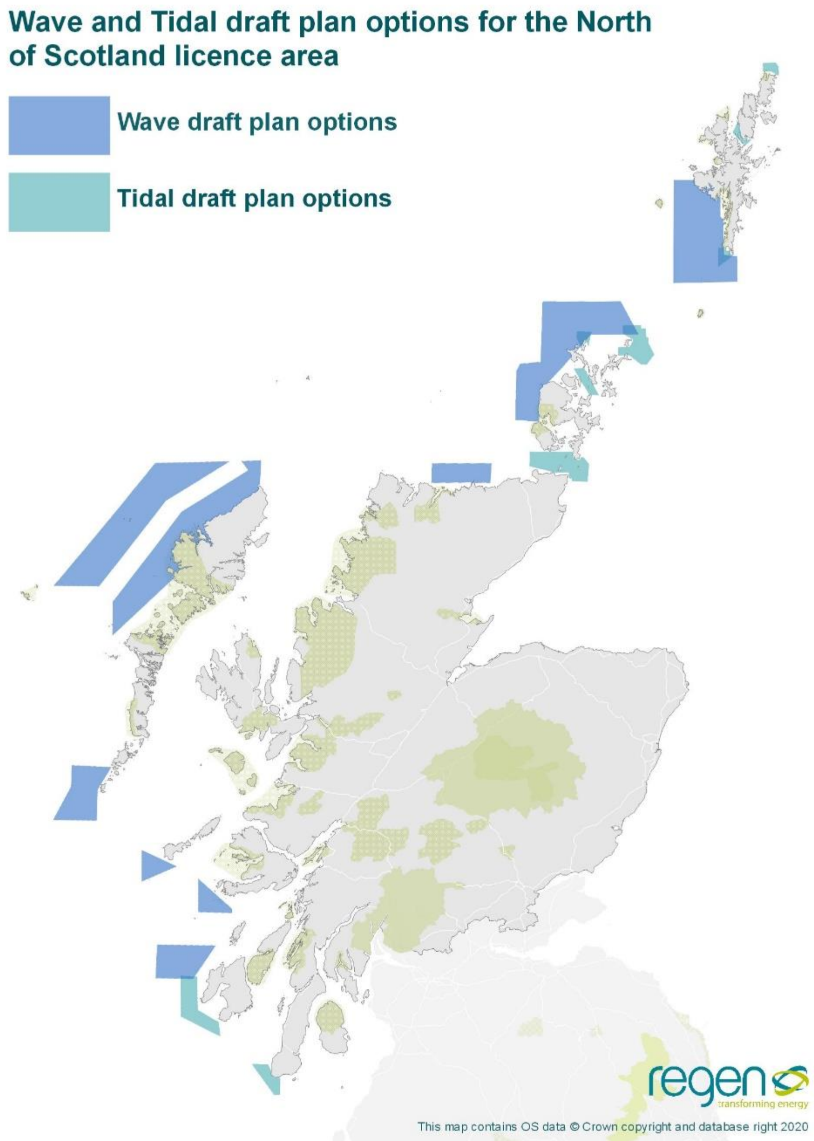
Figure 15 Comparison of marine generation projections in the North of Scotland licence DFES analysis to the FES 2020



Factors that will affect deployment at a local level:

- The future of wave and tidal energy is uncertain, and it should be recognised that the industry is still in a period of technology development.
- Marine Scotland developed draft Sectoral Marine Plans[xiii] for wave and tidal energy in Scotland in 2013, but known technical challenges facing wave and tidal projects, combined with the removal of subsidy support to marine projects, meant that Scottish Ministers never formally adopted these plans.
- Whilst there are a handful of small scale tidal/wave projects connected to the distribution network in the North of Scotland licence area, the potential for future additional capacity remains limited out to 2050. With the transmission network being a voltage tier lower than that of England and Wales, the potential for distribution network connected sites is potentially even more limited. The DFES has, however, acknowledged the progress of the two known pipeline projects in the **Consumer Transformation** and **Leading the Way** scenarios.
- The geographical distribution factors applied for marine generation capacity are actual locations of the two pipeline projects and the wave and tidal resource regions, as identified through the draft marine sectoral plan developed by Marine Scotland in 2013. See Figure 16.

Figure 16 Map of wave and tidal resource areas from Marine Scotland draft marine sectoral plans (2013)



Relevant assumptions from National Grid FES 2020:

Assumption number	4.1.2 (Other renewables including marine generation)
Steady Progression	Low support where other renewables (e.g. tidal) cannot complete solar and wind generation.
System Transformation	Support for large scale renewable technologies (i.e. tidal).
Consumer Transformation	Small scale generation connected to local supply chains. May be community owned.
Leading the Way	Focus on low carbon technologies promote a wide range of renewable technologies including marine sources at all scales.

Stakeholder feedback overview:

A discussion was had with the Chair of the Marine Energy Council (MEC) and the MEC response to the recent government CfD on support for marine energy, along with industry reports, has been used to inform this technology projection. Scotland has long been acknowledged as a leading location for innovative wave and tidal energy projects.

References and data sources:

SSEN connection data, Marine Scotland online project information, Marine Energy Council future development insights. Marine Energy Council 'Potential of Marine Energy Projects in Great Britain: A Call for Evidence', Highlands and Islands Enterprise https://www.hie.co.uk/our-region/our-growth-sectors/energy/energy-in-our-region/marine-energy/

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[x] European Marine Energy Centre EMEC: http://www.emec.org.uk/
[xi] Marine energy had a minima CfD for 100 MW at £305 per MWh to be installed by 2019, but this was withdrawn owing to budget limitations placed on the Levy Control Framework introduced in early 2016.
[xii] UK Government Consultation on support for wave and tidal energy using Contracts for Difference (2020) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/913042/marine-energy-projects-call-for-evidence.pdf
[xiii] See Draft Sectoral Marine Plans for Wind, Wave and Tidal (2013): http://marine.gov.scot/information/draft-sectoral-marine-plans-wind-wave-and-tidal-2013

6. Biomass electricity generation in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers biomass fuelled generation connecting to the distribution network in the North of Scotland licence area. This includes both biomass for power generation and biomass CHP. However, it does include biomass used solely for heat, or bioenergy with carbon capture and storage. **DFES building block ID Gen_BB010**.

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

Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	44	44	44	44	44	44	44	44
System Transformation		44	44	42	34	19	19	19
Consumer Transformation		44	44	42	34	26	32	36
Leading the Way		44	44	34	19	26	32	32

Overview of technology projections in the licence area:

The North of Scotland licence area has significant local biomass resource as a by-product of the forestry industry, this is unlike many others areas of the country. The licence area has a large baseline of distribution network connected biomass totalling 44 MW with biomass boiler capacities ranging from 0.1 MW to 15 MW. This range in size is a result of a number of different biomass generation business models, such as:

- Large scale biomass plants for power generation
- Large and medium scale biomass CHP plants, used as part of heat networks to supply heat to nearby homes and businesses
- Smaller, farm-scale biomass plants, making use of local feedstock and securing RHI payments

The National Grid ESO FES 2020 assumes that in the medium term, many of the larger-scale sites on the distribution network decommission and are replaced by larger, transmission connected biomass plants with co-located carbon capture and storage (CCS) technologies. The SSEN DFES has adopted this assumption in the relevant scenario projections.

There is, however, potential for an increase in the uptake of smaller-scale biomass plants, pending Scottish Government's aims to publish a Bioenergy Update in early 2021[xiv]. There is also the potential that some of the 126 MW of current backup diesel generation on Scottish Islands could be replaced by biomass or biomethane generation, or an alternative hydrogen fuel. As agreed with SSEN planners this has been noted but has not been modelled.

Scenario projection results:

Baseline (up to end of 2019)

- There are 12 biomass generation sites connected to the distribution network in the North of Scotland licence area, totalling of 44 MW.
- The largest is the Speyside biomass CHP plant, which recently increased its capacity to 15 MW.

Near term (2020 – 2025)

- There is a 0.2 MW site with an accepted connection offer and recent planning permission. This site therefore is modelled to connect by 2022 in all scenarios in the SSEN DFES analysis.
- There have also been two unsuccessful biomass projects in the licence area:
  - A 3 MW biomass plant at Keihill was refused in planning in 2019,
  - A 15 MW project at Georgemas which was abandoned in 2015.
- These two sites have, therefore, not been modelled to progress in any DFES scenario, due to an overarching preference for large scale, transmission connected biomass with CCS in the scenarios.

Medium term (2025 – 2035)

- The total capacity of biomass connected to the distribution network falls in the medium and long term under **Leading the Way**, **Consumer Transformation** and **System Transformation**. Though transmission network connected biomass generation with CCS could see an increase in connected capacity in these scenarios.
- The SSEN DFES has therefore reflected the decommissioning of existing plants when they reach the end of their operational life. This is assumed to be c.20 years from coming online, at which point they are to be replaced with transmission connected biomass with CCS.
- There are no instances of this on the distribution network as the high costs of CCS technology could prevent it from being viable for future smaller-scale biomass generation plants, that would be developed operating without subsidy support.
- This consideration is also compounded by the fact that the transmission network is a voltage tier lower in Scotland (132kV or above), thus the potential for biomass generation directly connecting to the distribution network in the licence area would be even smaller.

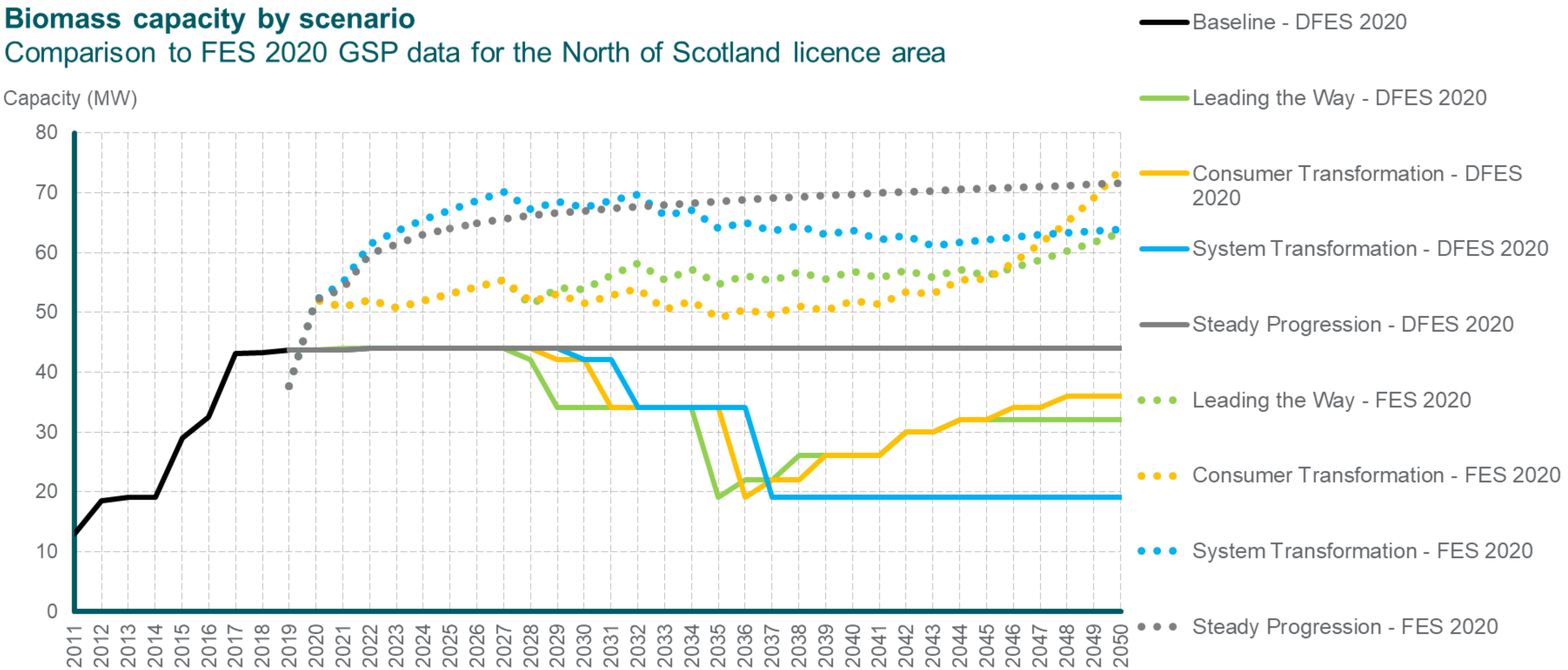
Long term (2035 – 2050)

- There is some potential for additional small scale dispatchable biomass capacity under **Leading the Way** and **Consumer Transformation** in the long term, particularly around areas with the potential for district heating.

The spatial distribution of new biomass generation sites is based on the location of existing sites either currently connected or identified by developers through planning applications.

- Whilst not included in the projection data scope of this year's DFES analysis, there are a number of diesel generators located on the Scottish islands, totalling some 126 MW of connected capacity. These are used predominantly as a back-up to the subsea supply cables connected to the mainland, to ensure security of supply to the island communities. From consultation with the Scottish Government it is clear that there is likely to be a need to look at low carbon alternatives to delivering back up supplies to the Islands. Biomass is likely to be one of the options, given the technical similarities between diesel and biomass power stations.

Figure 17 Summarising scenario projection graph for energy from waste, with comparison to FES regional



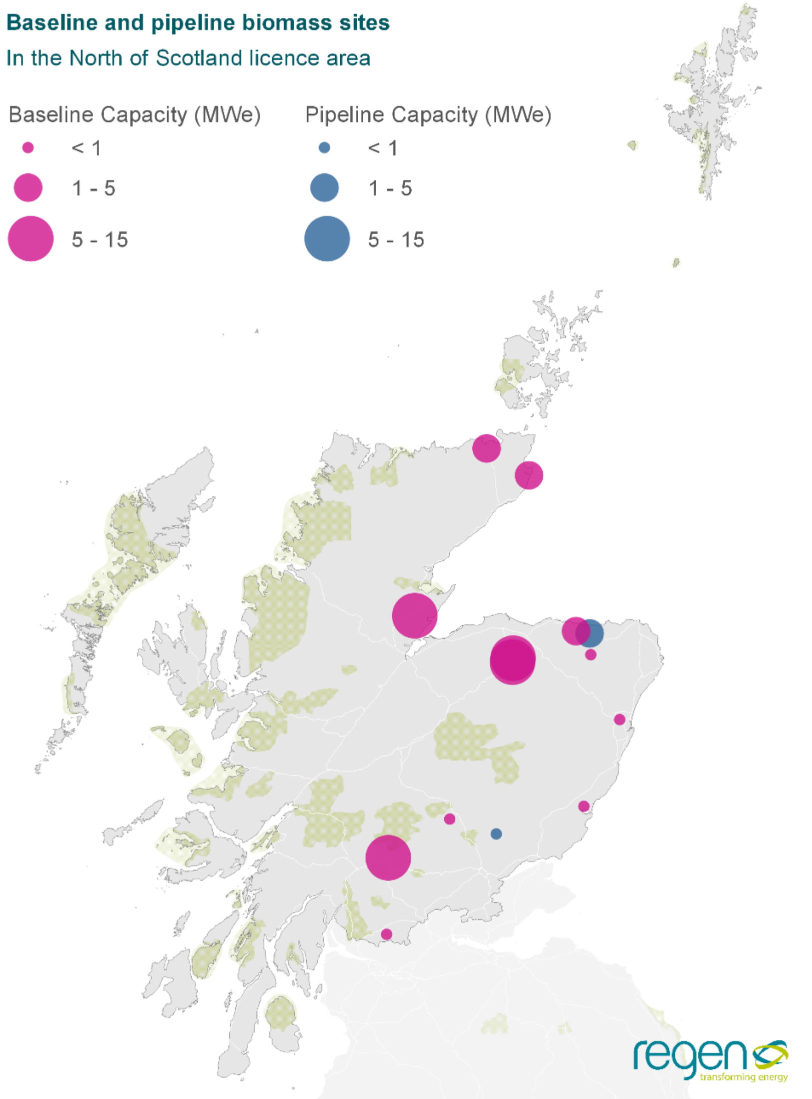
Reconciliation with National Grid FES 2020:

- The core assumptions underpinning the SSEN DFES analysis for biomass are in line with the FES 2020 projections.
- However, some scenario projection results differ, due to local or spatial factors.
    - The FES 2020 regional projections suggest a near term increase in biomass capacity in the North of Scotland licence area. However, there is a minimal contracted pipeline of capacity in the SSEN connections data, as well as two failed sites seen in the Renewable Energy Planning Database which do not progress because of a preference for transmission connected biomass plant with CCS. Therefore, the near term deployment of additional biomass is limited in the DFES analysis.
- The limited number of new biomass sites, causes larger step changes in the DFES capacity projections, reflecting individual site capacities connecting, or being removed after reaching the end of their operational life. In the FES 2020 regional projections, the projection is much less stepped/smoother.

Factors that will affect deployment at a local level:

- Each of the three commercial biomass classifications have been considered separately for geographical distribution. In summary:
    - Large scale biomass plants for power generation decommission in the medium term in the net zero scenarios
    - Biomass used in heat networks increases in the long term in **Leading the Way** and **Consumer Transformation**.
    - Farm scale biomass does not change in the projection period.
- The geographical distribution reflects the subsectors. The long term projection for biomass used in heat networks has been modelled by increasing the capacity of existing sites located near urban areas where heat networks may be developed.

Figure 18 – Biomass baseline and pipeline sites connecting to the distribution network in the North of Scotland licence area



Relevant assumptions from National Grid FES 2020:

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

References:

SSEN connection data, System Wide Resource Registers (GB), the TEC register, the Renewable Energy Planning Database, Climate Emergency declaration data, Regen consultation with local stakeholders and discussion with technology developers.

[xiv] See page 11 of the Scottish Government Update to the Climate Change Plan (December 2020): https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/

7. Waste (incineration) electricity generation in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers all forms of electricity generation from waste, including both incinerators and Advanced Conversion Technologies (ACT) that are connected to the distribution network in the North of Scotland licence area. **DFES Building block ID number Gen_BB011.**

Data summary for energy from waste in the North Scotland licence area:

Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	19	19	41	41	41	41	41	41
System Transformation		19	41	32	32	32	32	22
Consumer Transformation		19	41	41	41	41	32	32
Leading the Way		19	41	32	32	32	32	22

Overview of technology projections in the licence area:

The carbon emissions from older unabated waste incineration plants are not consistent with a net zero emissions targets. As a result, it is assumed in the scenarios that meet net zero targets, that connected incineration plant capacity reduces after 2028, as these older facilities reach the end of their lifetime and the capacity is not replaced.

ACT gasification plants are expected to have lower associated carbon emissions and are a compatible technology with net zero 2050 targets, assuming that the residual emissions are abated. The DFES analysis assumes that all ACT facilities with planning permission, of which there is a single 6 MW pipeline project in the North of Scotland, go ahead in all scenarios. However, there have been cases in the past where ACT projects have failed and therefore there is uncertainty associated with near term projections for this technology in the licence area. ACT facilities are also not projected to decommission across the analysis period, in any scenario.

Under a **Steady Progression** scenario, it is assumed that both incinerators and ACT sites do not decommission between 2019 and 2050.

Scenario projection results:

Baseline (up to end of 2019)

- There is a total of 19 MW of energy from waste fuelled electricity generation connected in the North of Scotland licence area.
- There is a 9MW connected waste generation site in the licence area, the Baldovie incineration plant in Dundee which secured a connection agreement in 1999 and increased its capacity to 19 MW in June 2020.

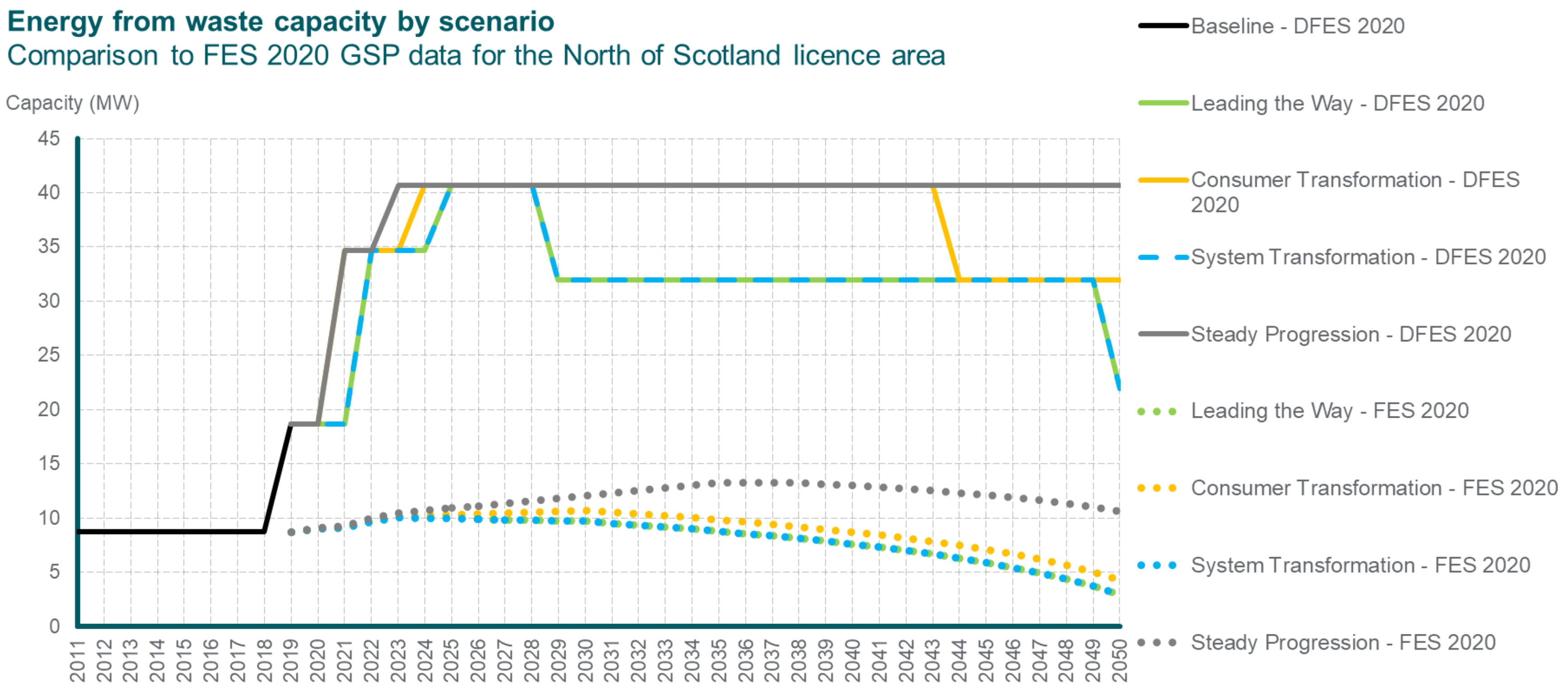
Near term (2020 – 2025)

- There are two energy from waste generation sites with accepted connection offers in the licence area, totalling 22 MW.
- A 16 MW incineration plant is currently under construction, according to the Renewable Energy Planning Database and therefore has been modelled to connect by 2022 in all scenarios in the DFES.
- The further 6 MW ACT plant was granted planning permission in 2019. This is modelled to connect by 2025 in all scenarios.

Medium and long term (2025 – 2050)

- No additional capacity has been projected beyond the known pipeline, this aligns with the FES 2020 regional projections for the licence area.
- The medium and long term waste generation projections were determined by decommissioning the baseline and pipeline sites, based on a defined asset lifetime, which varies according to the scenario:
    - In **Consumer Transformation**, incinerators have a lifetime of 45 years
    - In **Leading the Way** and **System Transformation**, incinerators have a shorter lifetime of 30 years, due to decreasing waste resource availability, as a result of higher societal change and less waste produced overall, in these scenarios.
- No ACT capacity is modelled to decommission by 2050, based on an assumption that they are compliant with a net zero emissions target.
- All energy from waste generation sites remain connected up to and beyond 2050 in **Steady Progression**.
- In addition, it is assumed that the municipal waste produced per person will decrease towards 2050 meaning there may be less available and thus the generation site load factors may change also.

Figure 19 Summarising scenario projection graph for energy from waste, with comparison to FES regional



Reconciliation with National Grid FES 2020:

- The assumptions underpinning the DFES analysis are largely in-line with the FES 2020 regional projections, however the results differ due to local factors and spatial distribution.
- SSEN connection data suggests a baseline capacity which is higher than the FES 2020 baseline for the North of Scotland licence area. This is possibly due to an incinerator that increased its capacity in June 2020, potentially not being included in the FES 2020 regional data.
- Near term deployment is significant due to the pipeline sites which both have planning permission and are expected to connect in all scenarios thus doubling the capacity in the licence area in the near term in the DFES.
- Where the FES 2020 regional projection data shows a smooth decline, the DFES analysis of connected and contracted energy from waste generation sites results in a decommissioning of actual sites, thus the capacity projection is much more stepped down.

Relevant assumptions from National Grid FES 2020:

Assumption number	4.1.11 (Waste generation)
Steady Progression	No great change in waste management from society; leaving waste available as a fuel source.
System Transformation	Less waste to burn in general due to a highly conscious society adapting to low waste living.
Consumer Transformation	Limited societal change in waste management; less waste than current produced, limiting waste to burn generation.
Leading the Way	Less waste to burn in general due to a highly conscious society adapting to low waste living.

References:

SSEN connection data, System Wide Resource Registers (GB), the TEC register, the Renewable Energy Planning Database, Climate Emergency declaration data, Regen consultation with local stakeholders and discussion with technology developers.

8. Landfill gas, sewage gas and biogas in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers electricity generated from renewable engines connected to the distribution network in the North of Scotland licence area. This technology sector is broken down into three renewable gas generation sub-technologies: landfill gas, sewage gas and biogas from other anaerobic digestion (AD) (e.g. food waste). The analysis focuses on CHP plants that generate electricity and excludes plants that are solely used for heat and biomethane production. **DFES Building Block ID number Gen_BB004.**

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

Technology	Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Anaerobic digestion	Steady Progression	8	8	10	12	16	19	21	22
	System Transformation		8	14	19	25	29	31	30
	Consumer Transformation		8	15	21	29	35	38	38
	Leading the Way		8	16	23	32	41	47	56
Landfill gas	Steady Progression	20	20	20	20	20	20	20	20
	System Transformation		20	20	20	20	20	3	1
	Consumer Transformation		20	20	20	20	20	3	1
	Leading the Way		20	20	20	3	1	1	0
Sewage gas	Steady Progression	2	2	2	2	2	2	2	2
	System Transformation		2	2	2	2	2	2	2
	Consumer Transformation		2	2	2	2	2	2	2
	Leading the Way		2	2	2	2	2	2	2

Overview of anaerobic digestion projections in the licence area:

Feedstock from waste is a critical factor in the potential to develop new/additional AD capacity. The North of Scotland licence area has low potential for AD, as 71% of local authorities in the area already have food waste collection policies, which means a lot of the municipal feedstock is already accounted for in the licence area. The grade of agricultural land in the North of Scotland is also relatively low and as a result, the baseline and projections are below 2% of the national GB FES 2020 projections.

In the medium and long term, demand for 'green gas' is expected to increase for a variety of applications including transport, gas grid injection and heat networks. There is also the potential opportunity, which has been highlighted by the Committee on Climate Change[xv], to use biomethane in larger generation plants with carbon capture and storage to create negative emissions. It is likely therefore that AD produced biomethane for small scale electricity generation will be limited.

Overview of landfill gas projections in the licence area:

Landfill gas capacity is expected to decline over time in the three scenarios that meet net zero targets, as residual waste is either gasified or directly burned, as opposed to buried. Baseline landfill gas sites connected to the distribution network are assumed to have a lifetime of 30 to 40 years in these three net zero scenarios. Under **Steady Progression** however, these sites do not decommission and are instead repowered.

Overview of sewage gas projections in the licence area:

From consultation with Scottish Water Enterprise, there are currently no plans to increase electricity generation from their biogas or biomethane resources; therefore the DFES has not projected any change in sewage gas used for electricity generation across the timeframe.

There is some uncertainty over whether sites in the long term might convert to biomethane as demand for green gas rises. However, the DFES has aligned more with the FES 2020 projections in the longer term, and therefore this uncertainty has not been directly reflected.

Scenario projection results:

Baseline (up to end of 2019)

Anaerobic digestion:

- The North of Scotland licence area currently has 19 sites, totalling 8 MW, of AD driven generation connected to the distribution network. This accounts for around 1.2% of the baseline capacity in GB.

Landfill gas:

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

Sewage gas:

- According to SSEN connection data and the AD Biogas Map, there are four sites, totalling 1.5 MW, of sewage gas generation connected to the distribution network in licence area.

Near term (2020 – 2025)

Anaerobic digestion:

- There are two AD generation sites with an accepted connection offer in the licence area, and one in the Renewable Energy Planning Database.
- These pipeline sites together total 3 MW.
- The DFES has modelled two of these sites to connect by 2023 in the three scenarios that meet net zero targets.
- The remaining site connects in all scenarios, as it has both planning permission and an accepted connection offer.

Landfill gas:

- There are no landfill gas generation pipeline sites in the SSEN connections data.
- No increase in landfill gas generation capacity has been projected licence area under any scenario.
- To reflect Scotland's carbon reduction targets, landfill gas generation capacity begins to decline from 2032 in **Leading the Way**.

Sewage gas:

- There is one pipeline site with an accepted connection offer of 0.2 MW. This site connects in all scenarios by 2024.

Medium term (2025 – 2035)

Anaerobic digestion:

- In the medium term, AD generation capacity is assumed to be primarily driven by local authorities requiring additional food waste processing facilities from the mid-2020s. A moderate increase in connected capacity is seen in all scenarios in this timeframe.

Landfill gas and sewage gas:

- There is no change projected in the connected capacity of landfill gas and sewage gas generation from 2025 to 2035.

Long term (2035 – 2050)

Anaerobic digestion:

- The development of additional AD generation capacity will be driven by technology cost reductions, potentially through modularisation, and the potentially high revenues that could be captured from AD plants providing flexibility and balancing services to the electricity networks.
- However, an increase in connected generation capacity is expected to slow in the longer term due to competing demands for biomethane as a fuel option for zero carbon heat, green gas injection or transport and as the government incentivises a switch to larger plants that can achieve negative emissions (e.g. Bio Energy Carbon Capture and Storage).
- In addition to this, it is assumed that food waste produced per person will likely decrease towards 2050, meaning there may be less feedstock available for AD processing.

Landfill gas:

- Older landfill gas sites are expected to decommission as a result of declining waste resource availability and some competition with other waste processing technologies, such as energy from waste.
- Landfill gas sites are assumed to have a lifetime of 30 to 40 years in the scenarios that meet net zero targets by 2045 and therefore sites begin to decommission from 2032. Sites are assumed to come offline sooner in the North of Scotland licence area than other parts of the country, reflecting Scotland Government's ambitious target to reduce greenhouse gas emissions by 75% by 2030.
- Under **Steady Progression**, a scenario has been considered where all existing distribution network connected landfill gas sites with connection agreements, remain online out to 2050.

Sewage gas:

- In the long term, the scale of use of sewage gas for electricity generation is unclear.
- Whilst there might the potential for Scottish Water to increase use of sewage gas for power generation, discussions did not indicate this was currently a priority. The DFES has therefore not modelled any increase in sewage gas electricity generation under any scenario; this assumption aligns well with the FES 2020 assumptions and projections.

Figure 20 Summarising scenario projection graph for anaerobic digestion

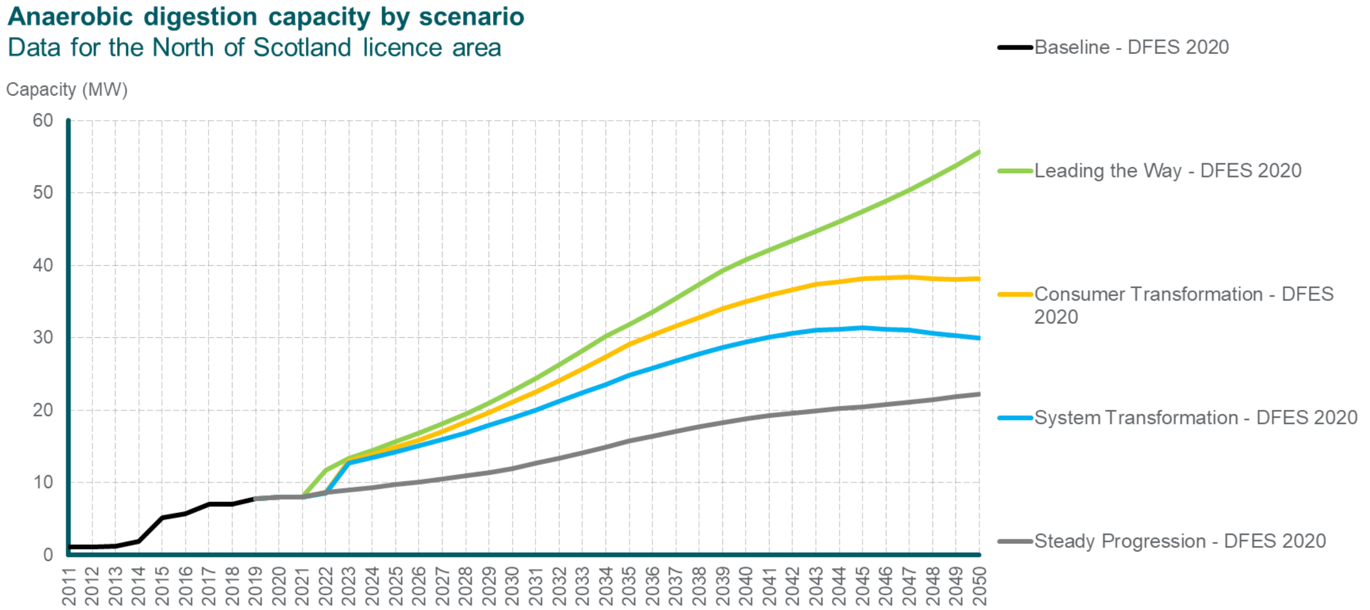


Figure 21 Summarising scenario projection graph for landfill gas

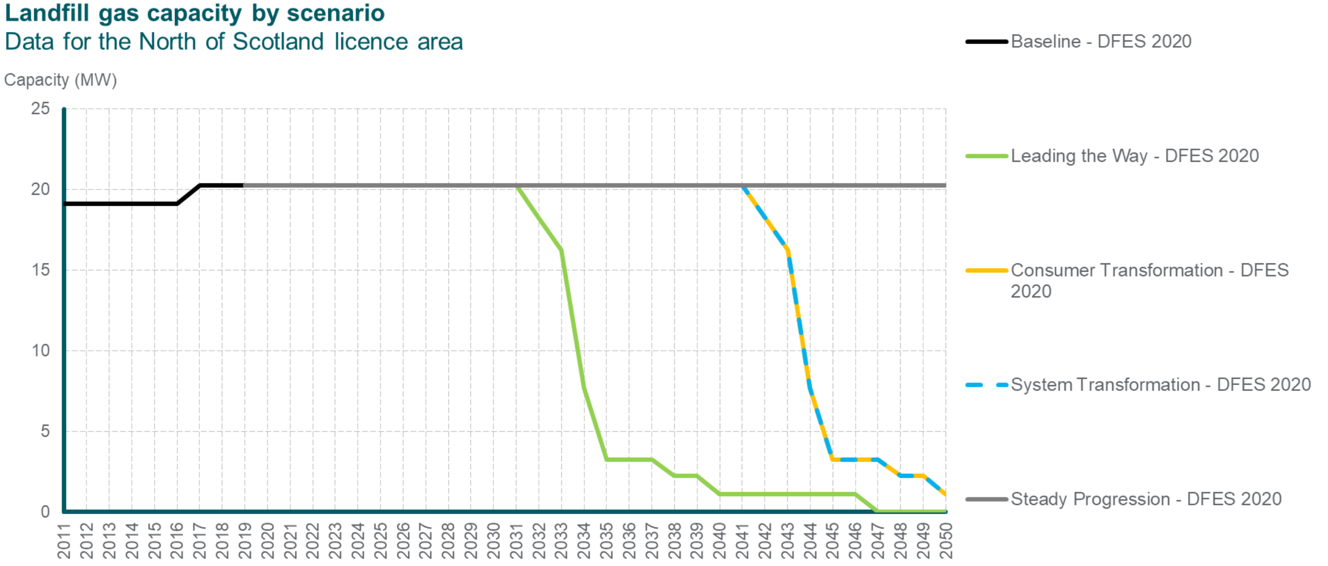


Figure 22 Summarising scenario projection graph for sewage gas

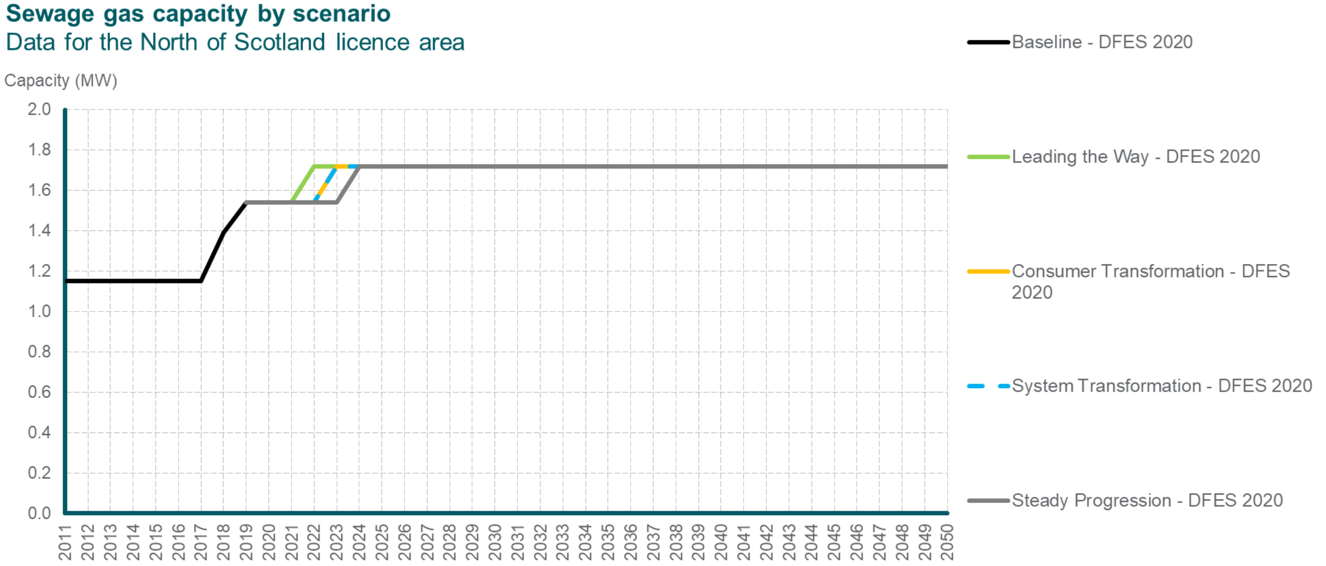
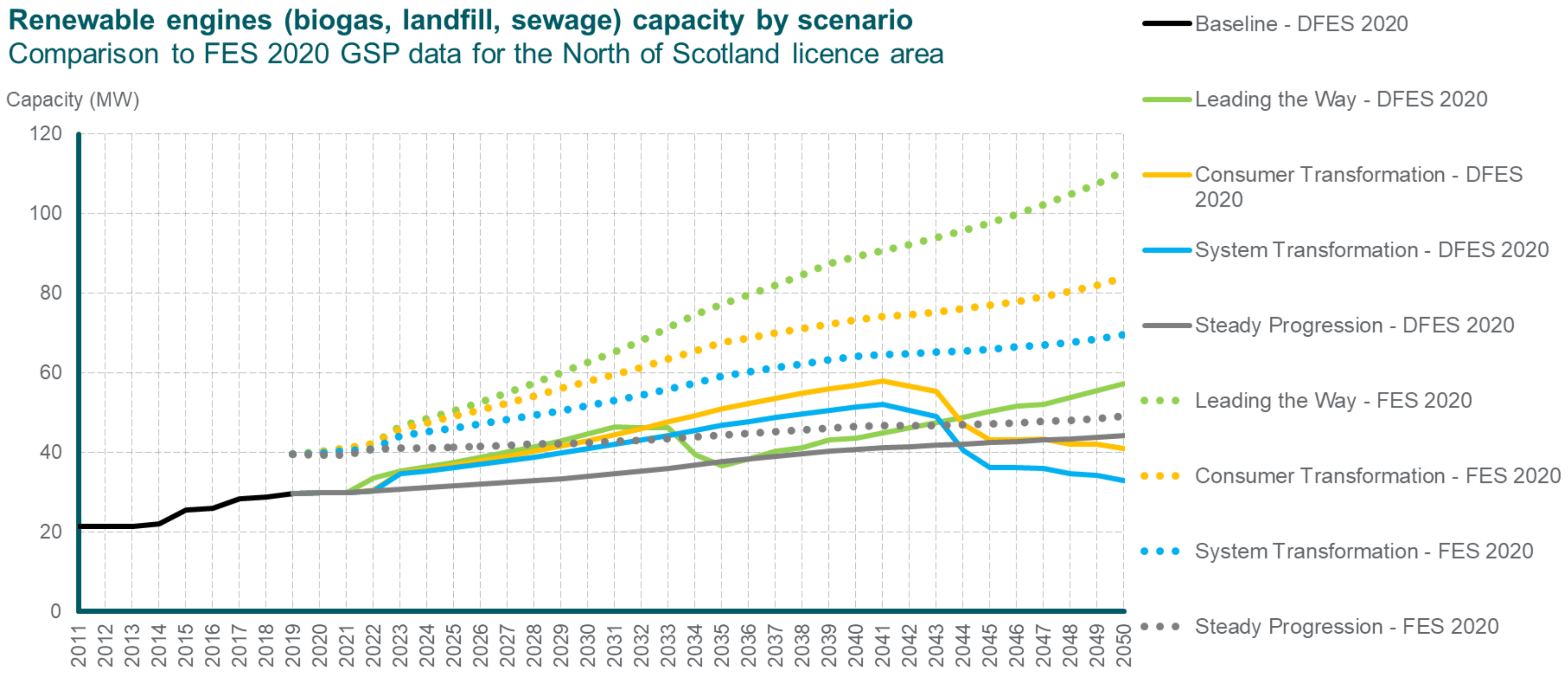


Figure 23 Summarising DFES scenario projection graph for renewable engines, with comparison to FES regional data



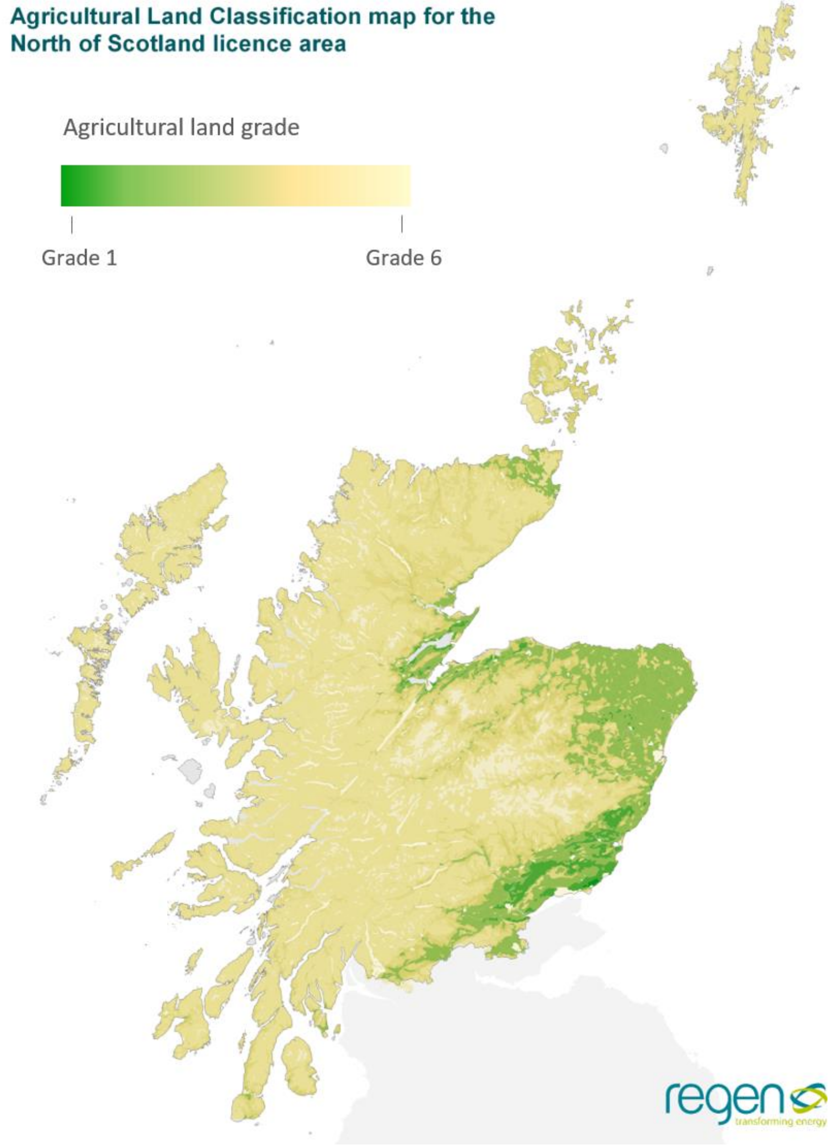
Reconciliation with National Grid FES 2020:

- The assumptions underpinning the DFES analysis are in line with the FES 2020 results, however the results differ in some areas, due to local factors or spatial distribution.
  - The DFES baseline capacity is lower than the FES 2020 baseline for the North of Scotland licence area by 10 MW.
  - The increase in renewable engines generating capacity comes primarily from AD
  - It has been assumed in the DFES for the North of Scotland that the landfill gas sites are decommissioned after an operational life of 30 to 40 years, due to a reduction in available waste resource and ambitious emission reduction targets in Scotland. This results in significant drops in renewable engine capacity in the medium and long term in the DFES.
  - This decommissioning method for sites in the medium and long term means that the decline in total capacity is more stepped.
- Under **Steady Progression**, a scenario has been considered where all existing distribution network connected landfill gas sites with connection agreements, remain online out to 2050.

Factors that will affect deployment at a local level:

- The spatial distribution of future AD sites that connect to the distribution network is weighted towards areas with sufficient agricultural land grade (grade 1 and 2 – see Figure 24) and also towards local authorities that do not yet collect food waste as potential new feedstocks can arise in these areas.
- In the North of Scotland licence area, only 29% of local authorities do not collect food waste, which means there is not much residual feedstock left to exploit. This information was collected as part of a survey Regen send to local authorities as part of the new developments study.

Figure 24 Agricultural land classification map of the North of Scotland licence area



Relevant assumptions from National Grid FES 2020:

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

Stakeholder feedback overview:

Scottish Water were consulted in regard to their future strategy and plans for sewage gas generation and biomethane production. Feedback was provided that they currently do not have any sewage sludge gas-to-grid injection sites in their portfolio. They also fed back that they are seeking to review their biogas strategy, but as of yet, have no plans to increase their current biomethane production.

Therefore, the DFES has not modelled any decline or increase in sewage gas capacity on the electricity network. However, sewage gas sites converting to potentially produce (or inject) biomethane, remains an uncertainty factor in the longer term.

References:

SSEN connection data, System Wide Resource Registers (GB), the TEC register, the Renewable Energy Planning Database, Climate Emergency declaration data, Regen consultation with local stakeholders and discussion with technology developers.

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

9. Gas fired generation in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

DFES technology building blocks:

- **Non-renewable Engines (Combined Heat and Power (CHP)) - Gas [Gen_BB001], [Gen_BB002] and [Gen_BB003]**
- **Non-renewable Engines (non CHP) – Gas Reciprocating Engines [Gen_BB006]**
- **Gas Open Cycle Gas Turbines (OCGTs) (non CHP) - [Gen_BB008]**

The analysis covers any natural gas fuelled electricity generation in the North of Scotland licence area, connecting to the distribution network. This includes sub technologies of OCGTs, gas CHPs and gas reciprocating engines. Distribution network CCGTs area are not included in the DFES, with no baseline projects or projections out to 2050 in any scenario. The analysis also includes hydrogen fuelled electricity generation, which has been modelled to connect to the distribution network in areas where there is the potential for hydrogen gas network conversion by or before 2050, in the **System Transformation**, **Leading the Way** and **Consumer Transformation** scenarios.

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

Gas sub-technology	Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Gas OCGTs	Steady Progression	0	0	0	0	0	0	0	0
	System Transformation		0	0	0	0	0	0	0
	Consumer Transformation		0	0	0	0	0	0	0
	Leading the Way		0	0	0	0	0	0	0
Gas reciprocating engines	Steady Progression	0	1	64	64	64	64	64	63
	System Transformation		1	21	21	21	20	0	0
	Consumer Transformation		1	21	21	21	20	0	0
	Leading the Way		1	21	21	21	20	0	0
Gas CHPs	Steady Progression	53	53	53	53	53	41	41	10
	System Transformation		53	53	38	17	7	1	0
	Consumer Transformation		53	53	36	16	4	0	0
	Leading the Way		53	38	17	5	1	0	0
Hydrogen peaking plants	Steady Progression	0	0	0	0	0	0	0	0
	System Transformation		0	0	0	14	17	23	24
	Consumer Transformation		0	0	0	2	5	8	8
	Leading the Way		0	0	0	2	5	11	11

Overview of technology projections in the licence area:

The capacity of decentralised natural gas fired generation in the North of Scotland is relatively low compared to some other parts of the UK. This reflects a higher than average amount of the licence area being off the gas network. By far the most abundant type of natural gas generation asset in the licence area is small scale onsite gas CHPs. These assets provide electricity (and recovered heat) to many local businesses and buildings in city regions, such as Aberdeen Infirmary, Dundee University, a supermarket in Inverness and a Golf and Country Club in Invergowrie. There are also some higher capacity gas reciprocating engine projects in the licence area that are seeking to connect within the 2020s. The DFES analysis has therefore focussed on the development potential for the pipeline sites (as new fossil fuel generators within the scenarios) and the potential for many of the baseline sites to decommission across the 2030s and 2040s, in line with both the net zero compliancy of **Leading the Way**, **Consumer Transformation** and **System Transformation**, as well as the 2045 net zero target year in Scotland. The longer term DFES analysis also considers the potential for some of these known sites and projects that may operate more commercially, to convert their generator assets to be able to run on hydrogen instead of natural gas, in city or local authority regions within the licence area that have been identified as hydrogen supply zones.

For the three scenarios that are compliant with the target to achieve net zero emissions by 2045 in Scotland, all natural gas generation is decommissioned before 2045 and a moderate hydrogen peaking capacity in specific modelled to come online between 2035 and 2050. In the **Steady Progression** scenario, the capacity of natural gas fired generation continues to increase slowly out to 2050, and no hydrogen generation is modelled to come online.

At a high level, the long term role of natural gas and hydrogen fuelled generation in North Scotland is uncertain. Gas generation is an inherently flexible and responsive technology that can potentially support the operability of the electricity system in the near-term. However, with natural gas being a carbon intensive fuel and exhaust emission abatement technologies potentially being prohibitively costly to fit to smaller scale generators, the running of unabated natural gas generation is at odds with Scottish Government's recently announced[xvi] ambitions for reducing carbon intensity of electricity generation between now and 2023, as well as longer-term carbon emission targets set for 2030 and 2045. Similarly, whilst some areas of Scotland are being considered a hub for hydrogen development, uncertainty remains around the strategy for hydrogen production, hydrogen supply infrastructure and the locational or national scale of hydrogen demand. This creates some uncertainty around distributed hydrogen generation.

Scenario projection results:

Baseline (up to end of 2019)

- There are 37 operational natural gas generators, totalling c.53 MW, in the North of Scotland licence area. These are almost entirely small-scale gas CHPs (many with capacity of 1 MW or less), that are located onsite at businesses, commercial buildings or other operational sites, including hospitals, universities, farms, supermarkets, sports and leisure centres, hotels and golf clubs.
- There are only three sites that have a capacity greater than 10 MW, two of which are located on the Scottish islands of Orkney and Shetland. The bespoke nature of the electricity and heat supply to these islands means that the scenario analysis has considered the future of these assets in the context of their specific island energy supply plan, due to the need to balance the net zero emissions targets in Scotland and maintaining security of supply to the islands, and the expected operational life of the current assets connected on the islands.

- There are no gas OCGTs operating on the gas distribution network in the North of Scotland licence area, potentially related to the lower transmission network voltage tiers in Scotland.

Near term (2020 – 2025)

- There are five natural gas generation projects with accepted connection offers in the licence area, totalling c.99 MW.
- Four of these projects, totalling c.98 MW, are commercial scale reciprocating engine sites.
- From reviewing local planning portals, a 35 MW project located in Fraserburgh appears to have a deferred planning decision in 2018 and a 1.2 MW located at a malt brewery in Inverness received planning approval in 2016.
- From reviewing Capacity Market auctions, a 20 MW project located in Dundee successfully pre-qualified in the 2019 T-1 and T-4 auctions (the latter for 2023 delivery). However, it does not appear to have been awarded a Capacity Agreement for either auction.
- No development information could be found for the remaining 43 MW of pipeline capacity.
- The DFES has therefore modelled c.64 MW of additional gas fired generation to connect to the network in the early 2020s in **Steady Progression**. In **Leading the Way**, **Consumer Transformation** and **System Transformation**, only 21 MW goes through to connection.

Medium term (2025 – 2035)

- With both an interim target to reduce carbon emissions in Scotland by 75% by 2030[xvii] and a target to source 50% of energy demand in Scotland from renewable sources[xviii], the DFES has sought to decommission a proportion of the 53 MW of unabated natural gas CHPs across the late 2020s and 2030s in **Consumer Transformation** and **System Transformation**.
- A more accelerated decommissioning of the baseline was modelled in the **Leading the Way** scenario, reflecting an even more ambitious decarbonisation trajectory, with only 17 MW of unabated natural gas generation remaining connected to the distribution network in the North of Scotland after 2035, most of which is located on the Scottish islands, which will be subject to their individual island energy supply plans.
- In **Steady Progression** the 53 MW gas CHP baseline is modelled to continue operating across the 2020s and out to the late 2030s, reflecting a much slower decommissioning of these legacy CHP sites.

Long term (2035 – 2050)

- No additional natural gas generation has been modelled to connect in any scenario between 2035 and 2050. This reflects Scottish Government ambitions to reduce the presence of fossil fuel generation in Scotland, by targeting to source 50% renewable energy and reduce greenhouse gas emissions by 75% by 2030.
- The decommissioning of existing baseline and pipeline sites is modelled to continue in the scenarios, based on categorisation of the connection year, size and gas generation technology class. This culminates in no unabated natural gas generation operating on the distribution network in the licence area by 2044 in **Leading the Way** and **Consumer Transformation** and by 2045 in **System Transformation**.
- The commercial scale reciprocating engine sites modelled to connect in the 2020s in **Steady Progression**, continue to operate in this scenario beyond the 2050 timeframe of the DFES, reflecting less low carbon generation connecting to system and an increased reliance on fossil fuels and not achieving net zero by 2045 in Scotland.

Hydrogen and hydrogen fuelled electricity generation in Scotland

In March 2020, Scottish Government announced the launch of the Hydrogen Assessment Project[xix], working alongside Scottish Enterprise and Highlands and Islands Enterprise. This project is seeking to evaluate the role that hydrogen could play in Scotland achieving net zero emissions by 2045. The results of this project should be known towards the end of 2020, but with other initiatives such as The Hydrogen Coast project (led by the gas distribution network operators SGN, National Grid and Pale Blue Dot) identifying North East Scotland as having the potential to "*lead the way in developing a hydrogen economy*"[xx], the DFES has identified the potential for hydrogen supply areas within the licence area.

This analysis has subsequently led to the development of scenario projections for hydrogen fuelled electricity generation in the licence area. The location of these potential hydrogen gas network supply areas has been modelled by identifying known hydrogen development and trial projects in North Scotland such as H2 Aberdeen, SGN's H100 project in Fife. In addition to this, the modelling has also identified potential future hot spots for hydrogen development, such as heavy transport fuelling hubs and industrial areas.

The analysis has then sought to identify the relevant ESAs that fall within these potential future hydrogen supply zones, and a proportion of the baseline natural gas sites (and thus their MW capacities) have been modelled to essentially 're-power' as hydrogen fuelled generation sites in the late 2030s and 2040s. The geographic scope of hydrogen supply zones is most widespread in **System Transformation**, as the scenario with the highest abundance of network hydrogen, second in **Leading the Way** and a limited number of hydrogen supply areas have been modelled in **Consumer Transformation**. This scenario-specific modelling of hydrogen zones has therefore created an equivalent range of hydrogen electricity generators connecting by 2050 in the scenarios. By 2050:

- In **System Transformation**, 28 hydrogen generation sites, totalling 24 MW, connect by 2050, across the Aberdeen city region and Aberdeenshire, Dundee city region, and some on-gas areas within the Moray and Stirling local authority boundaries.
- In **Leading the Way**, 21 hydrogen generation sites, totalling 11 MW, connect by 2050, across the Aberdeen city region, Aberdeenshire and Dundee city regions.
- In **Consumer Transformation**, 9 hydrogen generation sites, (8 MW), connect by 2050, in the Aberdeen and Dundee city regions only.
- In **Steady Progression**, no hydrogen generation sites are modelled to connect by 2050.

As a general consideration, the business case for hydrogen fuelled electricity generation is likely to be challenging, with hydrogen as the future input fuel almost certainly set to be more expensive than natural gas is today. Contrarily, Scottish Government and SGN are actively reviewing the potential role of hydrogen in Scotland and the islands also seeking to trial and explore how hydrogen could benefit island communities[xxi]. In addition to this, from the recently published Climate Change Plan Update and the Hydrogen Policy Statement[xxii], it is clear to see that Scottish Government has ambitions for hydrogen production and use in Scotland. This may result in a potentially stronger adoption of hydrogen fuelled electricity generation (as one use case of many being considered), than is seen in the DFES 2020 results for the North of Scotland licence area. However, the amount of hydrogen electricity generation that may operating on the transmission network is unclear. A notable level of uncertainty around distribution network connected hydrogen generation has been reflected in scenario outcomes in the 2020 DFES. The Hydrogen Policy Statement from Scottish Government was published in December 2020 after the DFES 2020 analysis was complete. SSEN will however use this, and the expected Hydrogen Action Plan, to inform the DFES 2021 analysis in more detail.

Figure 25 Comparison of gas CHP projections in the North of Scotland licence DFES analysis to the FES 2020

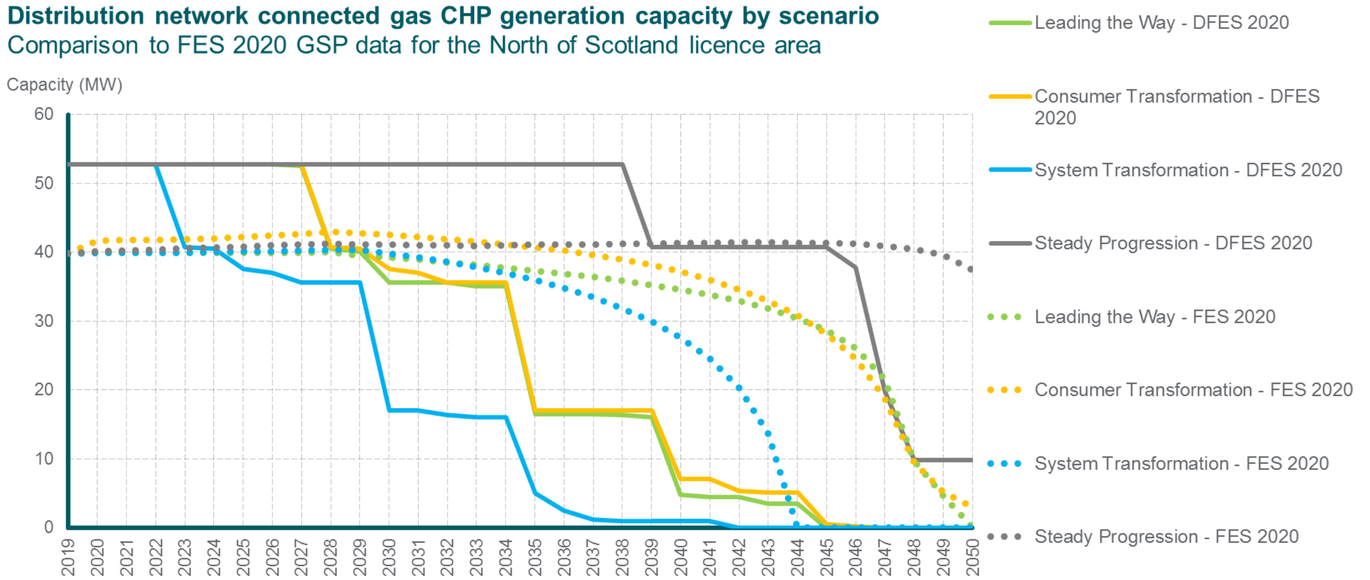


Figure 26 Gas reciprocating engine projections in the North of Scotland licence from DFES analysis

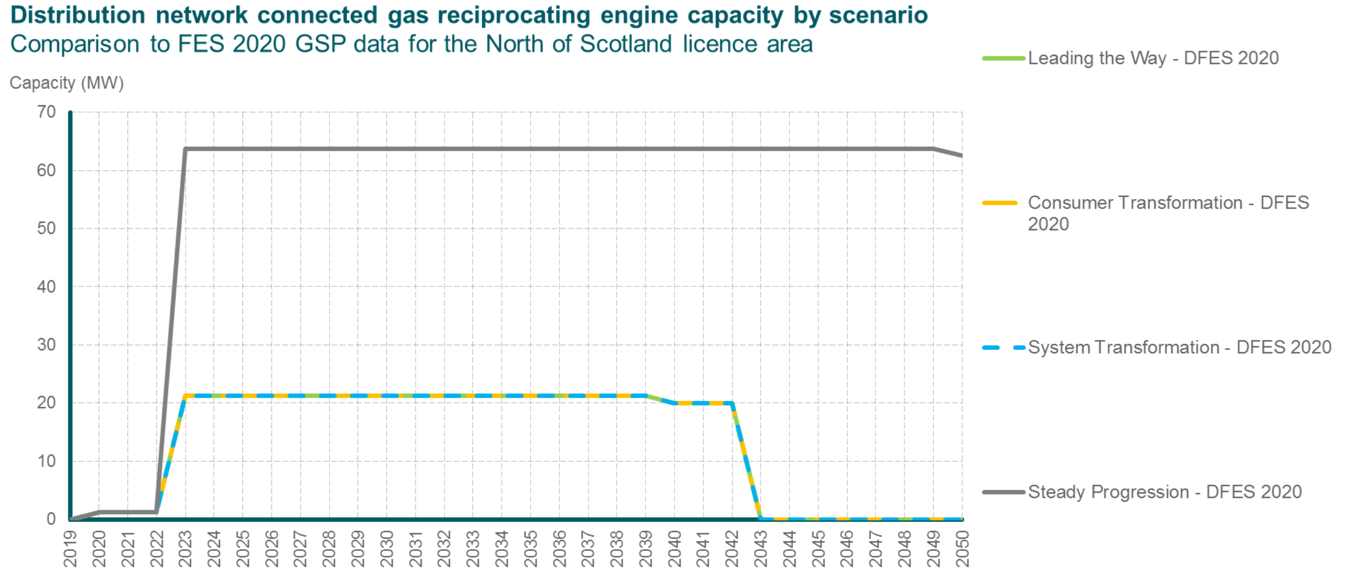
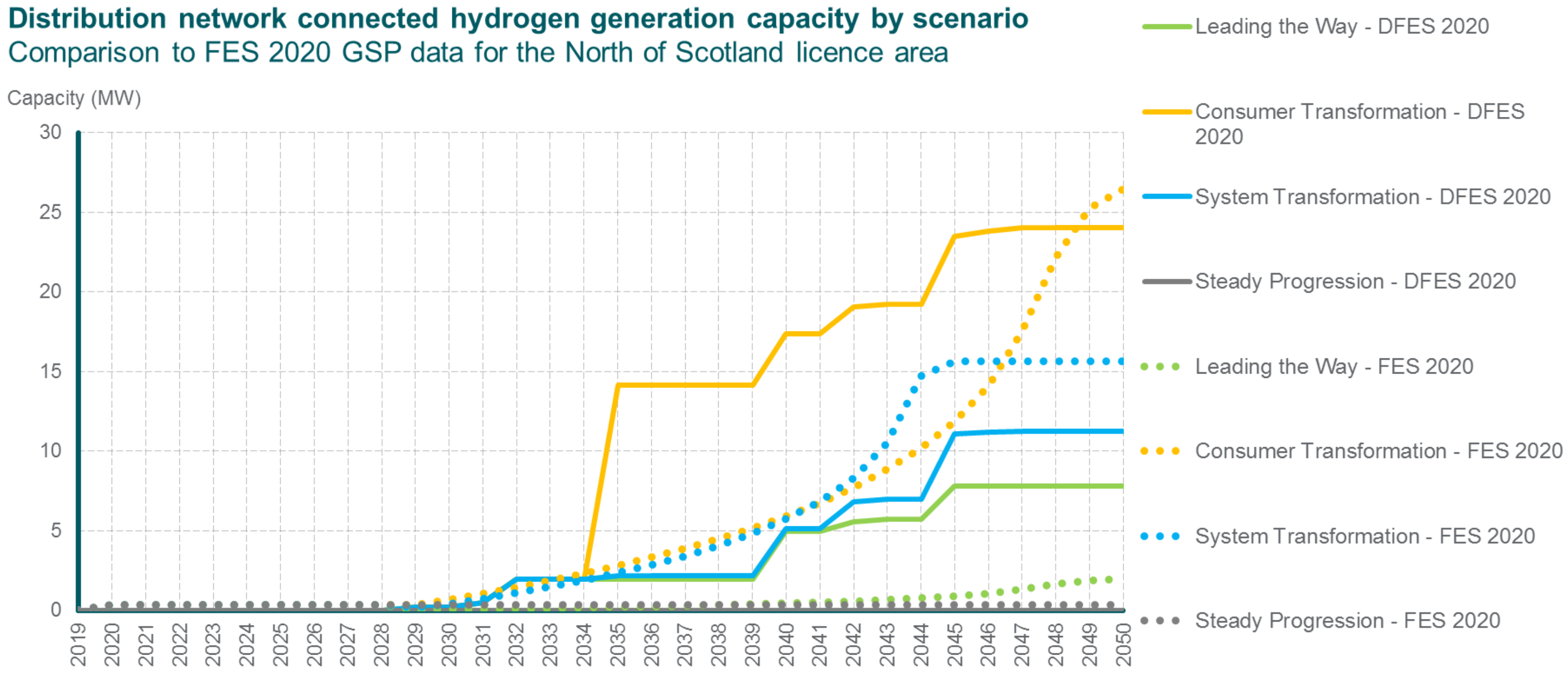


Figure 27 Hydrogen peaking plant projections in the North of Scotland licence from DFES analysis

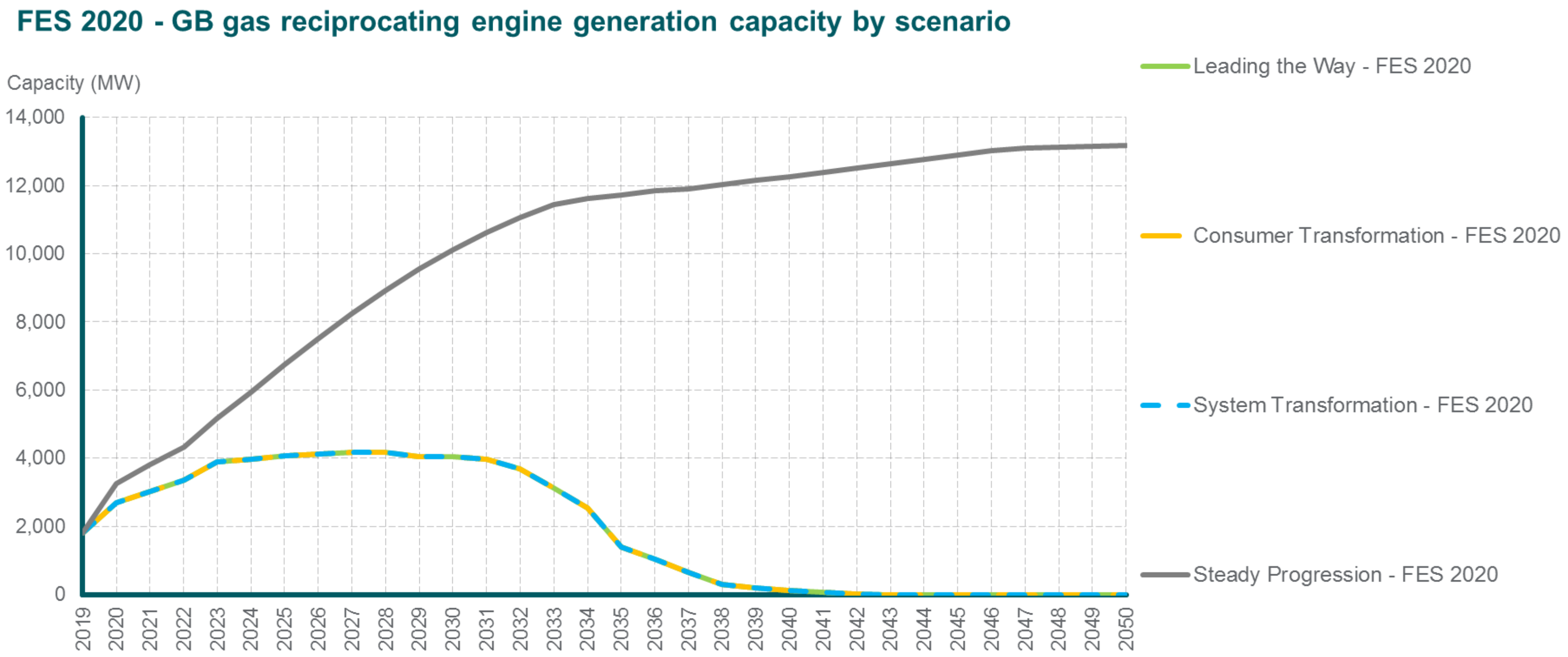


Reconciliation with National Grid FES 2020:

- The DFES and FES concur on there being no existing or future **CCGT** or **OCGT** projects in the North of Scotland licence in any scenario.
- With regards to **gas CHPs** in the licence area (see Figure 25):
  - The FES GSP level data has a lower baseline than the DFES (40 MW compared to 53 MW). This could be down to misclassification of technologies or gas sub-technologies in the data.
  - The near, medium and long term gas CHP trends across the scenarios in the FES differ notably to the DFES.
  - The FES projects a smoother, more gradual reduction in connected gas CHP capacity in **Leading the Way**, **Consumer Transformation** and **System Transformation** and practically a flattening of capacity in **Steady Progression** out to the 2040s.
  - The DFES however has modelled to decommission specific baseline projects in all scenarios, including some legacy (e.g. 1980s/early 2000s) gas CHPs coming offline in the 2040s in **Steady Progression**.
  - This reflects Scottish Government aspirations to reduce reliance on fossil fuel generation in Scotland by 2030-2045 and subsequently leads to a much more stepped reduction in connected gas CHP capacity in all scenarios in the licence area.

- With regards to **gas reciprocating engines** in the licence area (see Figure 26):
    - The FES GSP data for the North of Scotland licence area has no projections for reciprocating engine capacity in any scenario.
    - The DFES modelling has diverged from this high level technology assumption, primarily due to the awareness of c.99 MW of gas reciprocating engine projects with accepted connection offers in the licence area.
    - In addition to this, GB projections for distribution network connected reciprocating engine capacity ranges from 4-10 GW within the 2020s, rising to c.13 GW in **Steady Progression** by 2050, (see Figure 28).
    - It can be considered that the potential uptake of this sub-technology on the distribution network in the North of Scotland is likely to be low overall, due to the lower transmission voltage tiers in Scotland and a lower than average gas network coverage. The DFES has effectively reflected this consideration, with the DFES projections in **Steady Progression** being c.0.5% of the GB total in 2050.

Figure 28 FES 2020 GB gas reciprocating enging projections

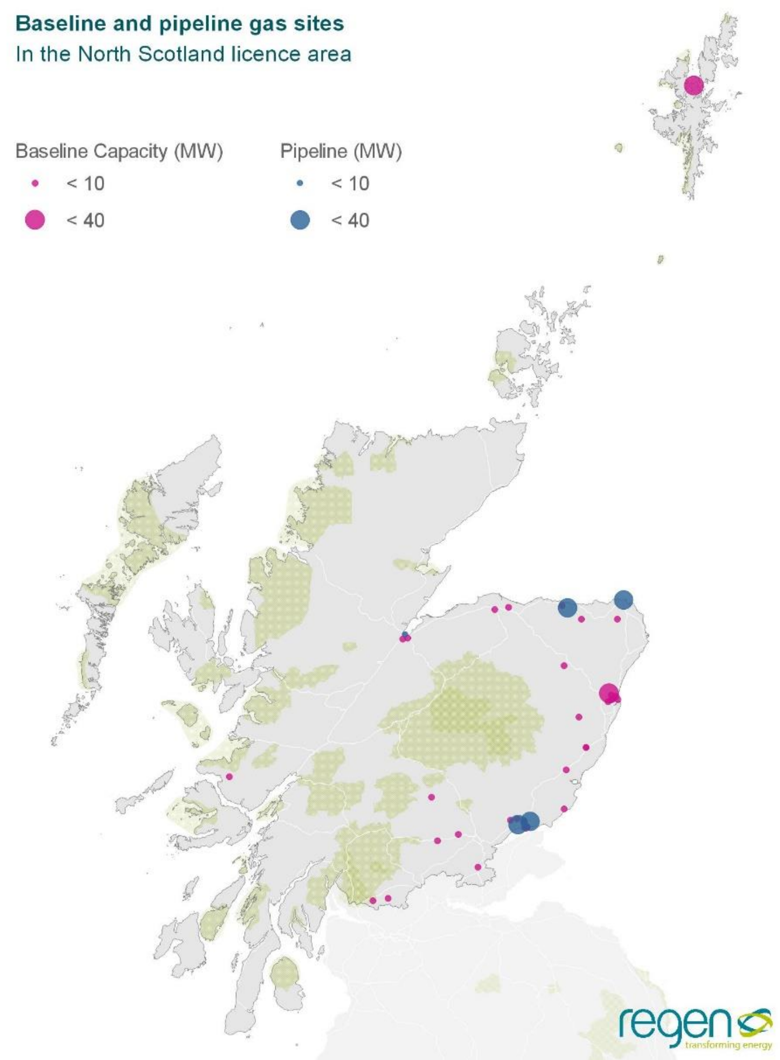


- With regards to **hydrogen fuelled generation** in the licence area (Figure 27)
    - The FES GSP projections align to the DFES projections across the scenarios by 2050.
    - However, the FES has modelled a much smoother, more gradual increase in connected capacity between 2030 and 2050 in **System Transformation** (the scenario with the highest connected capacity). Whereas the DFES has sought to model specific baseline project capacities within identified future hydrogen supply areas, resulting in a much more stepped increase in capacity in this scenario across the 2030s and 2040s.
    - The method by which the DFES allocates project capacity in other scenarios (see "Hydrogen and hydrogen fuelled electricity generation" section above), sees a slightly lower overall capacity connecting in **Leading the Way** and contrarily a slightly higher capacity connecting in **Consumer Transformation** in the DFES by 2050, compared to the FES GSP projections. Though with these variances being less than 10 MW across the licence area in each case, the impact on the network can be considered low to moderate, when compared to the future projections for other generation technologies in the North of Scotland licence area.

Factors that will affect deployment at a local level:

An obvious consideration around natural gas and hydrogen fuelled electricity generation is the lower than average gas network coverage in the North of Scotland licence area. The islands and highlands region are entirely off-gas and gas network coverage in the middle regions of the licence area is also quite low. This essentially limits the potential for new natural gas generation capacity to connect in the near-term and the potential for hydrogen fuelled electricity generation in the longer term, to the east and southern areas of the licence area.

Figure 29 Map of distribution network natural gas baseline and pipeline sites in the North of Scotland licence area



- For modelling the decommissioning of existing natural gas generation sites in the DFES, the actual location of known baseline and pipeline sites have been used. Similarly, the distribution of the few pipeline sites that have been modelled to connect in the 2020s (e.g. in **Steady Progression**) also use their respective site locations.
- For modelling the connection of hydrogen fuelled generation in the 2030s and 2040s, a spatial analysis of hydrogen development projects, hydrogen technology trials and potential hydrogen network conversion areas was completed and compared to baseline and pipeline natural gas sites. The sites that both fell within these nominated potential hydrogen supply ESAs and those classified as being a potentially viable site to switch fuels (e.g. industrial premises or commercial operators that aren't currently running a gas CHP purely for self-use), were modelled to connect in **System Transformation** between 2035 and 2050. A lower number of these hydrogen supply ESAs were nominated in **Leading the Way** and a shortlist of ESAs in Dundee and Aberdeen city regions only were nominated in **Consumer Transformation**.

Relevant assumptions from the National Grid FES 2020:

Assumption number	4.1.31 (Unabated small scale thermal generation)
Steady Progression	**Less focus on decarbonisation compared to other scenarios**. Diesel plant retired later than other scenarios.
System Transformation	**Initial growth in gas peaking plant as renewables grow (instead of high growth in storage technologies), later switching to Hydrogen.**
Consumer Transformation	**Initial growth in gas peaking plant as renewables grow (instead of high growth in storage technologies), later switching to alternate sources of flexibility such as storage and V2G**.
Leading the Way	**Low use as scenario sees greater use of other technologies (e.g. storage).** Earliest closure of diesel reciprocating engines.

Stakeholder feedback overview:

Engaging with the Scottish Government provided some steer on the future aspirations for fossil fuel generation in Scotland. Firstly there are three relevant energy and decarbonisation headline targets that have affected the modelling of existing and new natural gas generation:

1) The target to achieve net zero greenhouse gas emissions by 2045
2) The target to reduce greenhouse gas emissions by 75% by 2030
3) The target to meet Scottish energy demand with 50% renewable sources by 2030

Scottish Government has also set out a vision to 2030 for the roles of the electricity and gas distribution networks[xxiii], which refers to the increase in low carbon generation connecting to the distribution network and the reduction of fossil fuels. More specific feedback was received with regards to an aspiration to see no new >50 MW gas generation sites operating in Scotland. However, some near-term increase in smaller scale flexible gas generation capacity could be seen, but the outcome of these prospective projects could be down to local planning authorities.

References:

SSEN connection data, EMR Delivery Body Capacity Market Registers, Scottish Government policy documents, online planning portals.

[xvi] See Scottish Government Climate Change Plan Update (p75-76): https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/
[xvii] See Scottish Government climate change policy on reducing greenhouse gas emissions: https://www.gov.scot/policies/climate-change/reducing-emissions/
[xviii] See Scottish Government policy on renewable and low carbon energy: https://www.gov.scot/policies/renewable-and-low-carbon-energy/
[xix] See Scottish Hydrogen & Fuel Cell Association: http://www.shfca.org.uk/news/2020/3/19/scotland-government-announces-their-hydrogen-assessment-for-net-zero
[xx] See SGN, National Grid and Pale Blue Dot, *The Hydrogen Coast* (Sep 2019): https://pale-blu.com/wp-content/uploads/2019/09/sgn-summary_digital.pdf
[xxi] See Shetland Islands Council article on the role of hydrogen (Sep 2020): https://www.h2-view.com/story/shetland-islands-council-gives-hydrogen-the-green-light/
[xxii] See Scottish Government Hydrogen Policy Statement: https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/
[xxiii] See Scotland's electricity and gas networks: vision to 2030: https://www.gov.scot/publications/vision-scotlands-electricity-gas-networks-2030/pages/6/

10. Diesel generation in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

DFES technology building block: Non-renewable Engines (non CHP) - Diesel [Gen_BB005]

The analysis covers any commercially operating diesel generation plants that are able export to the distribution network in the North of Scotland licence area. The analysis does not include back-up diesel engines located on some commercial and industrial premises that are only operated when mains supply failure occurs and cannot export. After consultation with the SSEN network planning team, the 126 MW of standby diesel generators located on the Scottish islands have also been excluded from the DFES modelling, reflecting the bespoke nature of these generators in providing security of supply to the island communities. Consideration can however be given for biomass or hydrogen generation to potentially replace these island diesel generators in the longer term, as a form of dispatchable thermal generation with lower carbon emissions than unabated diesel.

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

Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	0	20	20.5	20.5	0.5	0	0	0
System Transformation		0	0.5	0.5	0	0	0	0
Consumer Transformation		0	0.5	0.5	0	0	0	0
Leading the Way		0	0.5	0.5	0	0	0	0

Overview of technology projections in the licence area:

For the North of Scotland licence area, the diesel generators that are situated on the islands have been omitted from the modelling after consultation with both the SSEN network planning team and the energy policy team at Scottish Government. The back-up or 'top-up' nature of these island diesel generators providing security of supply to the islands in cases where either the demand exceeds the supply limit of the subsea mains cables or if those cables fail[xxiv]. As described above, low carbon alternatives could be considered to replace these island diesel generators in the longer term, such as bioenergy (e.g. biomass) or green hydrogen generation (e.g. via electrolysed renewable electricity).
The DFES analysis has therefore an otherwise zero baseline in the licence area and thus focusses only on very near-term known pipeline sites within the licence area. The longer term projections in the three scenarios that are compliant with the target to achieve net zero emissions by 2045 in Scotland, has focussed on decommissioning these pipeline diesel engines and thus removing all diesel capacity (bar the island generators) well ahead of 2045. The long term outcome of having no distribution network connected diesel generation in all scenarios within the 2030s/40s, shows a higher degree of certainty than other generation technologies in the DFES. This outcome also reflects stringent environmental permitting and air quality regulations and ambitious emission targets in Scotland.

Scenario projection results:

Baseline (up to end of 2019)

- Whilst there are eight operational diesel engines totalling 126 MW in the North of Scotland licence area, these are all on the islands and have been omitted from the analysis, due to the critical role they play in maintaining electricity to island communities.
- Whilst there are likely numerous small-scale diesel back-up generators located at e.g. hospitals, office buildings, industrial sites, universities etc. across the North of Scotland licence area, these assets that operate in times of mains failure only, are not included in the scope of the DFES diesel generation analysis. Therefore, the baseline diesel capacity in the scope of the DFES in the licence area is zero.

Near term (2020 – 2025)

- There are two diesel projects with accepted connection offers in the licence area:
    - A 500 kW engine located at Bunloinn, that SSEN has been advised will be commissioned in 2021
    - A 20 MW diesel plant located at a Quarry in Rigifa, south of Aberdeen, that SSEN has been advised will be commissioned in 2020.
- Neither of these projects have submitted a planning application, nor has either site been active in any Capacity Market auctions.
- At 500 kW, the Bunloinn site may be looking to provide back-up services rather than operating within the Capacity Marker or other commercial markets such as Short Term Operating Reserve (STOR). However, registering an export capacity indicates the potential for non-standby type operation.
- The DFES has modelled the 500 kW plant to connect in all scenarios in 2021 and the 20 MW plant to connect in **Steady Progression** only.

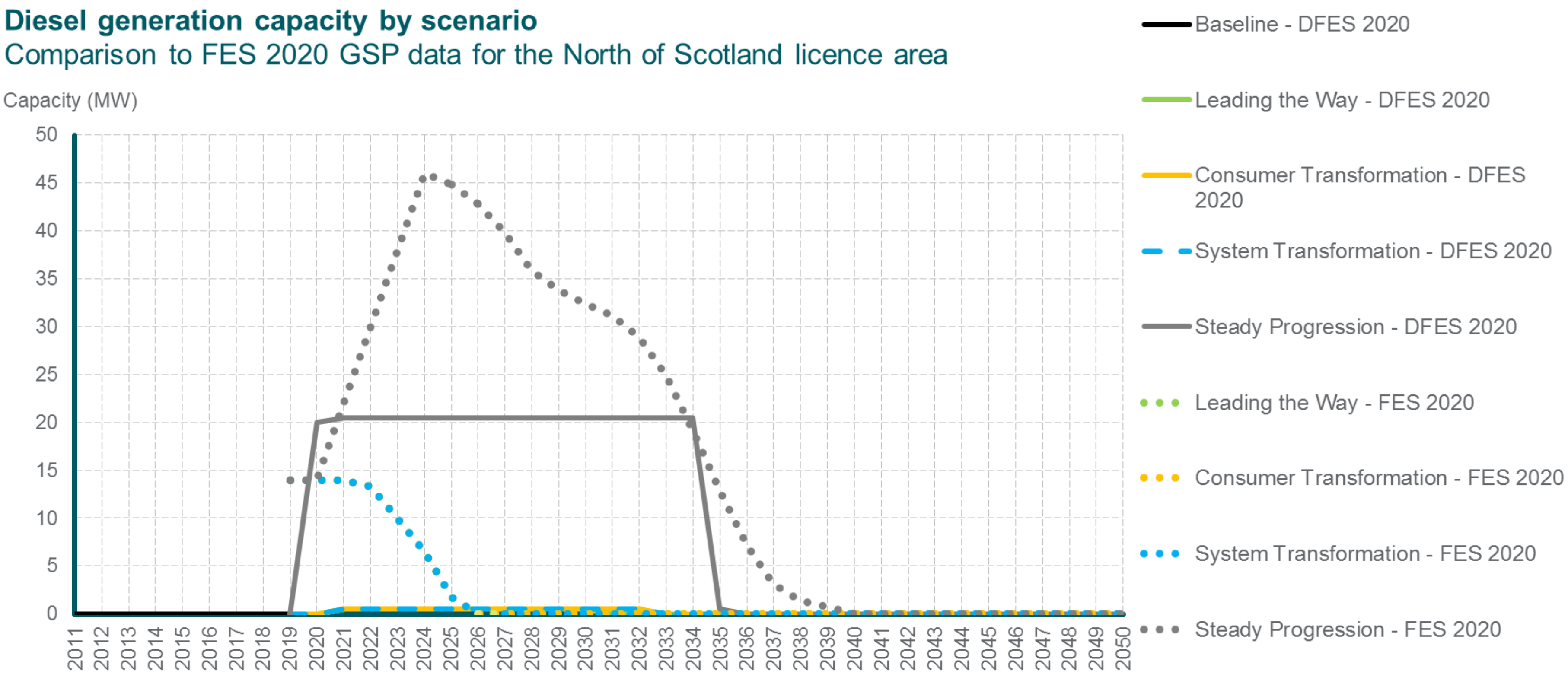
Medium term (2025 – 2035)

- The Medium Combustion Plant Directive (MCPD) has been placed into Scottish law[xxv], preventing unabated fossil fuel generators with a capacity greater than 1 MW, and installed after 20 December 2018, from operating in commercial markets. This requires operators to secure environmental permits that evidence the plants meets air quality and particulate emission limits. For diesel plants this could mean fitting costly exhaust emission filtration or abatement technologies.
- Plants between 5 MW and 50 MW will have to register for a permit by 1 Jan 2024 and comply with emission limit values by 1 Jan 2025. Plants between 1 MW and 5 MW will have to register for a permit by 1 Jan 2029 and comply with emission limit values by 1 Jan 2030.
- Whilst all >1MW generators will need to register for a permit, exemptions from the MCPD controls and emission limits include generators that operate for less 500 hours a year (e.g. back-up only generation).
- The DFES has therefore modelled the decommissioning of the 500kW pipeline site 10 years after it is modelled to come online in **Leading the Way**, 12 years after in **Consumer Transformation** and **System Transformation** and 15 years after in **Steady Progression**. This reflects a staggered approach to replacing back-up diesel that is exempt from MCPD with low carbon alternatives across the scenarios.
- The 20 MW pipeline site is also modelled to disconnect in **Steady Progression** 15 years after connection, reflecting the potential for emission abatement technologies and environmental permitting becoming cost-effective in this scenario.

Long term (2035 – 2050)

- No additional diesel generation has been modelled to connect in any scenario.
- No diesel capacity is operating in the licence area in any scenario by the mid/late 2030s.

Figure 30 Comparison of diesel generation projections in the North of Scotland licence DFES analysis to the FES 2020



Reconciliation with National Grid FES 2020:

- In general terms the FES scenario logic aligns very well to the DFES, with regards to:
    - **Steady Progression** being the only scenario with any increase in connected diesel generation capacity
    - **Leading the Way**, **Consumer Transformation** and **System Transformation** decommissioning all distribution network connected diesel generation c.5 years ahead of **Steady Progression**
    - No diesel generation capacity being connected to the distribution network in the North of Scotland, by 2035

The main variance between the regional FES numbers and the DFES for the North of Scotland licence area, is the baseline capacity. This is potentially due to the FES determining some of the island generators as non-standby, or an awareness of commercial diesel generators within the North of Scotland mainland that may not have featured in the SSEN connection baseline.

Factors that will affect deployment at a local level:

- One key consideration for the licence area is the future of the island diesel generators. Playing a critical role to maintain supply to the islands during outages or faults and to meet island demand, the generators could continue to operate up to, or even beyond the 2030s, until a viable low carbon alternative has been identified and deployed. From consultation with the SSEN network planning teams, these assets have been removed from the scenario projections, as they are assessed at a more granular level when undertaking network forecasting.
- The only geographical distribution factor applied for modelling diesel generation capacity across the licence area, is the actual location of the two known pipeline projects.

Relevant assumptions from National Grid FES 2020:

Assumption number	4.1.31 (Unabated small scale thermal generation)
Steady Progression	Less focus on decarbonisation compared to other scenarios. **Diesel plant retired later than other scenarios.**
System Transformation	Initial growth in gas peaking plant as renewables grow (instead of high growth in storage technologies), later switching to Hydrogen.
Consumer Transformation	Initial growth in gas peaking plant as renewables grow (instead of high growth in storage technologies), later switching to alternate sources of flexibility such as storage and V2G.
Leading the Way	Low use as scenario sees greater use of other technologies (e.g. storage). **Earliest closure of diesel reciprocating engines.**

Stakeholder feedback overview:

Engagement with both the Scottish Government and the Scottish island subsea cable programme team in SSEN, saw strong agreement with the modelling approach in the DFES to treat the island diesel generators in a different way to normal commercial diesel plants and thus take the decision to omit them from the modelling projections. Whilst not included in the ESA projection dataset supplied alongside this report, some consideration should be given to the potential future replacement of these fossil fuel generation assets on the islands with biomass, hydrogen or other waste stream driven generation in the longer term, as a lower carbon emission technology option that unabated diesel generation.

References:

SSEN connection data, EMR Delivery Body Capacity Market Registers, Scottish Environment Protection Agency, Local authority online planning portals (various).

[xxiv] See damaged cable supplying the Isle of Lewis, potentially for up to 12 months: https://renews.biz/64100/call-for-upgrade-to-failed-western-isles-interconnector/
[xxv] See Scottish Environment Projection Agency Medium Combustion Plant regulations: https://www.sepa.org.uk/regulations/pollution-prevention-and-control/medium-combustion-plant/

11. Other generation in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

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

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

Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
All scenarios	4.5	5	13	13	13	13	13	13

Overview of technology projections in the licence area:

- The baseline consists of 11 projects, totalling 4.5 MW in capacity.
- At an average capacity of 0.41 MW, these sites are predominantly CHP plants within buildings, where the fuel type is uncertain.
- The pipeline consists of 6 projects, totalling 8.4 MW in capacity. A project at RAF Lossiemouth accounts for 8 MW of this pipeline capacity.
- All pipeline projects connect according to their anticipated connection date, across the 2020s.
- Other generation is not projected beyond the baseline and pipeline. There is no difference between the scenarios for this technology.

Reconciliation with National Grid FES 2020:

- There is not ‘other generation’ technology in the National Grid FES 2020

References:

SSEN connection data.

Section 2 – Electricity storage

Battery storage

12. Electricity storage in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

DFES technology building blocks:

- **Batteries (Srg_BB001)**
- **Domestic batteries (G98) (Srg_BB002)**

The analysis covers any electricity storage projects that directly connect to the distribution network in the North of Scotland licence area.

The DFES analysis for energy storage has been categorised into four storage business models:

- **Standalone network services** – typically multiple MW scale, that provide balancing, flexibility and support services to the network. future battery project uptake is based upon a scenario-specific inflation of the baseline and pipeline that is reconciled more closely with the FES GSP projections. For the North of Scotland, this considers accessibility to the distribution network and the aforementioned network charging reforms[xxvi].

- **Generation co-location** – typically multiple MW scale projects, sited alongside renewable energy (or possibly other) generation projects. Future uptake is based upon the corresponding DFES scenario modelling for distribution network onshore wind and ground mount solar PV within the licence area. With a strong baseline and proposed future deployment of onshore wind capacity in the licence area, batteries connecting under this business model could significantly increase.

- **Behind-the-meter high energy user** – single MW or 'hundreds of kW' scale projects, sited at large energy user operational sites, to support onsite energy management or to avoid high electricity cost periods. Future uptake is based on modelling a scenario-specific proportion of known commercial and industrial properties in the licence area, that are suited to co-locating batteries behind the meter.

- **Domestic batteries** – typically 10-20kW scale batteries that households buy to operate alongside domestic rooftop PV, to exploit domestic time-of-use-tariffs, or to provide mains back-up support to the home. Future uptake is based upon the DFES scenario modelling for domestic rooftop solar PV in the licence area. The baseline connection data that informs the DFES focusses on assets that are mainly above 1 MW capacity and therefore may not include all existing domestic batteries. The datasets used to form the baseline of the DFES analysis will be reassessed for DFES 2021, as there may be publicly available registers when more domestic batteries begin to be installed (e.g. MCS or <1MW DNO connection data).

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

Installed power capacity (MW)		Baseline	2020	2025	2030	2035	2040	2045	2050
Standalone network services	Steady Progression	0	0	294	297	311	327	343	347
	System Transformation		0	155	156	164	172	176	176
	Consumer Transformation		0	294	308	370	407	427	436
	Leading the Way		0	294	308	401	441	450	450
Generation co-location	Steady Progression	1.2	1.2	73	96	101	116	122	125
	System Transformation		1.2	34	43	45	48	50	51
	Consumer Transformation		1.2	82	126	144	201	222	233
	Leading the Way		1.2	79	158	185	270	299	314
Behind the meter high energy user	Steady Progression	0	7	11	25	50	55	88	88
	System Transformation		4	7	16	26	29	62	62
	Consumer Transformation		9	13	31	92	124	158	158
	Leading the Way		9	27	98	105	116	138	138
Domestic batteries	Steady Progression	0	0	0.4	3	4	4	13	14
	System Transformation		0	0.2	0.4	0.5	0.6	1.4	1.4
	Consumer Transformation		0	1	16	24	40	74	114
	Leading the Way		0	9	46	112	178	202	215

Overview of technology projections in the licence area:

In the North of Scotland licence area, a significant amount of distribution network connected battery storage capacity (MW) is seen in all scenarios by 2050, compared to the very small 1.2 MW baseline. This reflects a significant near-term pipeline of 668 MW, including several projects that are in the c.20-50 MW range.

The highest connected is in the **Leading the Way** scenario, with c.1.2 GW modelled to connect to the distribution network by 2050. This is c.6% of the FES 2020 total GB projected capacity on the distribution network in this scenario by 2050. This reflects a moderate proportion of the pipeline going through to connection, additional standalone, generation co-location and high energy user projects connecting in the medium term and a notable overall uptake of domestic batteries by 2050 in this scenario.

The lowest connected capacity is seen in the **System Transformation** scenario, with 290 MW connected by 2050. This reflects a more general scenario assumption of a lesser need for distribution network connected flexibility, overall lower levels of electrification and renewable electricity generation deployment and a significantly lower uptake of domestic batteries. Also with the transmission network in Scotland being a voltage tier lower than the rest of the UK, some additional battery storage projects that may be connecting at 132kV between 2019 and 2050 are not within the scope of the DFES analysis for the North of Scotland licence area.

Whilst a significant increase in connected capacity is seen in all scenarios by 2050, beyond the sizeable pipeline there is a degree of uncertainty around the development of battery storage projects under any business model. This uncertainty relates to high levels of competition in national and local flexibility markets and challenging network charging reforms that could adversely impact the commercial viability of distribution network battery storage assets in the longer term. With the strong level of distribution network connected generation seen in the North of Scotland licence area (especially onshore wind), the proposed introduction of higher network costs in substation areas that are 'generation dominated', could possibly affect the viability of distribution network generation in the licence area. With battery storage currently being classed as a subset of generation for network charging purposes, this may similarly affect the connection costs for the export capacity element of a battery storage connection offer. However, with the clear network support and flexibility role that storage could provide to the electricity network in the licence area, Ofgem could consider either a dispensation or adjusting regulation for electricity storage in the future.

Scenario projection results:

Baseline (up to end of 2019)

- There are five projects totalling only 1.2 MW of distribution network connected battery storage capacity in the licence area
- Four of these are small batteries co-located with renewable energy projects on the islands of Eigg, Muck, Rum and Horse Island
- A 1 MW project is also co-located to the HyWind offshore wind farm in Buchan Deeps (20km off Peterhead).

Near term (2020 – 2025)

- There is a sizeable pipeline of distribution network battery storage projects with an accepted connection offer in the licence area. This 22 project pipeline totals c.668 MW and can be categorised as follows:
    - 17 sites, totalling 538 MW, are standalone battery projects
    - 4 sites, totalling 100 MW, are generation co-location projects
    - A 30 MW project located Aberdeen Airport, likely behind the meter.
- When assessing the development activity of these pipeline projects:
    - 12 sites, totalling 328 MW have received planning approval. These are entirely standalone or generation co-location battery projects
    - 3 sites, totalling 50 MW successfully pre-qualified in various T-4 or T-1 Capacity Market auctions. Two are standalone projects and one is likely co-located with an adjacent onshore wind turbine
    - Two 30 MW standalone battery projects located in Inverness and Fort Augustus were withdrawn from planning in the last 2 years.
- As a result of this analysis:
    - The 50 MW with positive development activity in the Capacity Market is modelled to connect in all scenarios in the early/mid 2020s in all scenarios. In each case, the connection year is based upon the Capacity Market delivery year that was identified from T-4 or T-1 auction register data.
    - The 309 MW with planning approval has been modelled to connect in all bar the **System Transformation** scenario, five years after the planning approval was received, unless SSEN planning team correspondence indicates an earlier anticipated connection year.

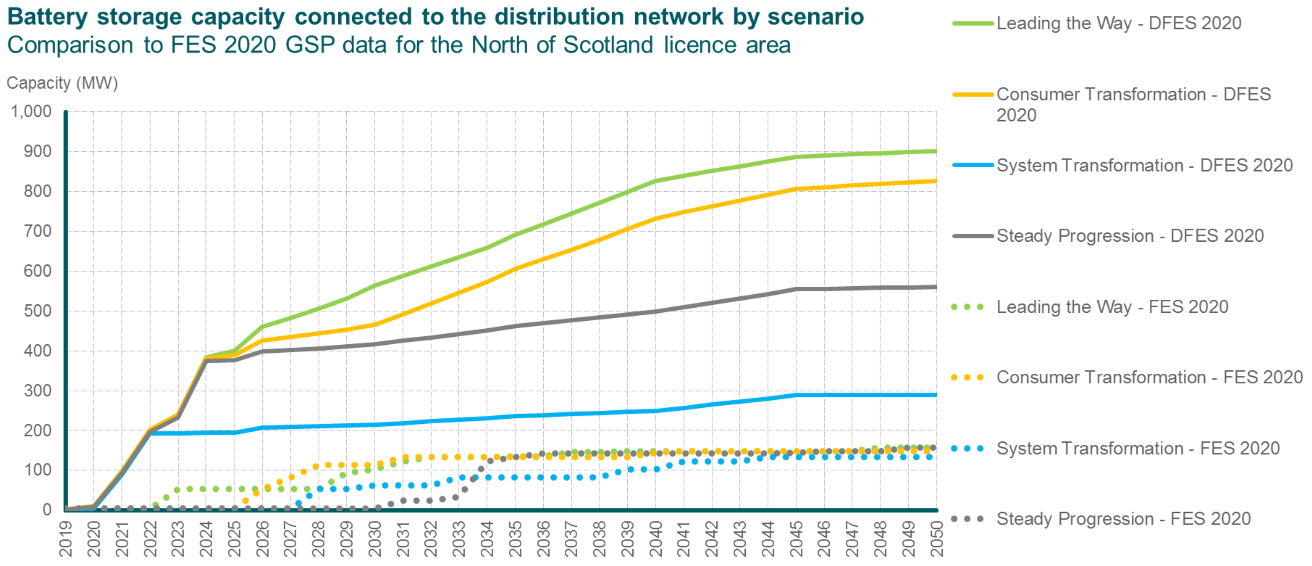
Medium term (2025 – 2035)

- Across late 2020s and early 2030s some of the pipeline projects with limited development evidence are modelled to connect in the **Consumer Transformation** and **Leading the Way** scenarios.
- The characteristics of the North of Scotland licence area and the resultant scenario outcomes can be summarised as follows:
    - A significant capacity of large scale solar is projected to connect to the distribution network in all scenarios, but this is most significant in **Leading the Way**, with just over 4.2 GW of onshore wind capacity connected by 2035. Contrarily, a fairly moderate amount of distribution network connected solar is modelled to come online in the licence area, reflecting below average irradiance. The scenario with the most generation co-located battery storage capacity in 2035 is **Leading the Way** with 106 MW and the scenario with the lowest capacity is **System Transformation** with 12 MW by 2035.
    - A moderate number of commercial and industrial properties (c.88,900) in the licence area in areas such as Dundee, Aberdeen and Inverness. This forms the basis of the uptake for some smaller scale batteries installed behind-the-meter at high energy user sites. This business model sees 78 MW connecting in **Leading the Way** and 20 MW connecting in **System Transformation** by 2035.
    - With over 740,000 homes in the North of Scotland licence area and a moderate uptake of rooftop solar in the **Leading the Way** and **Consumer Transformation** scenarios, there is also some potential for domestic battery installations in the medium term. This business model sees the most significant range of scenario outcomes by 2035, with c.103 MW being modelled to connect in **Leading the Way** (equivalent of c.41,000 homes), but only 0.3 MW (equivalent of 70 homes) in **System Transformation** by 2035.

Long term (2035 – 2050)

- The spread of total connected battery storage capacity in the licence area continues across the scenarios between 2035 and 2050.
- The accelerated uptake of battery storage in all business models in **Leading the Way** plateaus in the 2040s, whereas the trends in the other scenarios continues out to 2050. The limited uptake of domestic batteries continues in **System Transformation**.
- In the licence area by 2050, the total amount of distribution connected battery storage in **Leading the Way** reaches just under 1 GW. Most of this capacity is either standalone battery projects providing network services or batteries co-located with distributed renewable energy generation, likely to be dominated by onshore wind co-location, or potentially hydropower co-location in the longer term.
- The total amount of capacity in **System Transformation** reaches a much lower 290 MW. Most of this capacity is standalone battery projects, with a moderate amount of storage co-location capacity and only c.220 batteries installed behind-the-meter at high energy user sites. There are also only c.250 homes with a domestic battery in this scenario by 2050.

Figure 31 Comparison of large battery storage projections in the North of Scotland licence DFES analysis to the FES 2020

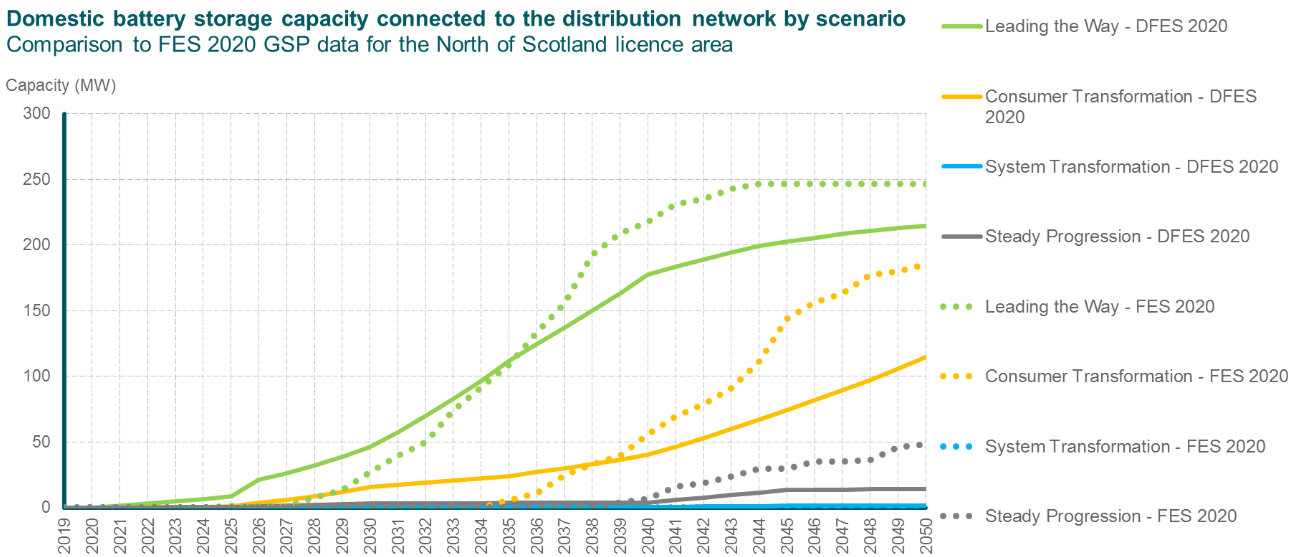


Total capacity of large scale storage business models:

- Standalone network services
- Generation co-location
- Behind the meter high energy user.

Equivalent to FES building block:
Batteries (Srg_BB001)

Figure 32 Comparison of domestic battery storage projections in the North of Scotland licence DFES analysis to the FES 2020



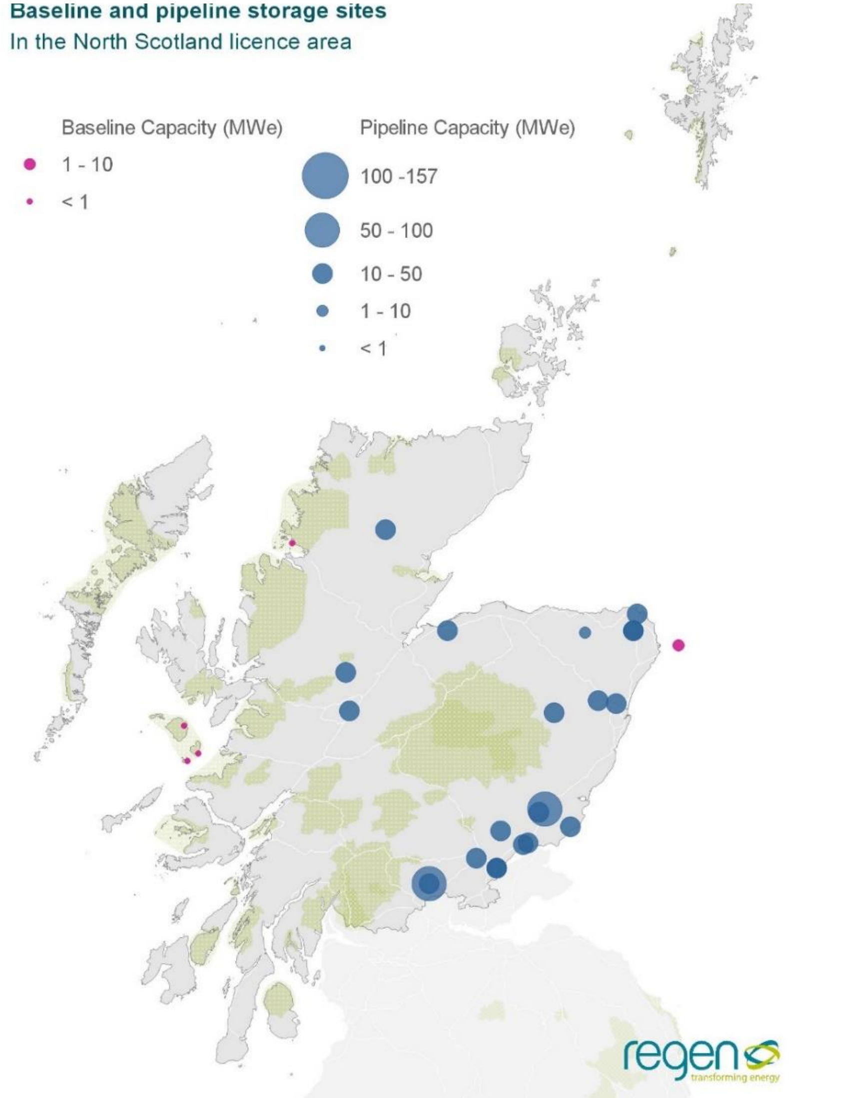
Total capacity of domestic storage.

Equivalent to FES building block:
Domestic Batteries (G98) (Srg_BB002)

Reconciliation to National Grid FES 2020:

- With regards to **large batteries**, (see Figure 31) the FES GSP projections for the North of Scotland licence area are significantly lower than the DFES projections. The reason for this significant variance is unclear, but the following factors were considered to justify such a notable divergence between the projections in the DFES and the FES 2020 GSP projections:
  - A notable proportion of the 668 MW pipeline has development evidence in the form of planning approval, Capacity Market activity or correspondence with SSEN network planning teams. The DFES has therefore modelled a significant deployment of battery storage capacity in the 2020s and 2030s in some scenarios.
  - Beyond this pipeline and out to 2050, with a notable number of non-domestic properties and a significant projected capacity of onshore wind in the licence area, the potential for additional battery storage co-located with high energy users and with renewable generators has been modelled in some scenarios.
- With regards to **domestic batteries**, (see Figure 32), the DFES projections align fairly well to the FES 2020 GSP projections in the licence area.
- The main areas where the DFES has diverged from the FES 2020 GSP projections are:
  - Fewer domestic batteries have been modelled to connect in the DFES by 2050 in all scenarios except for **System Transformation**. This reflects a consideration that the future role, use cases and value of domestic batteries to households is uncertain, so a proportion of the level of capacity assumed in **Leading the Way** in the FES in 2050 was resultantly reduced in the DFES.
  - Both the FES 2020 regional and DFES projections have practically no domestic batteries connecting in **System Transformation** between 2020 and 2050, with the DFES connected domestic battery capacity in the licence area being slightly higher (at 1.4 MW) than the FES GSP projections of 0.3 MW by 2050.

Figure 33 Map of baseline and pipeline battery storage projects in the North of Scotland licence area



- In general, the potential of widespread domestic battery uptake in the future is uncertain. Whilst potential use cases exist such as time-shifting exported domestic solar output to be self-consumed, participation in aggregated domestic flexibility services[xxvii] or exploiting domestic time-of-use-tariffs[xxviii], the sustainability of these as sources of guaranteed savings/income for homeowners in the long run is unclear. This explains in part the range of domestic storage capacity scenario projections seen in both the FES and the DFES out to 2050.

Factors that will affect deployment at a local level:

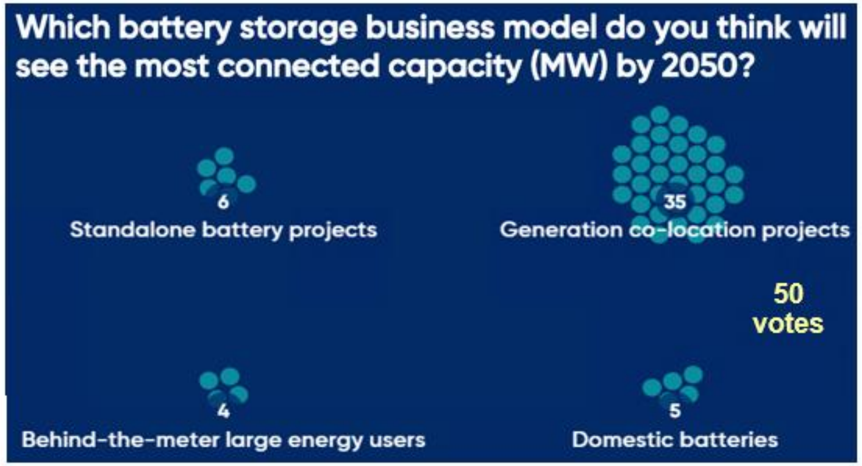
- The spatial distribution of new battery storage projects in the near term is based on the location of the identified pipeline sites.
- In the longer term, spatial distribution varies according to the four battery storage business models used in the modelling.
- The factors applied to distribute storage capacity into 11kV ESAs across the North of Scotland licence area, can be summarised as:
    - **Standalone network services:** Proximity to the 33kV electricity network.
    - **Generation co-location:** Proximity to ground mounted solar PV and onshore wind generation within the licence area
    - **Behind-the-meter high energy user:** Proximity to industrial areas and commercial buildings in city/urban areas
    - **Domestic batteries:** Domestic dwellings with rooftop PV.

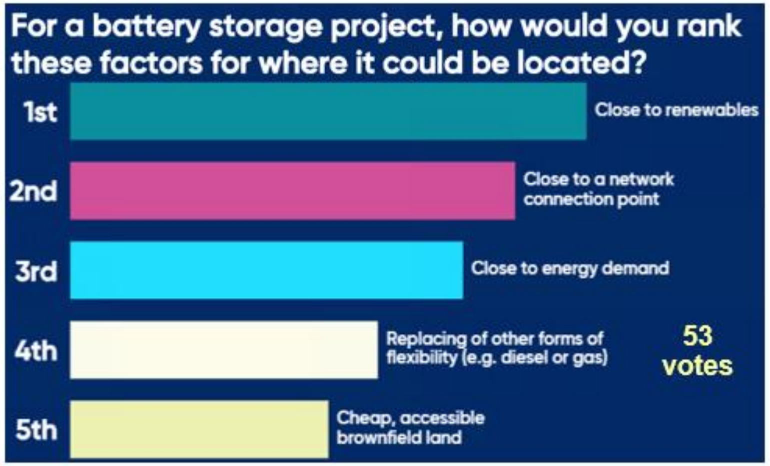
Relevant assumptions from National Grid FES 2020:

Assumption number	4.2.24 (Electricity storage of duration of 2 hrs or less) e.g. Domestic batteries and larger short-duration batteries	4.2.25 (Electricity storage of duration between 2 and 4 hrs) e.g. Medium batteries, compressed or liquid air storage)	4.2.26 (Electricity storage of duration longer than 4 hrs) e.g. Large batteries, compressed air and pumped hydro storage)
Steady Progression	Moderate levels of flexibility requirements encourage new storage. Not as much deployed compared to other scenarios.	Lower flexibility requirements means that this technology does not come forward at the volumes seen in the other scenarios.	
System Transformation	Not as much deployed compared to other scenarios due to high use of Hydrogen within this scenario.	Moderate levels of flexibility requirements encourage new storage. Not as much deployed compared to other scenarios due to high use of Hydrogen within this scenario.	Presence of high volumes of Hydrogen limit the need for long duration storage.
Consumer Transformation	High levels of variable clean generation and flexibility requirements encourage new storage technologies to emerge.	Flexibility requirements encourage new storage.	High levels of variable clean generation and flexibility requirements encourage new storage technologies to emerge.
Leading the Way	Even higher levels of flexibility requirements encourage new storage technologies to emerge at distributed and transmission levels.	High levels of flexibility requirements encourage new storage.	Even higher levels of flexibility requirements encourage new storage technologies to emerge at distributed and transmission levels.

Overview of stakeholder and regional input:

On the 25th August Regen, SSEN and the Energy Systems Catapult ran an interactive webinar with an online polling platform Mentimeter. This webinar engaged regional stakeholders with regards to future energy scenarios and local energy planning for the North of Scotland licence area. This included specific engagement around some of the key technologies in the scope of the DFES analysis, one of which was battery storage. Stakeholders were informed about the baseline and pipeline position in the licence area and asked questions regarding storage business models and locational factors. The results are summarised below:





This feedback prompted the DFES modelling to increase the uptake rate and overall connected capacity of the generation co-location storage business model across the scenarios out to 2050. The feedback around locational factors also aligned well with the assumptions made around geographic distribution factors, where more weighting is put towards proximity to the distribution network and renewables than land designations in the modelling.

References:

SSEN connection data, EMR Delivery Body Capacity Market Registers, online planning portals.

[xxvi] See Regen's webinar event discussing the proposed network charging reforms, that could incur potentially notable costs in 'generation dominated' primary substations in the North of Scotland licence area: https://www.regen.co.uk/event/the-significant-code-review-a-step-forward-for-decarbonisation/
[xxvii] See SSEN innovation project Social Constraint Management Zone: https://www.smarternetworks.org/project/nia_ssen_0036
[xxviii] See Octopus and Tesla time of use tariff around Powerwall home batteries: https://octopus.energy/tesla-energy-plan-faq/

Section 3 – Low carbon technologies and new sources of electricity demand

Electric vehicles

Electric heating and cooling technologies

Electric vehicle chargers

H_2

Hydrogen electrolysis

New property developments

regen transforming energy

Scottish & Southern Electricity Networks

13. Electric vehicles in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers Electric Vehicles (EVs) operated within the North of Scotland licence area. This includes non-autonomous cars, autonomous cars, buses and coaches, HGVs, LGVs and Motorcycles, including battery EVs and plug-in hybrid EVs.

DFES Building Block ID numbers Lct_BB001, Lct_BB002, Lct_BB003, Lct_BB004

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

Number of EVs (total)		Baseline	2025	2030	2035	2040	2045	2050
Battery EVs (thousands)	Steady Progression	3	27	100	259	537	812	899
	System Transformation	3	50	197	502	817	913	838
	Consumer Transformation	3	73	245	554	797	850	828
	Leading the Way	3	75	325	711	864	807	640
Plug-in hybrid EVs (thousands)	Steady Progression	3	19	45	84	114	75	22
	System Transformation	3	17	40	61	43	14	0
	Consumer Transformation	3	27	53	41	17	-	-
	Leading the Way	3	15	29	22	9	-	-

Overview of technology projections in the licence area:

- A more detailed overview of the specific assumptions used in Regen's Transport Model is available in the Electric Vehicle and Charger Assumptions Workbook which accompanies the DFES dataset. This workbook includes, for example, assumptions related to vehicle milage, vehicle efficiency, charging behaviour, charger utilisation etc
- At present, EVs (including plug-in hybrids) represent approximately 0.7% of all vehicles in the North of Scotland licence area, which is below the GB average of nearly 1%. This is, however, representative of other predominantly rural regions in GB. More urban centres in the region, such as for Dundee and Stirling city regions, have an EV uptake more typical of GB average.
- However, as a result of Scottish Government's ambition for transport decarbonisation, North of Scotland is projected to align with the GB average uptake rate for EV's by the mid-2020s.
- Electrification is the key route to decarbonising transport in the ESO FES 2020 scenarios, with hydrogen's role focussed in contributing to the decarbonisation of HGVs and buses in most scenarios. North of Scotland is projected to have a higher uptake of hydrogen vehicles compared to the national scenarios.
- All scenarios in ESO FES 2020 show a more rapid EV uptake compared to the ESO FES 2019. As the level of policy uncertainty has decreased, even the slower growth scenarios of **Steady Progression** and **System Transformation** have faster growth rates than in previous FES 2019 scenarios.
- A significant difference between the ESO FES 2020 and ESO FES 2019 scenarios is the introduction of Autonomous Vehicles (AVs) and a more significant reduction in overall vehicle numbers. This is particularly true for **Leading the Way**, which has a third fewer vehicles than **Steady Progression**.
- The reduction in vehicle numbers in ESO FES 2020 is facilitated by an increase in active and public transport use, an increase in average vehicle mileage, and the introduction of AVs which have high average annual mileage.
- Hydrogen vehicles numbers increase significantly throughout the 2030s, and are concentrated in HGVs, buses and LGVs in all scenarios but **Steady Progression**, which prioritises natural gas as a fuel in those vehicle archetypes.
- Analysis of AVs was introduced in ESO FES 2020. FES estimates these vehicles will represent between 9% and 23% of all cars by 2050. This is, therefore, the first SSEN DFES to include a preliminary analysis of AVs.

Scenario projection results:

Baseline (up to end of 2019)

- In the North of Scotland licence area, there is currently slower uptake across most of the highlands and islands, but a more rapid uptake in urban areas such as Dundee and Stirling. An exception is some of the islands, such as Orkney, which have seen very rapid adoption of EVs.
- The North of Scotland licence area, as well as the whole of Scotland, has more battery EVs in the Baseline than plug-in hybrid EVs. This is unusual compared to the GB average. This trend is assumed to continue as battery EVs quickly become the most prevalent low carbon vehicle in all scenarios.
- There are a total of 3,065 battery EV cars in the North of Scotland licence area, representing 0.3% of all vehicles in the licence area.
- There are a total of 2,879 plug-in hybrid EV cars in the North of Scotland licence area, representing 0.4% of all vehicles in the licence area.

Near term (2020 – 2025)

- Across all scenarios, the uptake of EVs is expected to accelerate significantly in the mid-2020s. The overwhelming majority of this uptake is from electric cars with electric vans, buses and other vehicle growing at a slower rate.
- It is projected that by 2025, there could be between 27,000 battery EVs in **Steady Progression** and 75,000 in **Leading the Way**. Therefore, by 2025 EVs are projected to account for up to 8% of all cars.
- Autonomous vehicle uptake starts in 2023 in all scenarios, however, uptake is very slow in the near term.
- Local initiatives to lower air quality or expand access to charging are expected to increase local uptake. 'Clean Air Zones' have been proposed in areas such as Dundee and Aberdeen and are assumed to go ahead in all net zero compliant scenarios in the near-term.

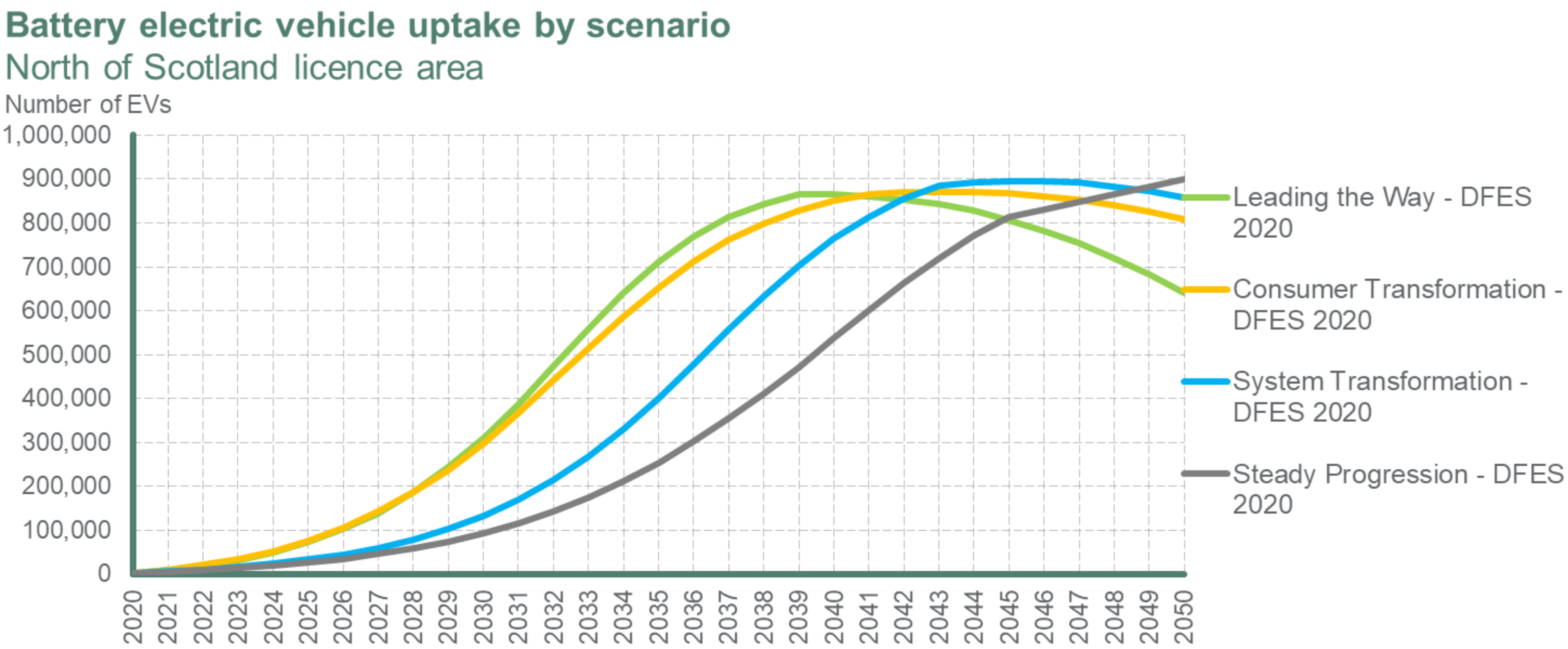
Medium term (2025 – 2035)

- The uptake of EVs is expected to continue increasing between 2025 and 2035 across all scenarios.
- **Steady Progression** has the fewest estimated battery EVs in 2035, with around 259,000. **Leading the Way** has the most, with over 711,000 battery EVs by 2035.
- EV uptake begins to slow in the mid-2030s as EV adoption approaches saturation and only the hardest-to-electrify vehicles such as HGVs, remain being fuelled by petrol or diesel. Other factors also contribute to uptake slowing, including the total number of vehicles reducing, increased use of AVs, and increased use of public transport and active travel.
- The uptake of AVs remains slow over this period, and while their uptake does begin to accelerate AVs only represent up to 1% of all cars by 2035.
- The uptake of plug-in hybrids slows and then reduces in **Leading the Way**, as a result of the assumed ban on their sale from 2032.

Long term (2035 – 2050)

- The uptake of EVs continues to increase in **Steady Progression**, right up until 2050 when battery EVs total nearly 900,000. In **System Transformation**, the uptake of battery EVs approximately flattens from the mid-2040s at around 910,000.
- In **Leading the Way** and **Consumer Transformation**, the numbers of EVs reduces from the late 2030s and mid-2040s, respectively. This is the result of societal change and technological development such as increased use of public and active travel and the rising number of AVs. Many homes opt to have one or no car at all, which results in a real term decrease in the number of company and private vehicles.
- The number of battery EVs and total vehicles in **Leading the Way** reduces substantially, peaking at 865,000 before reducing to 640,000 in 2050. The reduction in vehicle numbers is facilitated by an increase in active and public transport use, an increase in average vehicle mileage, and the introduction of AVs which have high average annual mileage.

Figure 34 Summarising scenario projection graph for the technology, with comparison to FES regional



Reconciliation with National Grid ESO FES 2020 and Scottish government ambition:

The 2020 DFES uses the ESO FES 2020 Building Blocks: Lct_BB001, Lct_BB002, Lct_BB003, Lct_BB004 as the starting framework for future projections. In order to reflect Scottish ambition for the decarbonisation of transport, the scenarios considered modelling carried out by Transport Scotland[xxix]', showing how EVs can contribute to the Scottish Government's ambition to phase out the need for petrol and diesel cars by 2032:

- **Consumer Transformation** and **Leading the Way** scenarios have adopted the Scottish Government's ambition to have zero petrol and diesel vehicles of any vehicle archetypes by 2045.
- Scottish Government's higher ambition for the uptake of electric buses, LGVs and HGVs when compared to the ESO FES 2020 scenarios has been adopted the **Consumer Transformation** and **Leading the Way** scenarios.
- Scottish Government's high ambition for hydrogen vehicles has been adopted into the **Consumer Transformation** scenario.

Interim assumptions have been made as to the uptake and distribution of autonomous vehicles in the absence of other information including:

- AV spatial distribution is treated the same as non-autonomous EVs due to a lack of information about their future uptake.
- It is assumed that the uptake of AVs in on and off street settings is the same as for non-autonomous EVs
- The uptake and distribution of AVs is an area that needs to be considered for future analysis when more evidence is available.

Scottish Government have, through the publication of their Climate Change Plan Update[xxx], committed to a number of actions, targets and ambitions around the decarbonisation of transport. As well as the 2032 phase-out of petrol and diesel cars, this includes:

- A commitment to reduce car kilometres by 20% by 2030, and to phase out the need for new petrol and diesel cars and vans by 2030
- £120 million for Zero Emission Buses, driving forward a fully decarbonised future for Scotland's bus fleet
- An aim for Scotland's rail services to be fully decarbonised by 2035

The launch of Scottish Government's Hydrogen Policy Statement also highlights a strategy to scale-up the opportunities for hydrogen in Scotland, this includes the creation of the Hydrogen Accelerator programme, as well as city region strategies for in Aberdeen and Dundee seeking to harness opportunities that hydrogen can bring to transport, fleet and city decarbonisation plans.

The National Grid ESO FES 2020 projections were produced before both the UK and Scottish Government announcements around the revised target years for the sale of petrol and diesel cars and therefore included an assumption that a ban would be between 2032 and 2040, for both battery EVs and plug-in hybrids. From discussion with the SSEN team it was decided that reflecting an accelerated ambition for the uptake of EVs could be achieved in the DFES for the North of Scotland without altering the existing projections, specifically:

- For the more ambitious scenarios (**Leading the Way** and **Consumer Transformation**), it was identified that the rate of sales of new electric cars goes beyond the historic car sales rate in 2030 already, this is illustrated in Figure 35.
- For the less ambitious scenarios, particularly **Steady Progression**, it was considered unnecessary to model fewer scenarios or augment EV uptake to match a more ambitious scenario. Discussions with the SSEN team concluded that the impact of EVs on the distribution network could essentially be modelled either without **Steady Progression**, or this scenario could be used to represent an outcome for EV manufacturing rates where the government's petrol and diesel limitation is not achieved.
- The full impact of the new UK Government plans and Scottish Government's Climate Change Plan Updates will, however, be considered in more detail in future DFES analysis and when new evidence becomes available.

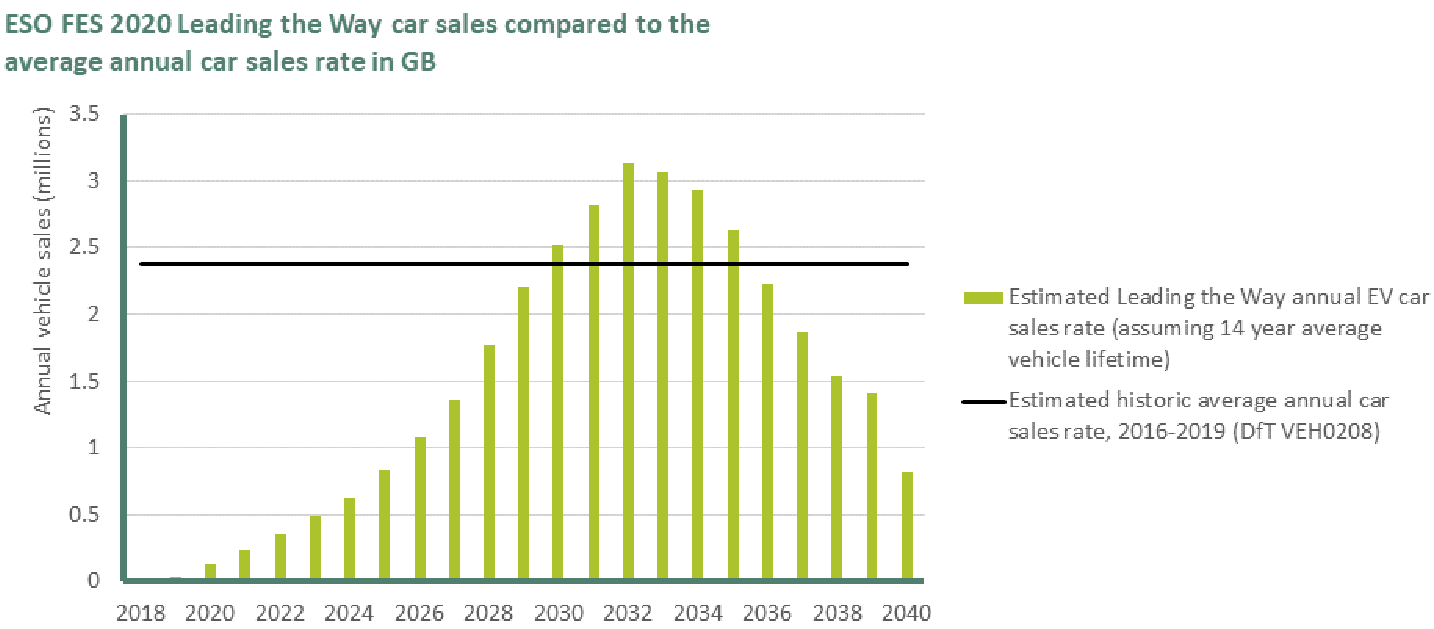


Figure 35 Sales rate of vehicles historically and in Leading the Way

Factors that will affect deployment at a local level:

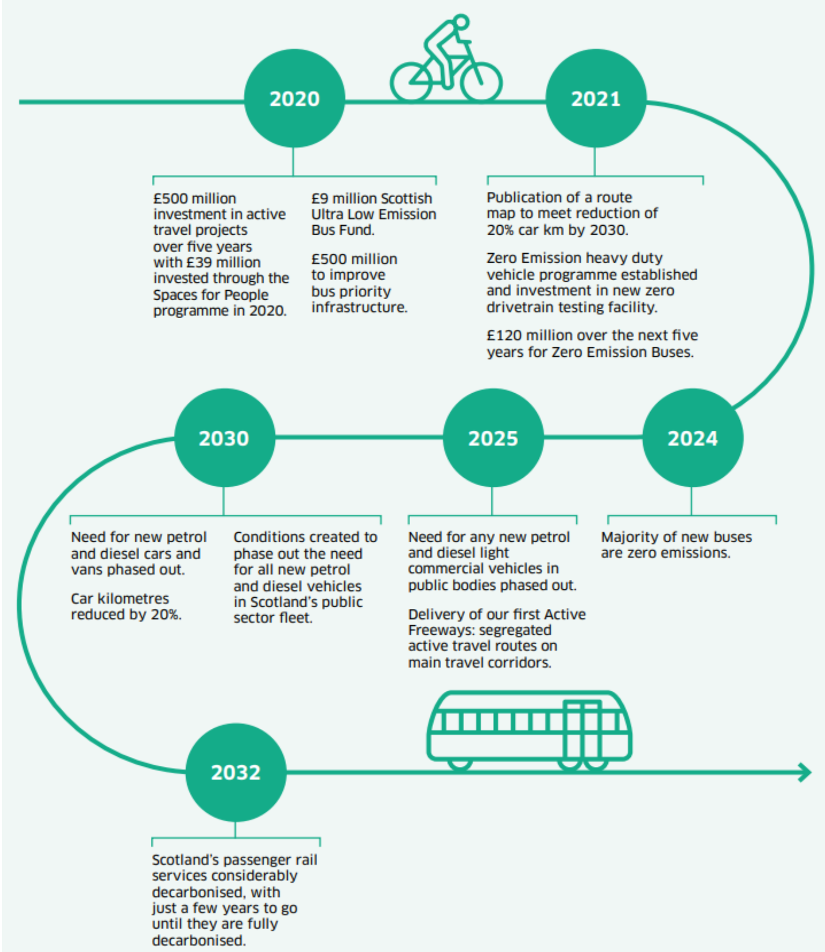
- The uptake of EVs was evaluated to a much higher granularity than ESAs. The uptake of EVs was evaluated to SSEN's 400,000 individual feeders, equivalent to street-level forecasts.
- A wide variety of datasets were used to analyse specific regional and feeder specific demographic and technical attributes and geographical characteristics. For example, in order to evaluate the distribution of houses with on and off street parking and their associated vehicles, SSEN connectivity data was used to identify the number of houses associated with a feeder, which were then classified by type of housing and vehicles with a combination of DfT, EPC, Census and Ordnance Survey data. While not perfect, owing to data limitations, this allowed a much more granular assessment of commercial and industrial activity connected to the network.
- In the SSEN DFES 2020 consultation events, stakeholders raised local plans and policies which could increase uptake and are included as positive weightings in the near and medium term.

- The spatial distribution of EV cars in the near term is based on the availability of on and off-street parking, affluence, rurality, existing vehicle baselines. However, the more ambitious scenarios see the impact of these factors on the uptake of EVs diminishing in the mid-2020s, and by the late 2020s EV uptake is assumed to be ubiquitous. This means that almost all consumers are assumed to have the same likelihood of adopting an electric vehicle. In order to evaluate the distribution of EVs to a feeder level, the above factors were interpolated down to individual feeders from the highest granularity of publicly available datasets.

Scottish Government policy context

- The "Reconciliation with National Grid ESO FES 2020 and Scottish government ambition" section above discusses how some of the Scottish Government transport policy ambitions have been reflected in the DFES 2020 projections.
- Transport Scotland has for several years operated its Switched on Fleets on programme where it has provided funding to public bodies to cover the leasing cost of an EV or price differential between ICE vehicles. In the Programme for Government 2019-20 a commitment was made to create the conditions to phase out the need for all new petrol and diesel vehicles in Scotland's public sector fleet by 2030; and phasing out the need for all new petrol and diesel cars from the public sector fleet by 2025.
- In December 2020 Scottish Government published their Climate Change Plan Update, which highlighted a number of ambitions, targets and supporting policies to decarbonise transport in Scotland. See Figure 36.
- Whilst many of the ambitions and potential milestone outcomes have been reflected across the DFES 2020 scenarios, the ramifications of this revised climate change plan will be analysed and fed in to the 2021 edition of the SSEN DFES for the North of Scotland licence area in more detail.

Figure 36: Scottish Government transport road map to 2032, from the Climate Change Plan Update (Dec 2020)



Relevant assumptions from National Grid ESO FES 2020:

Assumptions	3.3.5 (Battery Electric Vehicles), 3.3.2 (Autonomy)
Steady Progression	**Steady Progression** is the scenario with the least ambitious new petrol and diesel sales ban of 2040. **Steady Progression** assumes autonomous vehicles will be privately owned. In this scenario, this increases average miles travelled.
System Transformation	**System Transformation** assumes that in some cases a two-car household becomes a one car household, where shared autonomous vehicles meet some transport needs. However, most households still have two vehicles, which leads to a modest decrease of only 8% in the number of vehicles compared to **Steady Progression**.
Consumer Transformation	In **Consumer Transformation** autonomous vehicles, acting as a taxi service, often replace the need for a second car. They are used by consumers to commute to work or for leisure trips. Combined with greater use of public transport, this results in a 15% decrease in vehicles in this scenario, compared to **Steady Progression**.
Leading the Way	In **Leading the Way**, the high levels of societal change have led us to assume that use of autonomous vehicles and public transport reduces the overall number of cars as many homes opt to have no car at all, relying instead on shared mobility solutions, using AVs, which can accommodate four people. Total number of cars is one third less in 2050 than in **Steady Progression**.

Stakeholder feedback overview:

- The Scottish Government stated that they are not yet in a position to confirm whether or not there are any changes anticipated to the Scottish 2032 ambition however the direction of policy is towards more ambitious targets. The Scottish Government is assessing policies and proposals in relation to its update to the Climate Change Plan that will be published later this year. Transport Scotland has continued to progress work to inform EV uptake scenarios in relation to transport's contribution to greenhouse gas emissions and climate change targets in Scotland.
- At the Scottish stakeholder engagement workshop, stakeholders gave their opinion on the uptake rate of EVs in the North of Scotland licence area. The majority of stakeholders, as illustrated by the graphic below, did not think that the uptake of EVs in Scotland would catch up to the GB average until after 2030, on average. This has been reflected is the less ambitious scenarios of this DFES, while the more ambitious scenarios have assumed that uptake of EVs in Scotland will align quicker.
- Local initiatives to lower air quality or expand access to charging are expected to increase local uptake. 'Clean Air Zones' have been proposed in areas such as Dundee and Aberdeen and are assumed to go ahead in all net zero compliant scenarios in the near-term.
- Further detail on changes made to the modelling as a result of Scottish ambition can be seen in the *"Reconciliation with National Grid ESO FES 2020 and Scottish government ambition"* section.

References:

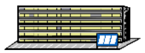
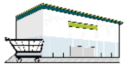
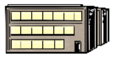
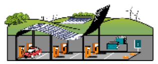
SSEN connection data, Scottish Government, Department for Transport, Climate Emergency declaration data, Regen consultation with local stakeholders, Census data, Regen EV and Electricity System forums.

[xxix] Data on the Scottish Government's projected uptake of EVs in "Policy Scenario 1" was provided to Regen by SSEN.
[xxx] See Scottish Government Climate Change Plan Update (December 2020), pages 113-133: https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/

14. Electric vehicle chargers in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

Off-street domestic		Homes with somewhere to park a private vehicle off-street
On street residential		Charging at roadside car parking spaces
Car parks		Charging at areas provided for parking only, thus 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 which 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

Please note that the projection units of domestic and non-domestic EV chargers are different. To illustrate the scale of EV charger uptake, domestic EV chargers are displayed in numbers while non-domestic EV chargers are displayed in total network connected capacity (MW). For non-domestic EV chargers, different numbers of chargers could be required to deliver the same amount of energy, making capacity a better indicator of future uptake and network impact. While this is also true of domestic chargers, since there is assumed to be less variability in their individual capacity, numbers of chargers is considered a more useful indicator of the scale of future uptake as it enables comparisons of chargers on a per household and per EV basis.

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

EV chargers		Baseline	2025	2030	2035	2040	2045	2050
Domestic off-street EV chargers (Total, numbers, thousands)	**Steady Progression**	2	14	48	110	277	368	382
	System Transformation	2	21	65	191	368	386	386
	Consumer Transformation	2	46	132	336	382	383	383
	Leading the Way	2	39	168	363	388	388	388
Non-domestic EV chargers (Total, MW)	**Steady Progression**	40	63	107	217	390	526	545
	System Transformation	40	69	132	315	536	621	648
	Consumer Transformation	40	131	316	529	610	623	623
	Leading the Way	40	117	305	574	671	677	678

Overview of technology projections in the licence area:

- A more detailed overview of the assumptions used in Regen's Transport Model is available in EV and EV Charging Assumptions Workbook which accompanies the DFES datasets. This assumptions workbook covers specific assumptions on vehicle mileage, EV efficiencies, consumer charging behaviour and charger utilisation rates etc.
- At present, the installation of public EV chargers is significantly above the GB average per EV vehicle in the North of Scotland licence area. The density of chargers is less if compared to the geographical size of the region. This reflects the support received and Chargeplace Scotland's active participation in the Scottish EV charger market. This trend is expected to continue in the near-term, until demand for charging increases.
- Hot spots for public charger deployment include some of the urban areas as well as some of the islands and tourist areas.
- There is significant uncertainty regarding the shape and size of the future charger network; in particular the split between off-street home charging versus public charging, as well as the market share between ultra fast charging hubs versus lower voltage on-street, neighbourhood and municipal charging. The DFES projections therefore aim to represent the envelope of the possible spread and rate of deployment of EV chargers. In many modelling areas there is a lack of behavioural evidence and so interim assumptions have been made.
- Compared to the previous 'SSEN high granularity projections for low carbon technology' [i] report, the uptake rate of EV chargers is higher and the envelope of charger capacity in 2050 has narrowed. This is predominalty due to an increased uptake of EVs in the less ambitious scenarios in the ESO FES 2020 compared to the 2019 report, thus narrowing the EV uptake projections.

- Projected public EV charger capacity has increased in this study due to the introduction of AVs. It is assumed that the uptake of AVs will result in less at-home charging, and more charging in public and fleet/workplace locations. However, the number of off-street domestic EV chargers are not necessarily lower, since most AV uptake occurs after the number of EVs peaks, in the 2040s.

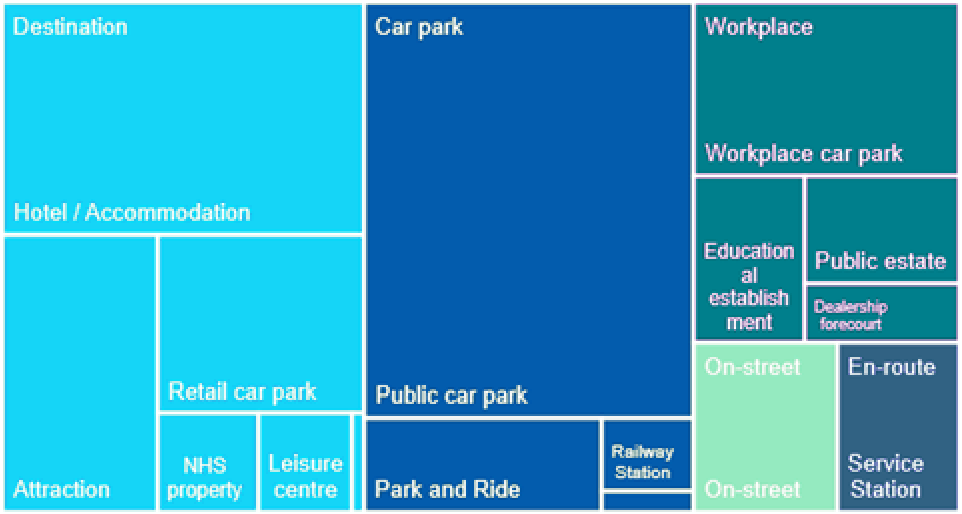
Scenario projection results:

Baseline (up to end of 2019)

- There are a total of 851 public EV chargers in the North of Scotland licence area. This is above the GB average for the number of vehicles in the area, predominantly due to Chargeplace Scotland's high installation rate.
- Approximately 38% of chargers in the licence area are in destination locations and 35% in car parks. The percentage of chargers that are in an on-street setting is just 5%, a percentage that is expected to increase substatially as the amount of privatly operated installations increases.
- It is estimated that there are over 2,000 domestic EV chargers in the North of Scotland licence area.

Public EV charger baseline

North of Scotland licence area, charger numbers, source: ZapMap



Near term (2020 – 2025)

- In all scenarios, the uptake of EV changers is expected to increase dramatically in the near term. EV charging investment is expected to be led by the public sector and Chargeplace Scotland in the near term however as the rate of EV uptake increases more private charging operators are expected. In **Consumer Transformation** more localised charger points, including residential on-street chargers are projected
- It is projected that by 2025, there could be between 63 MW of non-domestic off-street chargers in **Steady Progression** and 131 MW in **Consumer Transformation**.

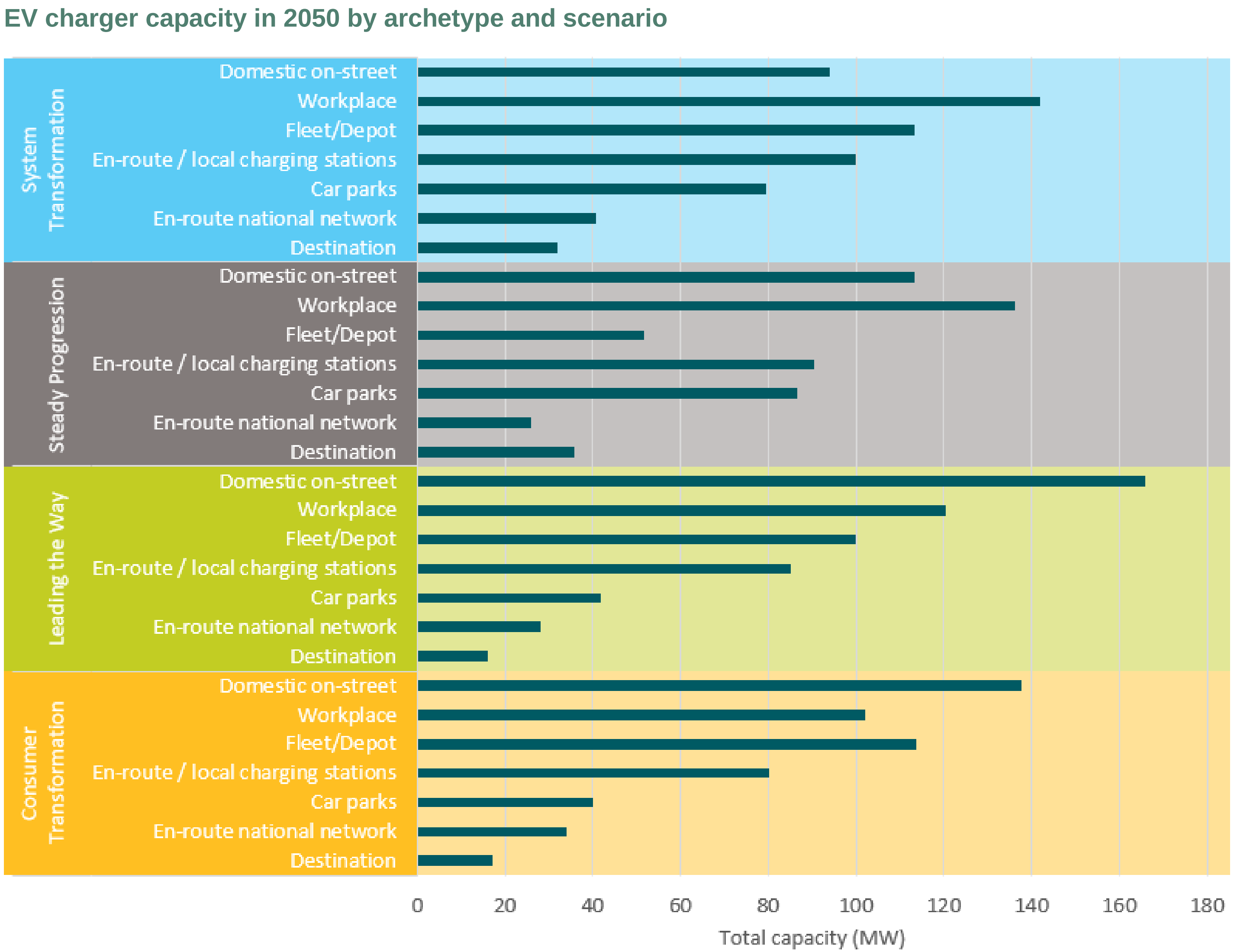
Medium term (2025 – 2035)

- Charger installations are expected to accelerate between 2025 and 2035 across all scenarios.
- Public charging, including on-street charging is residential areas, and rapid charging hubs, is expected to increase substantially as EV usage increases, range increases and as more households without access to off-street parking adopt EVs.
- **Leading the Way** has the highest capacity, with around 363,000 domestic EV chargers and 574 MW of non-domestic capacity. **Steady Progression** has the lowest estimated EV charger capacity in 2035, with around 110,000 domestic EV chargers and 217 MW of non-domestic capacity.
- The rate of EV uptake begins to slow in the mid-2030s as EV adoption approaches saturation. Therefore, the installation rate of EV chargers also slows.
- It is likely that the increase in the number of EV charger locations may flatten, although the capacity and utilisation of existing charge stations is likely to increase.

Long term (2035 – 2050)

- In some of the ESO FES 2020 scenarios, notably **Leading the Way**, the uptake of EVs slows and then reduces significantly as consumers adopt new transport methods including public transport, shared vehicles and autonomous vehicles. However, while the number of EV vehicles may reduce their utilisation and mileage per vehicle increases significantly. The reduction in energy demand is therefore significantly less.
- The uptake of EVs and EV chargers continues to increase in **Steady Progression**, right up until 2050 when there are over 308,000 domestic EV chargers.
- In **Leading the Way** and **Consumer Transformation**, the total capacity of EV chargers is static from the late 2030s.
- The amount of EV charging capacity across the scenarios converges throughout this period as the total amount of energy EVs require converges. However, the scenarios maintain variation in the amount of centralised and decentralised charging capacity.

Figure 37 Summarising scenario projection graph for public EV chargers for the North of Scotland licence area



Reconciliation with National Grid ESO FES 2020:

- The ESO FES 2020 data publications do not provide sufficient regional or GSP level information to reconcile DFES EV charger projections with national projections.
- Factors that will affect the amount of EV charging infrastructure, primarily the energy consumption of EVs, are available in the ESO FES 2020 assumptions and data workbooks, and so are used where applicable in this study, including:
    - Projections of vehicle numbers (however, vehicle number projections have been augmented to represent Scottish ambition, as described in the Electric Vehicle section)
    - Projections of EV average annual mileage trends
    - Projections of EV and EV charger efficiencies
- At present there is a lack of evidence of future consumer charging behaviour, charger utilisation rates and vehicle ownership trends which results in uncertainty in the assumptions that must be made for the projection of future EV charging requirements. Therefore, assumptions have been made on topics including: (more detail is provided on these in the Regen Transport Model EV and EV Charger Assumption Workbook)
    - What proportion of annual EV energy requirements will be delivered at different locations (which EV charger archetypes)
    - EV charger utilisation rates at different locations.
        - The baseline capacity utilisation rates are where possible benchmarked against existing publications, trials and data sources.
        - In the short and medium term, the capacity utilisation rates trend towards a business model assessment of the utilisation rates required to be profitable, for the individual business models expected at each charger archetype.
        - In the long term, in the absence of other evidence, the capacity utilisation rates trend towards Regen's own assessment of utilisation rates at each charger archetype, based on anecdotal and circumstantial evidence.
    - These assumptions have been made using industry input and Regen analysis. As more behavioural data and other evidence becomes available, these assumptions will be further refined in the future. More detail on the specific assumptions used is provided in the Regen Transport Model assumptions spreadsheet.
- Interim assumptions have been made as to the behaviour of AV cars in the absence of other information, including:
    - The proportion of AVs that are private or shared in the absence of further information.
    - AV charging behaviour is similar to EVs, the key difference being an increase in fleet/depot charging.
    - AVs are associated with on and off-street households and charging at the same rate as EVs.

The uptake and distribution of chargers associated with AVs is an area that needs to be considered for future analysis.

Reconciliation with SSEN's 'High granularity projections for low carbon technology' study (June 2020):

Regen recently delivered similar analysis with SSEN in a study published here[xxxi]. This study used the ESO FES 2019 scenario framework and projections (ESO FES 2020 was not yet available) and was published in June 2020 after analysis was undertaken in Q4 2019 and Q1 2020. There are, therefore, a number of differences between the study's results due to several market developments and modelling changes between ESO FES 2019 and ESO FES 2020.

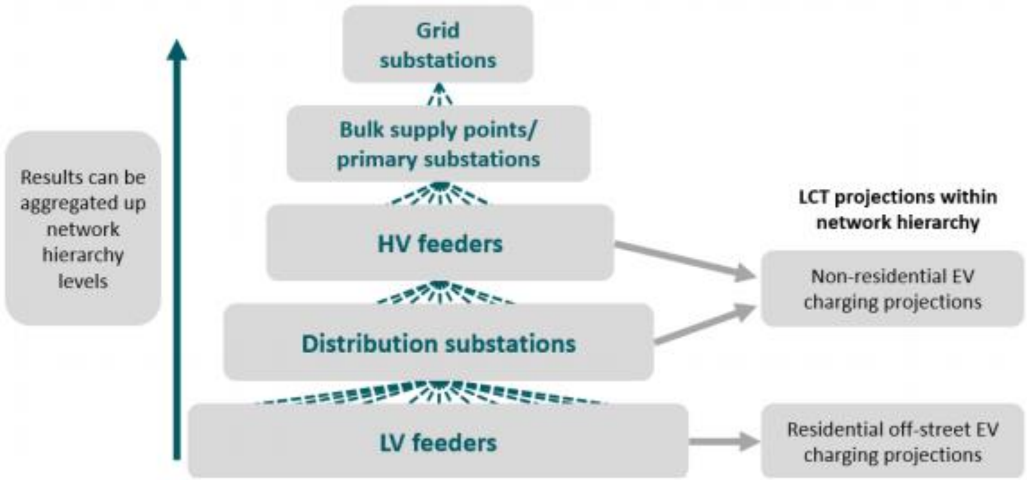
The changes include:

- Projected total EV charger capacity in the more ambitious scenarios has remained within a few percentage points of the June study. However, the narrowed range of EV projections that increased the uptake of EVs in the less ambitious scenarios has increased the total charger capacity in those less ambitious scenarios by between 25% and 40%.
- Projected public EV charger capacity has increased in this study due to the introduction of AVs. It is assumed that the uptake of AVs will result in less domestic charging, and more charging in public and fleet/workplace locations. However, the number of off-street domestic EV chargers are not necessarily lower, since most AV uptake occurs after the number of EVs peaks, in the 2040s.
- EV capacity levelling out in the previous study, but due to the uptake of AVs in the 2040s, it has been modelled that charging behaviour changes and there is an increase in public and fleet charging.

Factors that will affect deployment at a local level:

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

Simlified electricity network hierachy



Assigning data to individual substations and technology archetypes

1) Scale factor

How many situations are suitable for chargers at each substation? Spatial data including, for example:

- Number of homes (Source: SSEN)
- Number commercial and industrial (Source: SSEN)
- Number of petrol stations (Adddressbase)
- Number of car parks (Adddressbase)

2) Uptake factor

What is the attractiveness of the situation for each technology archetype at each substation? Spatial data including, for example:

- Urban/ rural setting
- Affluence
- Road miles distribution
- Number of jobs
- On/off gas heating
- On/off street parking
- Car park size

- The take up of home EV chargers is distributed in the near term towards more urban, sub-urban and affluent areas and those where there are high levels of off-street parking.
- The spatial distribution of non-domestic chargers was produced differently for each archetype.
    - En-route local and national charging locations were distributed based on the density of local housing, the volume of local traffic, the distribution of existing petrol stations and the road classification on where the site is located.
    - Car parks, workplace and fleet depot locations were identified from Ordnance Survey data.
    - The on street residential analysis was undertaken in parallel with the off-street parking analysis to identify vehicles associated with on street parking.
- The distribution analysis uses affluence as one of the key factors driving the uptake of EV chargers in the near term. For the more ambitious scenarios, from mid to late 2020s, the underlying assumption is that EVs will become ubiquitous. Therefore, the growth in demand for EVs in both on street and off-street areas, lower and higher affluence areas begins to increase at equivalent rates.
- In order to evaluate the distribution of Chargers to a feeder level, the above factors were interpolated down to individual feeders from the highest granularity of publicly accessible datasets that are available. In addition, Ordnance Survey Addressbase data has been used to identify the locations at which EV chargers could be located.
- The previous study experienced difficulties in distributing EV charger uptake on the Scottish islands. It was identified that several Scottish islands have disproportional numbers of car parks and industrial sites for the number of vehicles likely to use them. A method to mitigate these difficulties has been used in this study, which places greater weight on the number of vehicles on the island and less on the number of car parking spaces and other scale factors.

Scottish Government policy context

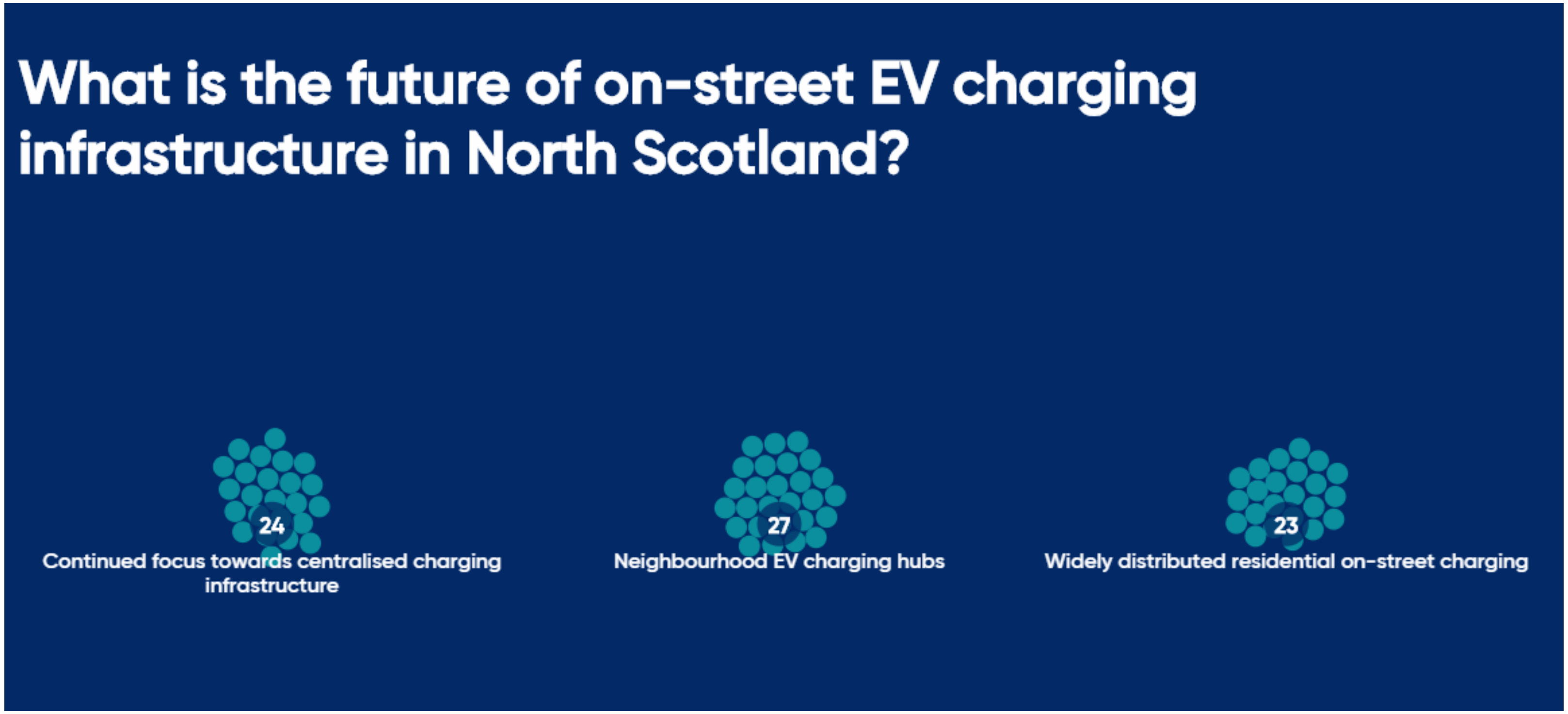
- Approximately 90% of all public EV chargers are operated by Chargeplace Scotland, a national network of EV chargers that is funded by the Scottish Government. This has resulted in a relatively centralised baseline of EV chargers, with more chargers in public locations such as car parks, public estates, and local charging infrastructure relative to other licence areas.
- Chargeplace Scotland’s dominant market position and centralised approach to EV charging is expected to continue in the short term, but as demand for EV charging increases it is expected that charging infrastructure in more decentralised locations will increase as public charging locations approach saturation.

Relevant assumptions from National Grid ESO FES 2020:

Assumption number	Based on 4.1.13 (Level of home charging)
Steady Progression	Charging at home is limited by a lack of viable solution for those without off-street parking. A more centralised approach to EV chargers is adopted.
System Transformation	Emphasis on public rollout of fast chargers to allow rapid charging. More rapid and fast public charging is demanded from consumers due to more limited near home charging opportunities.
Consumer Transformation	Charging predominately happens near home. Emphasis on home chargers, taking advantage of consumer engagement levels in flexibility. Leads to some disruption (e.g. reinforcing local networks)
Leading the Way	Charging happens similarly to how it happens today, with various types receiving investment to support an accelerated uptake of electric vehicles. Accelerated rollout of charging infrastructure at home and in public places.

Stakeholder feedback overview:

- The Scottish government stated that the investment in public charging infrastructure to date in Scotland has largely focused upon ChargePlace Scotland to pump-prime the early market. Going forward the work the Scottish government are progressing with the Scottish Future's Trust and through the EV Strategic Partnership is geared towards leveraging private investment in Scotland which may, therefore, influence opportunities and the balance of where charging infrastructure is located. There is a standing presumption that the greatest EV charging opportunities will follow a hierarchy of home, workplace and public. Uncertainty associated with the pandemic might also influence this dynamic.
- Further detail on changes made to the modelling as a result of Scottish ambition can be seen in the *"Reconciliation with National Grid ESO FES 2020 and Scottish government ambition"* section.
- At the North of Scotland stakeholder engagement event, stakeholders gave their opinion on the future of EV charging infrastructure in SSEN's North of Scotland licence area. There was a split view as to whether on-street and residential public charging will adopt a more centralised or decentralised approach. This topic was also discussed with the Scottish Government, who saw a more centralised approach to EV charging in Scotland when compared to GB, due to Chargeplace Scotland's activities. This has contributed to the future charging assumptions in this study, which has adopted a more centralised approach to EV charging infrastructure when compared to assumptions made in SSEN's South licence area.



References:

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

[xxxi] See High granularity projections for low carbon technology uptake, June 2020: https://www.regen.co.uk/wp-content/uploads/Regen-SSEN-High-granularity-LCT-projections-Final.pdf

15. Heat pumps and direct electric heating in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers all variants of electrically fuelled heating technologies within the scope of the DFES, specifically:

Domestic heat pumps – electric heat pump systems providing space heating and hot water to domestic buildings. This technology is divided into two sub-categories:

- Non-hybrid domestic heat pumps - powered purely by electricity – **DFES building block Lct_BB005**
- Hybrid heat domestic pumps - a combination of a gas boiler and electric heat pump. In the net zero scenarios, the gas boiler is supplied by hydrogen in the latter years of the scenario projections – **DFES building block Lct_BB006**

Commercial heat pumps – as per the domestic heat pumps, but supplying commercial buildings:

- Non-hybrid commercial heat pumps – **DFES building block Lct_BB007**
- Hybrid heat commercial pumps – **DFES building block Lct_BB008**

Direct electric heating - a system using electricity to provide primary space heat and hot water to domestic buildings, that is not driven by a heat pump. Typically, this is night storage heating or direct radiant electric heating. This does not include heat networks. **No building block ID.**

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

Number of homes		Baseline	2020	2025	2030	2035	2040	2045	2050
Non-hybrid heat pumps	Steady Progression	11,368	12,362	16,213	19,315	37,754	63,486	115,580	159,003
	System Transformation		14,854	29,283	61,197	104,267	141,622	195,869	198,771
	Consumer Transformation		14,305	107,521	290,355	421,306	506,899	564,149	572,313
	Leading the Way		14,982	90,513	242,761	348,025	440,107	501,985	510,149
Hybrid heat pumps	Steady Progression	0	0	285	2,259	7,356	9,738	15,451	26,188
	System Transformation		0	3,314	6,789	20,840	32,561	42,396	42,396
	Consumer Transformation		0	1,626	5,024	16,258	26,489	29,873	29,873
	Leading the Way		0	5,971	17,970	43,899	73,490	89,327	89,327

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

Number of commercial properties		Baseline	2020	2025	2030	2035	2040	2045	2050
Non-hybrid heat pumps	Steady Progression	1,486	1,591	1,951	2,224	4,378	7,417	13,711	18,890
	System Transformation		1,917	3,669	7,696	13,146	17,483	23,359	22,675
	Consumer Transformation		1,845	11,860	29,281	38,640	43,258	46,321	45,661
	Leading the Way		1,934	9,993	24,480	33,330	39,370	42,831	43,002
Hybrid heat pumps	Steady Progression	0	0	15	119	388	514	816	1,383
	System Transformation		0	175	358	1,100	1,719	2,239	2,239
	Consumer Transformation		0	86	265	858	1,399	1,577	1,577
	Leading the Way		0	315	949	2,318	3,880	4,717	4,717

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

Number of homes		Baseline	2020	2025	2030	2035	2040	2045	2050
Direct electric heating	Steady Progression	130,572	131,137	133,872	135,280	133,924	132,519	131,062	129,546
	System Transformation		131,137	132,568	128,286	124,118	120,117	116,267	112,549
	Consumer Transformation		131,137	119,802	95,473	89,814	86,699	83,735	80,905
	Leading the Way		131,137	121,264	101,517	97,726	95,019	92,395	89,843

Overview of technology projections in the licence area:

- In line with decarbonisation strategies across the country, the North of Scotland licence area sees a dramatic shift to low carbon heating in all three of the scenarios that meet net zero targets.
- Engagement with Scottish Government around heat decarbonisation ambition (including some of measures and targets highlighted in the recently published Climate Change Plan Update[xxxii]) has been reflected in all scenarios, particularly under **Consumer Transformation** and **Leading the Way**. This results in the North of Scotland licence area seeing rapid heat pump roll-out in the near and medium term, reflecting high levels of ambition to decarbonise off-gas and on-gas homes in Scotland. This has a correlative effect of limiting the uptake of hybrid heat pumps, which are not a focus of Scottish Government's heat decarbonisation strategy.

- In the more electrified **Consumer Transformation** and **Leading the Way** scenarios, c.77% of homes are heated by a non-hybrid or hybrid heat pump by 2045, as Scotland's net zero target year. Whilst not directly connecting or impacting the electricity distribution network, it should be noted that the remaining 23% of homes in the licence area will also be heated by alternative low carbon heating technologies, such as hydrogen boilers or district heat networks.
- The North of Scotland is a unique licence area, with many factors directly impacting low carbon heating options. 44% of homes in the licence area are not connected to the mains gas network, three times the GB proportion of 15%. This results in heat pumps playing a strong role in heat decarbonisation across the licence area, even in scenarios where hydrogen is available for heating on-gas homes.
- Furthermore, the particularly rural and remote areas of the Highlands and Islands in the north and west of the licence area experience high prices for oil, LPG and solid heating fuels. This has already resulted in high levels of electrified heat in these areas.
- Uptake of commercial heat pumps see a similar trajectory to domestic heat pumps. However, the penetration of heat pumps is lower than in domestic homes, due to the higher proportion of commercial units expected to use direct electric heating throughout the scenario timeframe. Currently, according to non-domestic EPC records, almost 50% of GB commercial properties are heated by electric heating, compared to 8% of domestic households.
- Under the **Consumer Transformation** and **Leading the Way** scenarios, just over 60% of commercial properties are heated by a form of heat pump in 2050. **Leading the Way** has a significantly higher number of hybrid heat pumps.
- Direct electric heating is compliant with net zero emissions targets, and is therefore not explicitly targeted for heat decarbonisation measures. However, as one of the most expensive heating methods and being less fuel-conversion efficient than heat pumps, scenarios with high levels of support for low carbon heating solutions will see a reduction in existing homes with direct electric heating over time. Scottish Government, through the Scottish Fuel Poverty Act (2019)[xxxiii] seeks to eradicate fuel poverty as far as is reasonably possible by 2040, therefore solutions such as direct electric heating is one of the solutions considered when aiming to tackle carbon emissions and fuel poverty.
- Conversely, direct electric heating is currently installed in some new build homes, and this will elicit an increase in direct electric heating deployment in homes in some scenarios, particularly in the near-term.
- In the long-term, all three net zero scenarios see a reduction in direct electric heated homes from today's levels, due to the prevalence of affordable electric heat pumps, hydrogen heating or low carbon district heat networks for the majority of homes in these scenarios. District heat networks, whilst not likely to be primarily fuelled by electricity, is a low carbon heating solution that is another key feature of Scottish Government's heat decarbonisation strategy. Therefore, whilst not a specific output or projection under the DFES 2020 scenarios, there could be a notable role for low carbon district heat networks supplying some clusters of homes in more urbanised areas of North Scotland in the longer term, especially under the **System Transformation** scenario.

Scenario projection results:

Baseline (up to end of 2019)

- There is a total of 11,368 heat pumps in the North of Scotland licence area, all of which are non-hybrid heat pumps. This represents 1.6% of homes, well above the GB average of 0.6%, due to the large proportion of off-gas and rural homes in the licence area and support for decarbonisation measures in the region.
- Many of these heat pump installations have been supported by the Domestic Renewable Heat Incentive (RHI). However in the remote Highlands and Islands areas, some heat pumps have also been installed without government support, reflecting costs of other heat options.
- The baseline is constructed from a combination of EPC and RHI data, aiming to capture heat pump installations that were not accredited for the RHI scheme. There are likely to be a minimal number of households with heat pumps that are not captured in the EPC or RHI data.
- There are a total of 130,572 homes heated primarily by direct electric heating in the North of Scotland licence area, based on analysis of EPC and Census 2011 data.
- This represents 18% of homes, compared to the GB average of 7%. The particularly high prevalence of electric heating is due to the high proportion of off-gas homes across the licence area, and the increased cost of alternative off-gas fuels such as oil and LPG in the particularly remote areas of the licence area, such as the Highlands and Islands.
- Consumers with electric heating tend to be in smaller properties and shared accommodation, also have a higher prevalence of fuel poverty.

Near term (2020 – 2030)

- Heat pump uptake increases slowly under the net zero scenarios in the near term. This growth is assumed to be supported by the Domestic RHI and the Green Homes Grant, which was launched in November 2020 and also supports the installation of domestic energy efficiency measures, which are required to run heat pumps effectively.
- There is a step change in installation rates under the more electrified **Consumer Transformation** and **Leading the Way** scenarios, reflecting strong Scottish Government ambitions to achieve high levels of non-hybrid heat pump deployment by 2025 and 2030 that were discussed during direct engagement with Scottish Government in October.
- Nationally, UK Government's ambition is to increase heat pump adoption to 600 thousand heat pumps per year by 2028[xxxiv]. Scottish Government's Climate Change Plan Update published in December 2020 has highlighted a similar ramping up of heat pump deployments in Scotland, suggesting "*the rate of acceleration required is somewhere between 40% and 50% year on year*".
- This high level of uptake and support for more efficient heat pumps results in some decrease in the number of existing homes with direct electric heating, as well as overall replacements of high carbon heating technologies, such as gas boilers, in some scenarios.
- With central and devolved government policy focusing on decarbonisation of off-gas homes in the near-to-medium term, the North of Scotland licence area, with over 40% of homes not connected to the gas network, sees a strong uptake of heat pumps over the coming decade. As a result, the vast majority of installed heat pumps are non-hybrids.
- Under **Consumer Transformation** and **Leading the Way**, 49% of homes in the licence area are heated by a non-hybrid heat pump by 2030.
- While Scottish Government ambitions are not met in **System Transformation** and **Steady Progression**, the DFES projections still see uptake levels ahead of the GB trajectory for these scenarios as a result of devolved ambition on decarbonisation of heat.

- Under **Consumer Transformation** and **Leading the Way** the ban on gas connections in new build housing in Scotland is implemented, increasing non-hybrid deployments from 2024 onwards as heat pumps become the default heating technology in new-build homes.
- Direct electric heating in existing homes remains stable under **Steady Progression**, with little uptake of heat pumps or district heating under which could drive removal of direct electric heating in these homes, and no substantial drive to remove oil or LPG heating systems, which could drive uptake in direct electric heating. The net result is direct electric heating remaining similar to the baseline, with new installations only in new build housing.

Medium term (2030 – 2040)

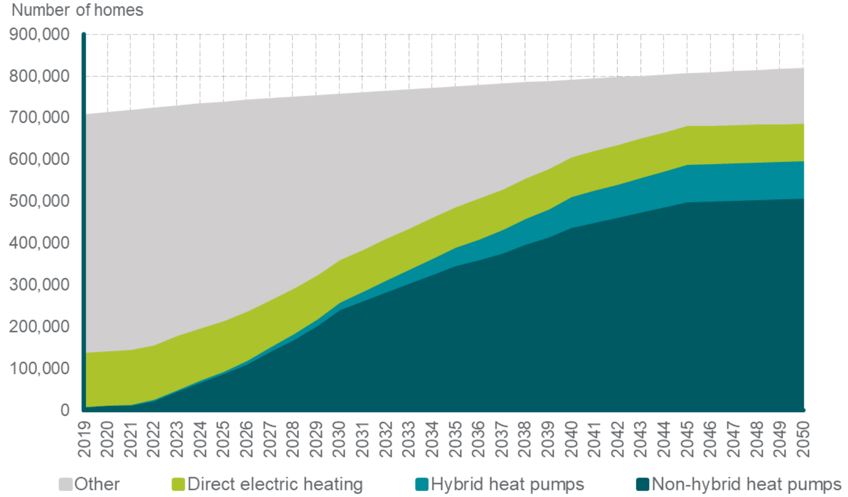
- Beyond 2030, the variance in the rate of heat pump uptake across the scenarios is driven by the national heat decarbonisation strategy and the availability of alternative hydrogen for domestic heating.
- Under **Consumer Transformation** and **Leading the Way**, heat pump installation rates decrease in the 2030s after very high levels of deployment in the 2020s. However, as energy efficiency measures are implemented, heat pump deployment now extends to homes that were previously less suitable for heat pumps due to poor energy efficiency or building form.
- **Leading the Way** has a significantly higher number of hybrid heat pumps.
- Under **System Transformation** and **Steady Progression**, deployment of heat pumps is slower and is still focused on the most suitable properties (highly efficient homes, homes with more floor space, areas with high levels of home ownership) and homes targeted for additional support such as; social housing, households in fuel poverty, off-gas homes.
- In **System Transformation** on-gas homes begin to be converted to green gas hydrogen and biomethane. Under **Steady Progression** gas heating continues to be fossil fuel methane.
- In new developments, heat pumps are still the most common heating system under **Consumer Transformation** and **Leading the Way**, due to the ban on gas connections in new homes, however the share of new homes heated by low carbon alternatives such as district heat networks increases. Direct electric heating is still installed in some new builds at levels similar to today, around 10%. This encompasses new builds with a low heating demand, such as highly efficient buildings and smaller dwellings, where the expense of direct electric heating is less of a concern compared to the higher capital cost of a heat pump system.

Long term (2040 – 2050)

- Under the **Consumer Transformation** and **Leading the Way** scenarios, the high levels of uptake seen in the 2030s continues to 2045, as Scotland achieves its 2045 Net Zero goal. By 2050, just fewer than 90% of homes are heated by a heat pump or direct electric heating under these scenarios, with the remainder heated via low carbon district heat, biomass or other biofuels.
- Beyond 2045, additional heat pump uptake is predominantly in new-build homes, resulting in a low heat pump deployment after this point.
- Under **System Transformation**, heat pump uptake remains moderate, as on-gas homes are predominantly fuelled by hydrogen. Off-gas homes are fully decarbonised by 2045 as per the other net zero scenarios, primarily through non-hybrid heat pumps. By 2050, 47% of homes in the licence area are heated by a heat pump or direct electric heating, with the majority of the rest heated by hydrogen boilers.
- **Steady Progression** uptake remains low as Scotland and GB fail to meet their legally binding net zero targets. 43% of North of Scotland homes are heated by a heat pump or direct electric heating by 2050, higher than the GB average, due to heat pumps predominantly featuring in currently off-gas homes in this scenario.

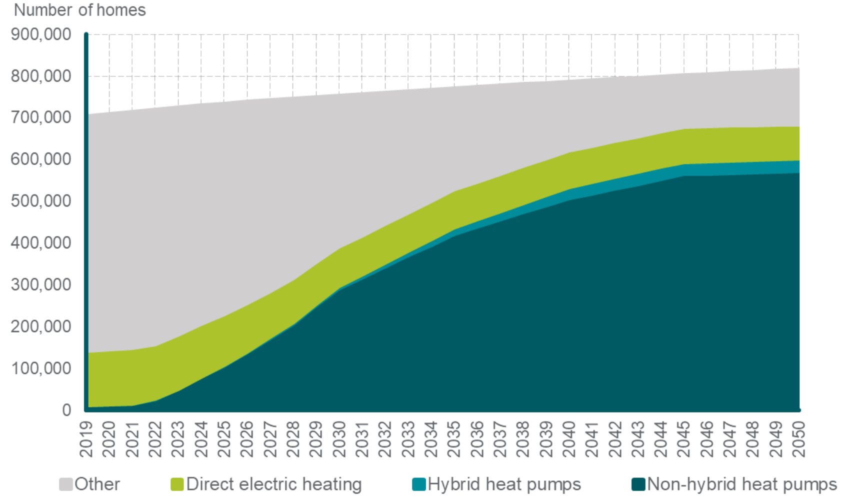
Figure 38: Breakdown of domestic heating projections for the North of Scotland licence area under the four scenarios

Domestic heating technologies in the North of Scotland licence area - Leading the Way



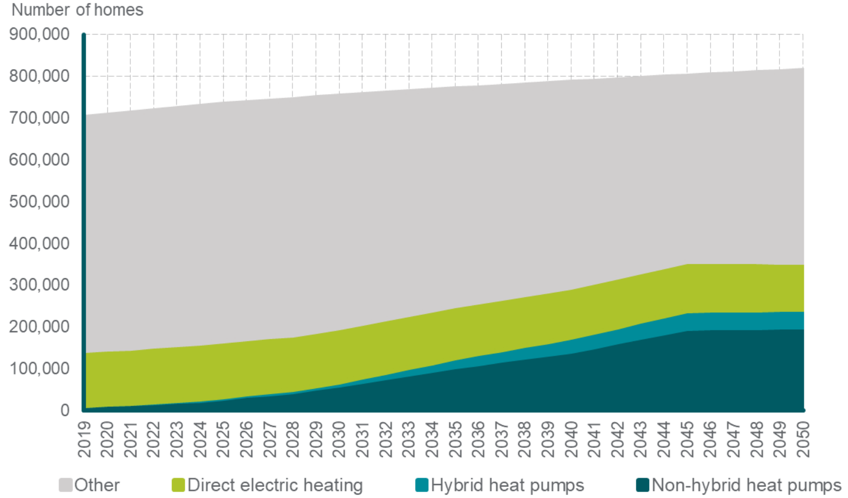
'Other' heating includes fossil fuels, hydrogen, district heating and bioenergy

Domestic heating technologies in the North of Scotland licence area - Consumer Transformation



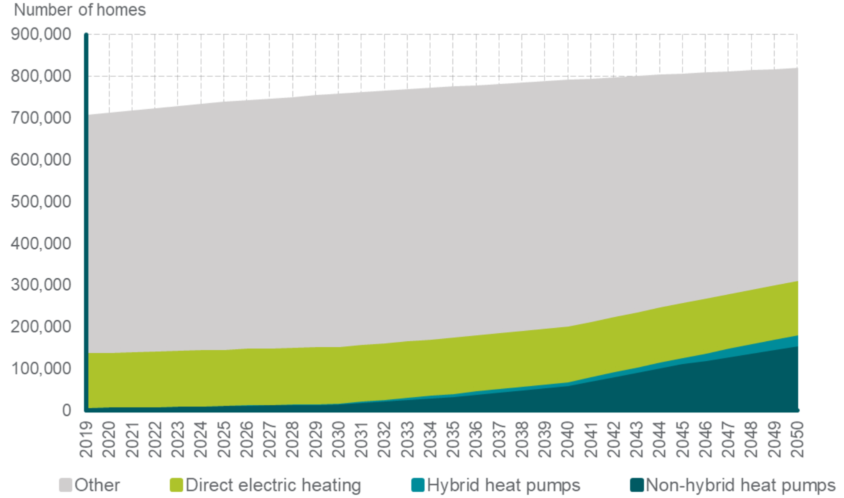
'Other' heating includes fossil fuels, hydrogen, district heating and bioenergy

Domestic heating technologies in the North of Scotland licence area - System Transformation



- 'Other' heating includes fossil fuels, hydrogen, district heating and bioenergy

Domestic heating technologies in the North of Scotland licence area - Steady Progression



'Other' heating includes fossil fuels, hydrogen, district heating and bioenergy

Figure 39: Non-hybrid heat pump projections for the North of Scotland licence area, compared to National Grid FES 2020 regional projections

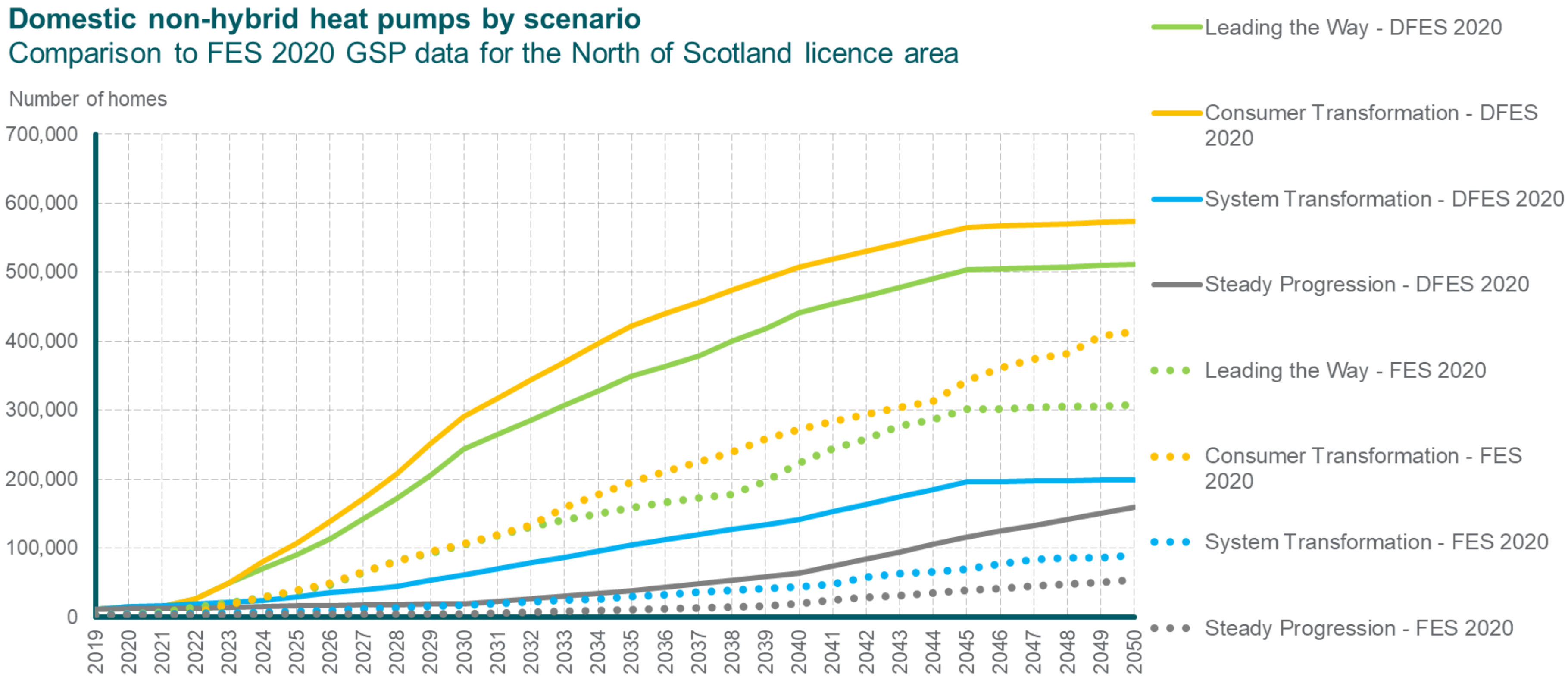


Figure 40: Hybrid heat pump projections for the North of Scotland licence area, compared to National Grid FES 2020 regional projections

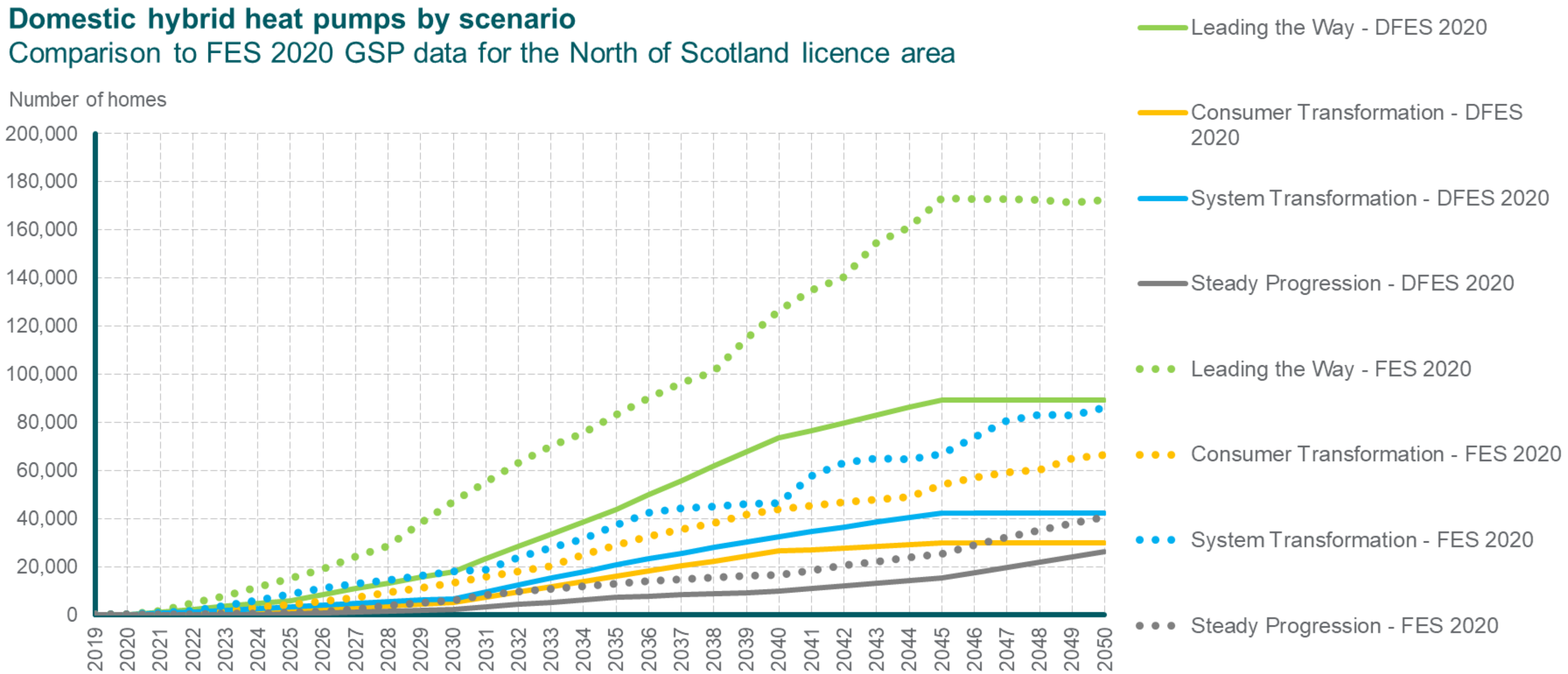


Figure 41: Direct electric heating projections for the North of Scotland licence area, compared to National Grid FES 2020 national projections scaled pro-rata

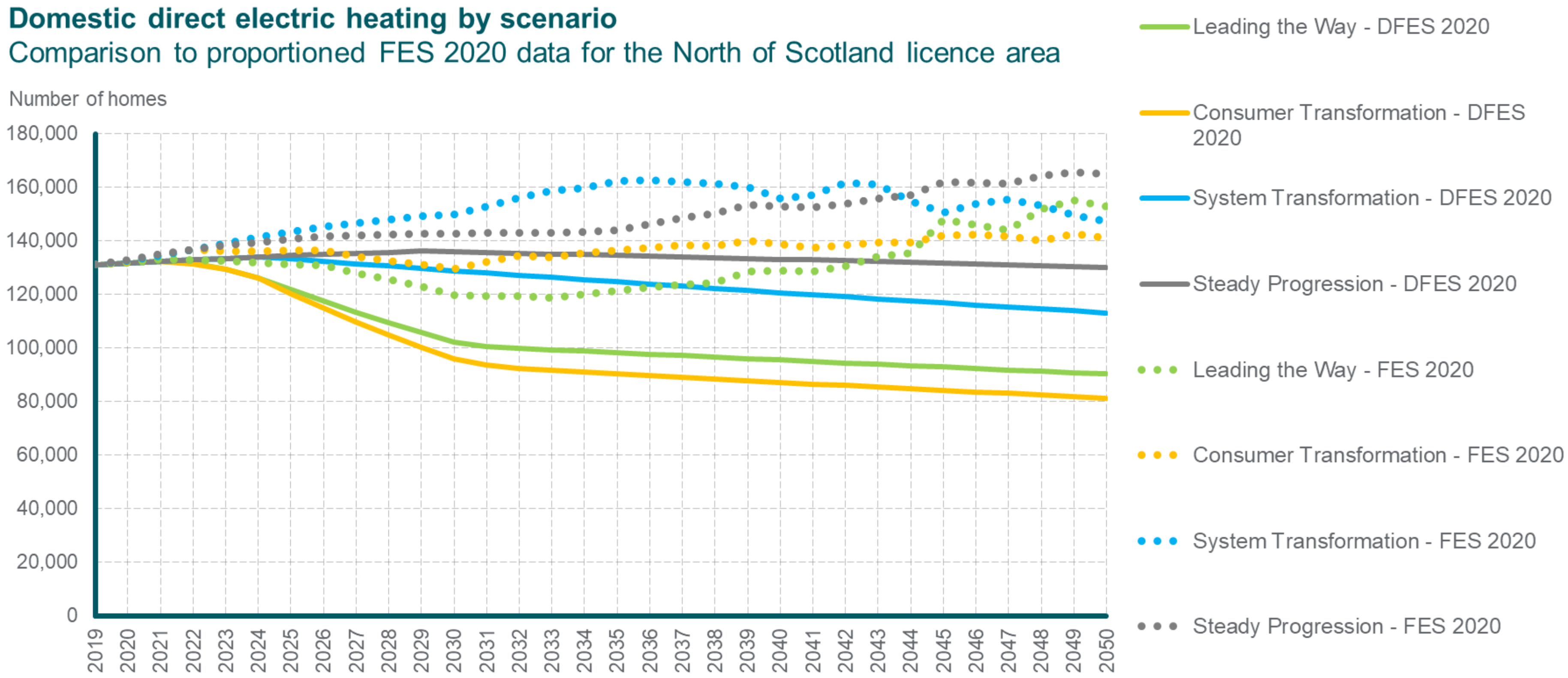
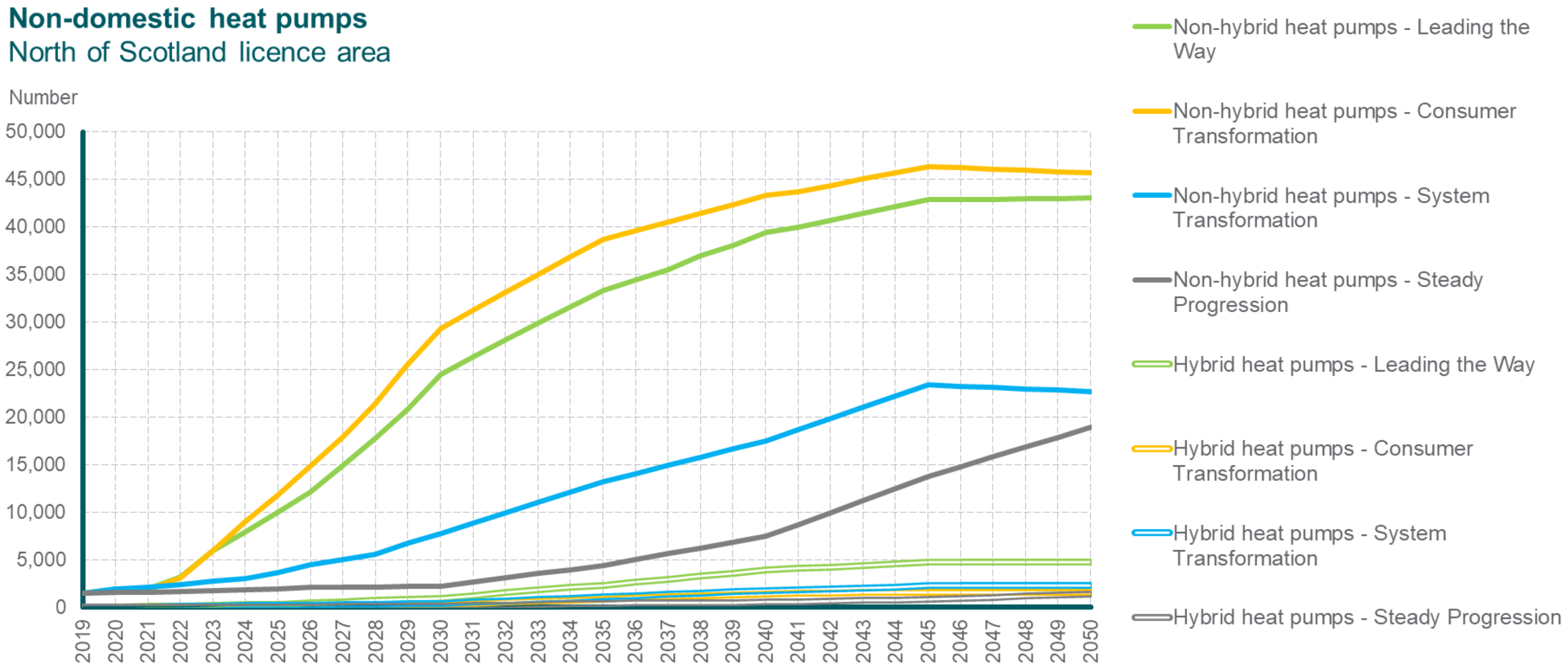


Figure 42: Non-domestic heat pump projections for the North of Scotland licence area



Reconciliation with National Grid FES 2020:

- In the period to 2030, the DFES scenarios for non-hybrid heat pumps in North Scotland are markedly higher than the FES 2020 regional projections. This is due to the nature of the housing stock and higher proportion of off-gas grid properties as well as the DFES reflecting Scottish Government ambitions for decarbonisation of heat.
- By 2050 the non-hybrid DFES projections are closer to the FES 2020 figures, although they remain higher due to the off-gas nature of the licence area.
- Hybrid heating follows a similar trajectory to the FES in all scenarios, albeit at a much-reduced level. This is due to the combination of Scottish Government ambition resulting in more homes choosing a non-hybrid heat pump, even in on-gas homes, and the much lower proportion of homes connected to the gas network in the North of Scotland licence area.

- As there is no regional data for direct electric heating in the FES 2020 dataset, a comparison has been made against GB scenario figures.
- In the North of Scotland licence area, every scenario sees an overall decrease in direct electric heated houses compared to the FES 2020 data. This is driven by Scottish Government and stakeholder ambition on heat pump deployment, as well as the lower than average development of new housing stock which might be electrically heated.
- In the FES 2020, electric heating is split into night storage heating and non-storage heating. In every scenario from 2019 to 2050, night storage heating represents 66% of total direct electric heating, and this high-level breakdown can reasonably be applied to the DFES projections also.
- In the FES 2020, electric heating is split into night storage heating and non-storage heating. In every scenario from 2019 to 2050, night storage heating represents 66% of total direct electric heating, and this high-level breakdown can reasonably be applied to the DFES projections also.
- There are no projections for the number of commercial heat pumps in the FES 2020.

Factors that will affect deployment at a local level:

- The uptake of heat pumps, and other consumer based Low Carbon Technologies (LCTs), was projected to a very high level of granularity within the SSEN low voltage network. Domestic heat pump uptake was evaluated to SSEN's over 400,000 individual feeders, equivalent to street-level forecasts, while non-domestic heat pumps were evaluated to SSEN's over 100,000 distribution substations roughly equivalent to a post code level.
- A wide variety of datasets were used to analyse regional and feeder specific demographic, technical attributes and geographical characteristics. For example, the key spatial and household characteristics used in this study for the uptake of heat pumps was information on gas network connectivity, household information evaluated from EPC data, affluence and home ownership. This data is available from MHCLG, Census, BEIS and ONS. While there are data limitations and some of this data needs to be interpolated down to a feeder level granularity, this analysis allows a much more granular assessment of scenario-based heat pump uptake on the network.
- However, as levels of deployment increase, uptake is assumed to become more evenly distributed. In the long term uptake is weighted towards those areas of low uptake in the early period.

Relevant assumptions from National Grid FES 2020:

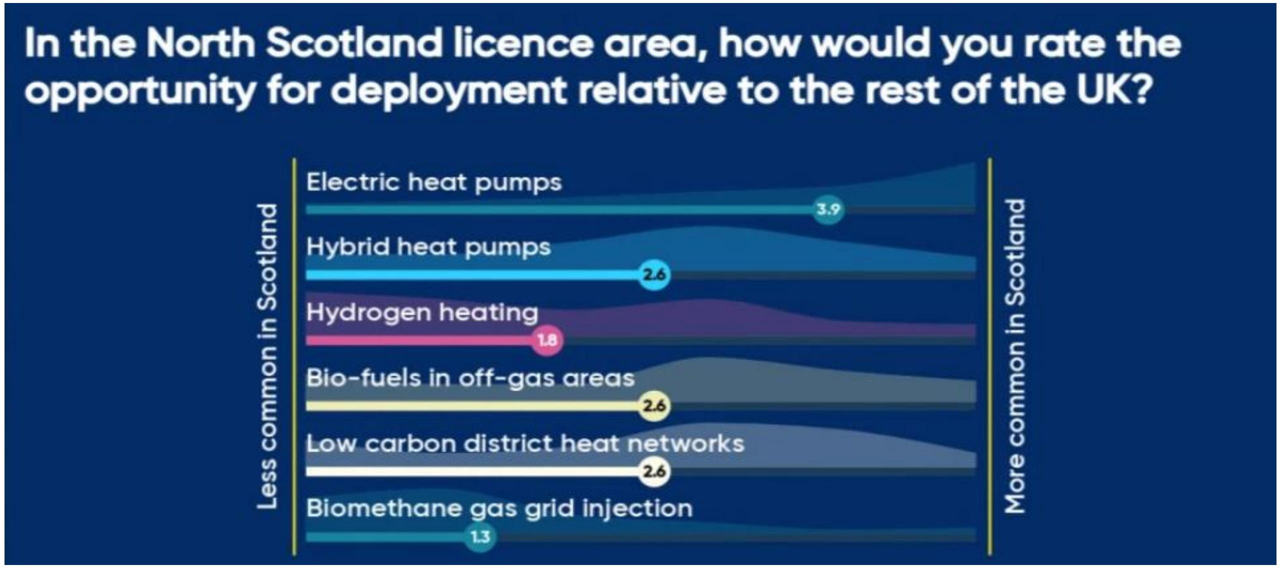
Assumption number	3.1.3 Heat Pump adoption rates
Steady Progression	Consumers continue to buy similar appliances to today
System Transformation	Low willingness to change lifestyle results in hydrogen being a preferred low carbon heating technology
Consumer Transformation	High energy prices and consumer willingness to adapt results in high levels of heat pump uptake
Leading the Way	High income, energy prices and green consumer ambition results in high levels of heat pump uptake

Stakeholder feedback:

Feedback received from the engagement webinar was used to sense-check the heat pump uptake projections, especially when considering the low carbon heating options for the North of Scotland licence area as a whole, and particularly for the unique situation of the islands in the licence area.

Local authority feedback on climate emergency and low carbon heat, such as heat pump or heat network strategies, were used to inform projections at a licence area and local level.

Scottish Government were directly engaged around their potential plans for heat decarbonisation across Scotland and in the North of Scotland licence area specifically. Scottish Government targets and aims were incorporated into the modelling under the scenario framework.



References:

Scottish Energy Performance Certificates, Scottish Census 2011, Renewable Heat Incentive data, Climate Emergency declaration data, Regen consultation with local stakeholders and local authorities. Regen Decarbonisation of Heat paper, SPEN DFES Data and Assumptions.

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xxxii See Climate Change Plan Update December 2020 (p92 to p111): https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/

xxxiii See Scottish Fuel Poverty Act (2019): https://www.legislation.gov.uk/asp/2019/10

xxxiv UK Government 10 Point Plan to achieve net zero https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

16. Small-scale solar PV in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers small-scale solar PV generation with capacity less than 1 MW connected to the distribution network in the North of Scotland licence area. This is typically rooftop solar PV, but may also include some small ground-mounted arrays.

This technology is divided into two sub-categories:

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

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

Installed capacity (MW)		Baseline	2020	2025	2030	2035	2040	2045	2050
<10 kW	Steady Progression	75	77	86	100	118	137	154	169
	System Transformation		77	99	153	211	264	308	340
	Consumer Transformation		77	118	195	282	367	446	517
	Leading the Way		77	99	153	210	263	307	338
10 kW – 1 MW	Steady Progression	20	21	25	28	32	35	38	39
	System Transformation		23	28	40	51	61	69	74
	Consumer Transformation		23	33	50	68	85	102	117
	Leading the Way		23	28	39	51	61	69	74

Overview of technology projections in the licence area:

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

Scenario projection results:

Baseline (up to end of 2019)

- There is 75 MW of domestic-scale solar PV in the North of Scotland licence area, equivalent to rooftop arrays on 3.3% of domestic buildings, above the GB-wide proportion of 2.9%.
- Almost all of these installations occurred between 2010 and 2019, supported by the Feed-in Tariff. The installation rate peaked at 17.5 MW installed in 2012. Deployment slowed notably as the Feed-in Tariffs reduced, with only 8 MW installed since 2016.
- The commercial-scale solar PV baseline totals 20 MW. As per domestic-scale installations, the Feed-in Tariff supported this deployment, and development tailed off since 2016.

Near term (2020 – 2025)

- At sub-megawatt scale, fewer projects are represented in the connection-data driven pipeline, especially for domestic scale solar PV.
- The trajectory for small-scale solar in the near term depends strongly on the uptake of the Smart Export Guarantee, and attractiveness of rooftop solar for homeowners in terms of installation costs.
- The **Consumer Transformation** scenario, with high levels of green ambition from the public and high near-term uptake of electrified transport, sees a corresponding uptake in solar PV due to both ambition and financial benefits.

Medium term (2025 – 2035)

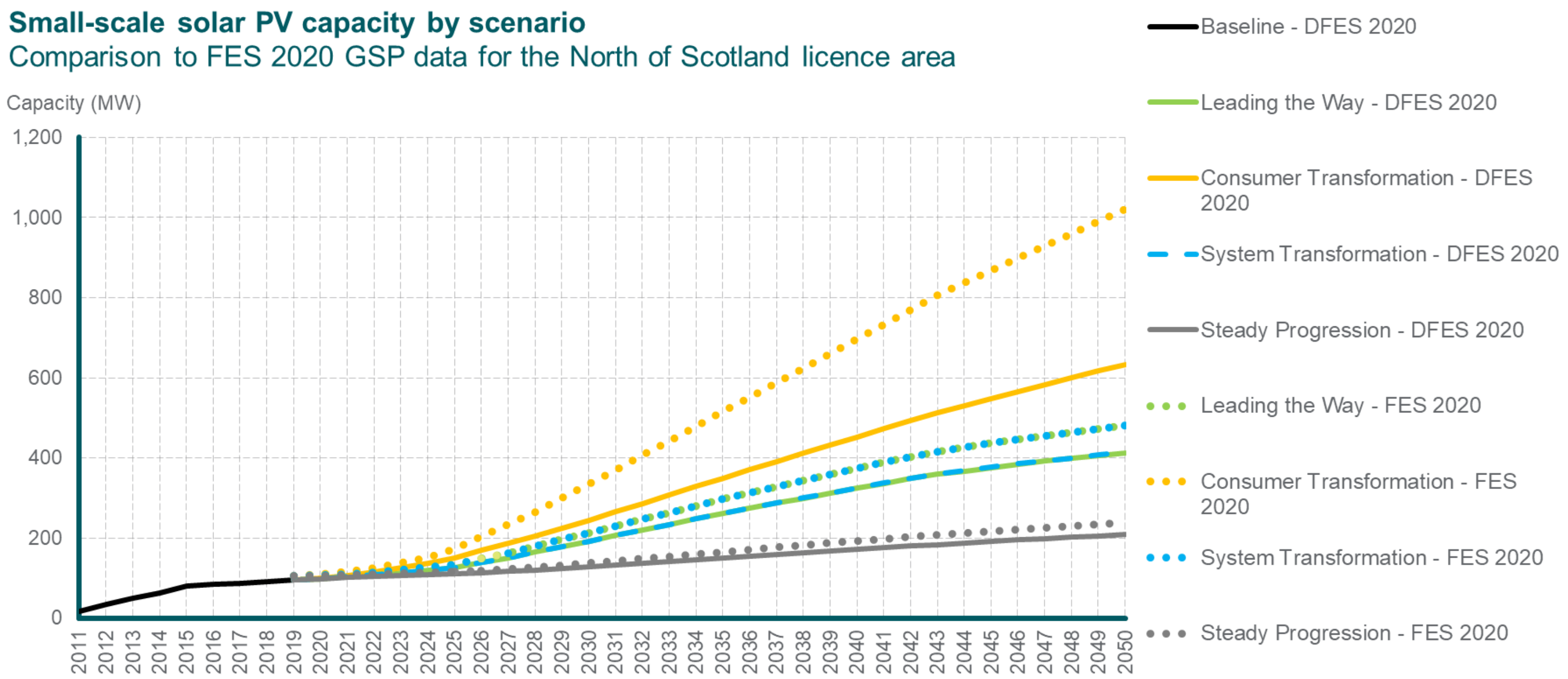
- Beyond the near term, small-scale solar uptake depends strongly on national trajectories rather than licence area factors.
- The North of Scotland licence area has lower levels of irradiance than the rest of the UK; however historic uptake is around 10% higher than the overall GB trajectory. This could be due to number of factors, from higher levels of social housing to more larger detached and semi-detached properties in rural areas. As a result of the balance between solar irradiance, factors such as social housing, affluence and available roof area, the uptake of rooftop solar PV in the North of Scotland licence area is expected to be in line with national trajectories.

- Rooftop solar PV on new build housing accounts for 10-20% of uptake in all scenarios, owing to lower installation costs than retrofit panels. Beyond the next few years, the volume of new housing developments is expected to reduce, especially in more rural areas of the Highlands and Islands where population is steady or expected to decline. Therefore, the impact of solar PV on new build housing decreases over time.
- As in the medium term, **Consumer Transformation** sees high levels of growth as a result of high consumer ambition and engagement, and high levels of electrification in transport, heat and cooling. The rate of installation under this scenario is similar to the rapid roll-out of rooftop solar PV seen in the first few years of the Feed-in Tariff (2010 to 2012). The two other net zero scenarios have strong uptake as panel costs fall, but to a lower extent that **Consumer Transformation** as decarbonisation of electricity is achieved through larger-scale projects.

Long term (2035 – 2050)

- The overall trends established in the medium term continue out to 2050, with some levelling-out of deployment in each scenario. This is due to a combination of a continued slowing of house building, especially in more rural areas, and the most suitable homes with adequate south-facing roof area having seen solar PV deployment in the preceding years of the scenarios.

Figure 43: Small-scale solar PV projections for the North of Scotland licence area, compared to National Grid FES 2020 regional projections



Reconciliation with National Grid FES 2020:

- As small-scale solar PV is more strongly driven by national considerations, support, policy and public sentiment, the DFES scenarios align strongly with the FES 2020 regional data throughout the projection period in terms of the range of projections between scenarios.
- The exception is the **Consumer Transformation** scenario, where the DFES uptake is significantly lower than the FES 2020 regional figures. The DFES modelling for this scenario results in a consistent deployment rate similar to the early years of the Feed-in Tariff were above the retail price of electricity for domestic customers. Even with decreasing installation costs for rooftop PV, increased electrification of transport, heat and cooling, and increased consumer engagement and ambition under this scenario, it is difficult to envisage a scenario where installation rates exceed the levels seen in 2010, when Feed-in Tariff rates exceed 50 p/kWh for domestic retrofit solar PV installations.
- All scenarios see lower levels of small-scale solar PV deployment in the long-term, beyond 2035. This is the result of assumptions in the DFES around the amount of new capacity attributed to new build housing and commercial properties, as the North of Scotland licence area is expected to see lower levels of house building than the national average in the long term.
- The near term pipeline for commercial-scale solar, and assumptions around solar PV on new developments, results in **Steady Progression** seeing higher levels of development in the DFES. However, this remains low compared to the three net zero scenarios, in line with the FES 2020 scenario framework.

Factors that will affect deployment at a local level:

- The uptake of domestic small-scale solar PV, and other consumer based Low Carbon Technologies was projected to a very high level of granularity within the SSEN low voltage network. Domestic small-scale solar PV uptake was evaluated to SSEN's over 400,000 individual feeders, equivalent to street-level forecasts, while commercial solar PV was evaluated to SSEN's over 1,400 ESAs.
- A wide variety of datasets were used to analyse regional and feeder specific demographic, technical attributes and geographical characteristics. For example, the key spatial and household characteristics used in this study for the uptake of domestic solar PV were information on affluence, social housing and home ownership. This data is available from MHCLG, Census, and ONS. While there are data limitations and some of this data needs to be interpolated down to a feeder level granularity, this analysis allows a much more granular assessment of scenario-based heat pump uptake on the network.
- However, as levels of deployment increase, uptake is assumed to become more evenly distributed. In the long term uptake is weighted towards those areas of low uptake in the early period.

Relevant assumptions from National Grid FES 2020:

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

Stakeholder feedback overview:

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

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

References:

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

17. Hydrogen electrolysis in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers any hydrogen electrolysers connected to the distribution network in the North of Scotland licence area. The analysis does not include electrolysers that are directly powered by renewable energy, such as those on Orkney and Unst, or large-scale electrolysers connected to the transmission network. Nor does it include blue hydrogen produced via the reformation of natural gas or other fossil fuels.

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

Installed capacity (MW)	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
System Transformation		1.5	1.8	2.9	14	40	83	124
Consumer Transformation		1.5	2.1	13	43	79	105	109
Leading the Way*		1.5	1.5	1.5	1.5	1.5	1.5	1.5

*Under the FES 2020 projections, Leading the Way has zero distribution connected electrolysers

Relevant assumptions from National Grid FES 2020:

Assumption number	4.2.19 (Hydrogen electrolysis)
Steady Progression*	High cost limits rollout of electrolysis – used mainly in transport.
System Transformation	Competition from SMR** limits rollout of electrolysis – used mainly in transport. SMR covers heat.
Consumer Transformation	Electrolysis used to decarbonise heat, transport and some I&C.
Leading the Way*	Electrolysis used to decarbonise heat, transport and I&C but rollout starts in the mid-2020s.

*Steady Progression and Leading the Way both have projections for additional hydrogen electrolysis capacity, with Leading the Way projecting 72GW of grid-connected electrolysis by 2050 for Great Britain, however these have all been allocated to the transmission network and thus there is no distribution connected electrolysers in either of these scenarios.

**Steam Methane Reformation. A process of producing hydrogen from natural gas, also known as “blue hydrogen”.

Overview of technology projections in the licence area:

In order to develop DFES projections for distribution network electrolyser capacity, the analysis has focussed primarily on the uptake of hydrogen vehicles and fleets, as this has been determined to be a significant driver for electrolysed hydrogen demand on the distribution network, based on analysis on existing projects. The use of hydrogen in wider transport, such as rail, has also been considered, after engagement with the Scottish Government and from reviewing their Rail Services Decarbonisation Action Plan[xxxv], which aims to decarbonise all of Scotland's rail network by 2035. The ban on the sale of new fossil fuel vehicles[xxxvi] that has been passed into UK law will result in an increase in hydrogen refuelling stations in the run up to and after 2035. North of Scotland accounts for 2.75% of UK industrial demand[xxxvii], which could be decarbonised by using hydrogen, as industry is difficult to electrify.

The North of Scotland is a prime location for hydrogen electrolysis, however there is significant amount of uncertainty around the level of development of hydrogen electrolysis as a new/emerging technology class. As it is the first time hydrogen electrolysis has been included in any level of detail in the ESO FES projections, there is uncertainty in a number of areas, including national policy framework, financial incentives and technology development. The main source of uncertainty for hydrogen electrolysis is around assessing:

- How much will connect to the distribution network compared to the transmission network
- The potential split between electrolysis and "blue" hydrogen
- The range of uses to which hydrogen may be put including transport, industrial processes, electricity generation and heating
- The potential for large scale hydrogen production to be concentrated in areas with existing chemical and refinery process industries

In Scotland, the voltage of the transmission network is a tier lower than in England, which may encourage more electrolysers to be connected to the transmission network. The level of network connected projects may also depend on the capacity of projects that use curtailed renewable energy, such as the 'Surf n Turf'[xxxviii] project on the Isle of Eday. These electrolysers that directly connect to renewable generators have been removed from the DFES analysis, as they are not drawing electricity from the distribution network, even for auxiliary supply, though this may not be a typical installation seen in many other areas of the UK, due to the bespoke operational nature of Scottish island renewable generation.

The FES 2020 projections[xxxix] do not show distribution connected electrolysers in the North of Scotland licence area under any scenario. Based on existing projects and stakeholder feedback, including the Scottish Government, it is considered likely that there will be distribution connected electrolysis in the North of Scotland. This has been modelled in the DFES in both the **System Transformation** and **Consumer Transformation** scenarios. A higher deployment of hydrogen reflects the ambition set out in the Scottish Climate Change Bill[xl], which sets out a target of net zero by 2045 and an interim target of a 75% reduction in greenhouse gas emission from 1990 levels by 2030. Also, the recently published Hydrogen Policy Statement[xli], highlights a strong potential for areas such as Aberdeen to become a hub for hydrogen production and use, as well as outlining some of the hydrogen electrolysis pilot projects being progressed in Scotland. At a high level, the DFES assumes:

- **Steady Progression** does not see any increase in electrolyser capacity, due to a lack of hydrogen policy support in this scenario.
- Under the **Leading the Way**, it is assumed that global innovation and investment will drive down costs and encourage commercialisation at scale from the early 2030s. This would require large scale electrolysers to meet demand, which would likely connect to the transmission network. It is envisaged that there will also be behind-the-meter electrolysers or regional electrolyser installations close to renewable generation sites.

The underlying assumptions in **Steady Progression** and **Leading the Way** have been mirrored in the DFES analysis, whereas **System Transformation** and **Consumer Transformation** deviate from the FES projections, through developing a more detailed bottom-up methodology. The results of this approach see 124 MW connecting in **System Transformation** and 109 MW connecting in **Consumer Transformation** by 2050, and only the 1.5 MW of baseline projects continuing to operate in **Leading the Way** and **Steady Progression**.

Scenario projection results:

Baseline (up to end of 2019)

- There is a total of 1.5 MW of hydrogen electrolysers connected to the distribution network in the North of Scotland licence area, comprising two hydrogen refuelling stations[xlii], both in Aberdeen. The Kittybrewster bus depot has the capacity to produce 360kg[xliii] of hydrogen daily, which is equivalent to c.12 MWh, enough for the current fleet of 10 hydrogen buses in Aberdeen.
- These depots both have on-site electrolysers which are connected to the distribution network.

Near term (2020 – 2025)

- There are no distribution connected electrolysis projects publicly in the pipeline in the licence area.
- A small increase in connected capacity is however modelled in **System Transformation** (1.8 MW) and **Consumer Transformation** (2.1 MW) by 2025, whilst connected capacity in **Steady Progression** and **Leading the Way** remains at the 1.5 MW baseline position.

Medium term (2025 – 2035)

- The demand for hydrogen electrolysers will potentially increase between 2025 and 2035, driven by the uptake of hydrogen fuelled heavy vehicle fleets and the introduction of mainstream hydrogen fuel cell electric vehicles. This vehicle fuel switching will be further incentivised by policy measures such as the ban on sales of new petrol and diesel cars by 2030[xliv]. The H2Mobility[xlv] project is aiming for 1,150 hydrogen refuelling stations to be operational across the UK by 2030. Hydrogen refuelling stations could likely be co-located with existing petrol stations, particularly ones with large HGV fuelling demand. As the fleet of hydrogen buses in Aberdeen potentially increases, the requirement for hydrogen refuelling stations will increase around Aberdeen, or the existing stations will need to increase their fuelling capacity to supply fuel to more vehicles per day.
- With Scotland's target of net zero emissions by 2045, and an interim target of a 75% reduction in emissions from 1990 levels by 2030, this period could see a large increase in hydrogen supply capacity in Scotland.
- The **Consumer Transformation** scenario assumes that green hydrogen will achieve cost parity with blue hydrogen in the mid-2030s, while **System Transformation** does not see electrolysis reaching cost parity in the same timeframe, so blue hydrogen is the favoured production method. However, hydrogen produced via electrolysis, rather than hydrogen from natural gas, is needed for transport due to its purity.
- The recent Transport Scotland Rail Services Decarbonisation Action Plan sets out the need to "*reduce travel by unsustainable modes and promote green public transport*". By 2035, it aims to have Scotland's rural rail networks powered by battery or an alternative traction. This includes the "*provision of infrastructure for the storage and supply of hydrogen to trains*". Electrolyser developers are already starting to trial

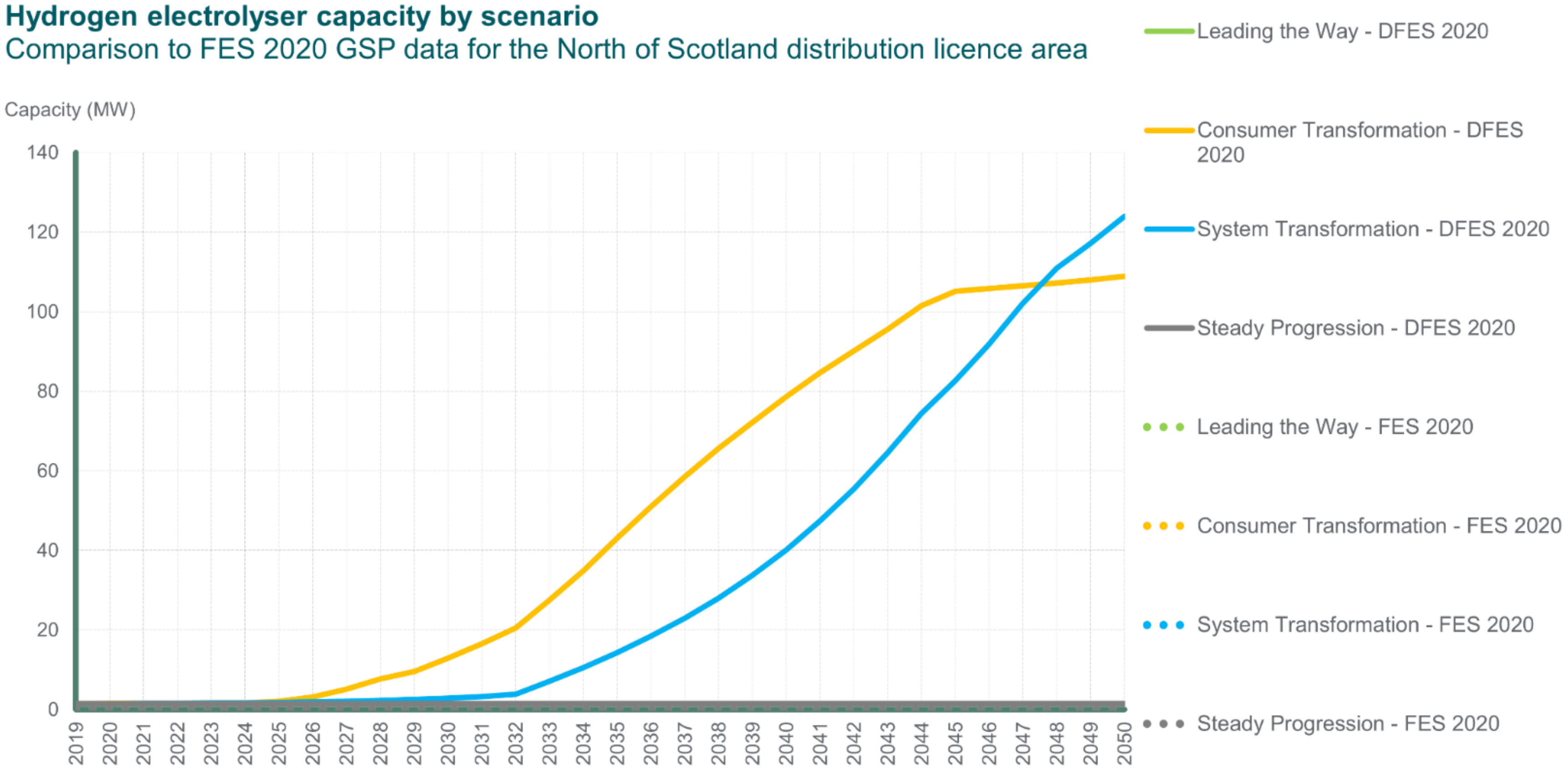
the use of hydrogen in trains. A large train refuelling station is likely to be c. 30 MW, while a smaller, rural depot could potentially have a 10 MW electrolyser[xlvi], which is the largest commercial electrolyser currently available[xlvii].

- The industrial clusters located in Grangemouth and Fife could encourage electrolysers to be located outside of the North of Scotland licence area, and the hydrogen transported by truck to areas of North Scotland. This would reduce the capacity of hydrogen production facilities within the North of Scotland licence area itself.
- This analysis culminates in the total electrolyser capacity reaching 43 MW in **Consumer Transformation** and 14 MW in **System Transformation** by 2035. Capacity remains at 1.5 MW in **Steady Progression** and **Leading the Way**.

Long term (2035 – 2050)

- With the ability to upgrade existing hydrogen refuelling stations to have a greater MW capacity, the development of new sites is likely to slow, and instead, existing locations are likely to be expanded to cater for more vehicles.
- Some smaller scale, more rural stations have been modelled to be developed built to meet 2045 net zero targets.
- Under **Consumer Transformation**, large depots will be built to support fleets of hydrogen buses and HGVs. The uptake of hydrogen fuel cell electric vehicles under **System Transformation** could see widespread deployment of hydrogen refuelling stations across the North of Scotland licence area from 2040.
- The use of hydrogen to fuel ferries, for example the BIG HIT[xlviii] project in Kirkwall, could also be seen in the North of Scotland licence area, in particular, on/around the Scottish islands and major ports. However, it is uncertain whether these would connect to the distribution network or use curtailed renewable energy generation. As a business model for hydrogen, this is most likely to occur under **Consumer Transformation**, as almost half of GB demand for electrolysed hydrogen in this scenario is for shipping.
- By 2050 the deployment of distribution network connected electrolysis reaches 124 MW in **System Transformation** and 109 MW in **Consumer Transformation**. Only the 1.5 MW of known baseline projects continue to operate in the **Steady Progression** and **Leading the Way** scenarios out to 2050.

Figure 44 - Comparison of DFES analysis to the FES 2020 projections of hydrogen electrolysis capacity in the North of Scotland licence area



Reconciliation with National Grid FES 2020:

The reconciliation analysis in this section is based on relevant FES 2020 projections[xlix] that relate to hydrogen electrolysis.

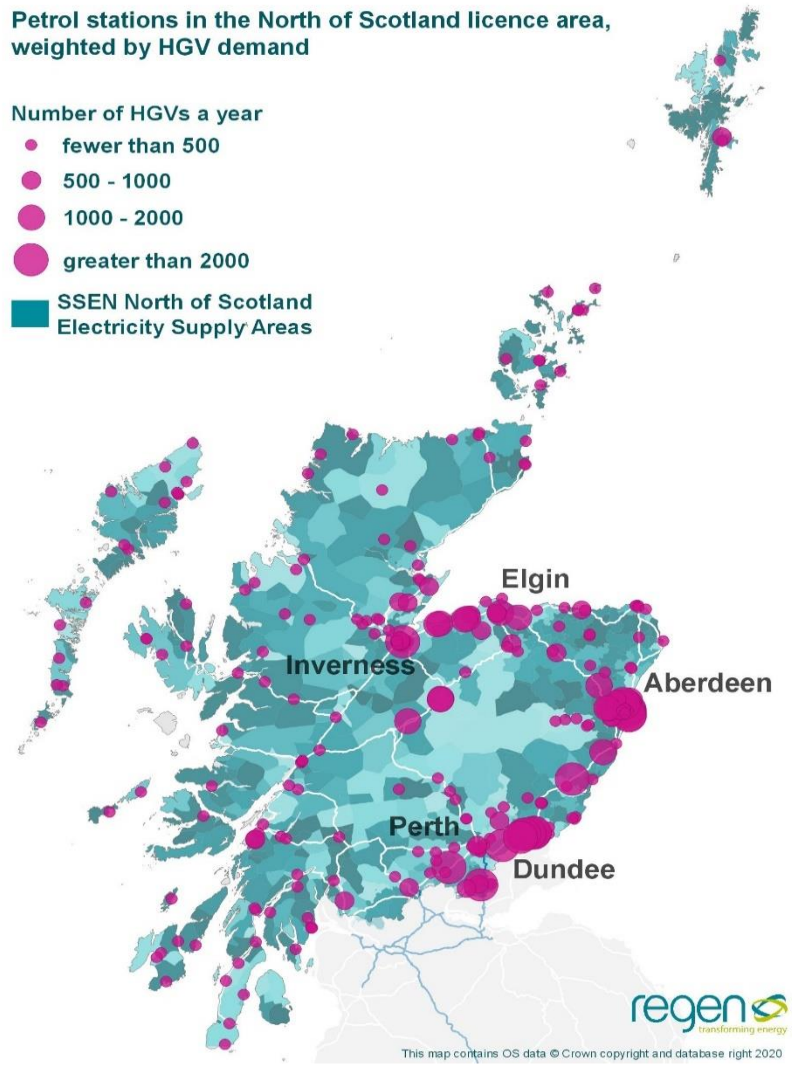
- The FES 2020 GB scenario projections for electrolyser capacity did not include the existing projects that were found through online research. The DFES projections have reflected the c.1.5 MW in the baseline under all scenarios.
- The FES 2020 projections show zero distribution network connected electrolysers in the North of Scotland licence area under all scenarios.
- From engaging Scottish Government and hydrogen electrolyser technology developers ITM Power, the DFES has opted to diverge from this high-level assumption.
- The DFES has resultantly used **System Transformation** and **Consumer Transformation** to represent two future pathways for the uptake of hydrogen electrolysis connected to the distribution network, where:
  - **System Transformation** has a centralised approach to hydrogen supply and includes the production of blue hydrogen produced from natural gas through reformation
  - **Consumer Transformation** has a much lower hydrogen demand, but most of this demand is met through electrolysis.
- Based on the current active hydrogen projects in the North of Scotland licence area, and engagement with stakeholders, it is assumed in these scenarios that there will be distribution connected electrolysis in the future, primarily driven by the demand for hydrogen as a fuel for heavy vehicles and thus a network of hydrogen refuelling stations.
- The **System Transformation** and **Consumer Transformation** scenarios also includes some hydrogen electrolysis capacity for trains; however, **Consumer Transformation** assumes this happens more rapidly, in line with Scotland's Rail Services Decarbonisation Action Plan.

Factors that will affect deployment at a local level:

- From engaging electrolyser technology developers, locational factors of hydrogen fuel cell electric vehicles and access to the gas distribution network were identified as priorities when deciding where to build hydrogen refuelling stations.
- The spatial distribution of hydrogen electrolysers in the North of Scotland licence area out to 2030 is primarily based on the location of existing hydrogen refuelling stations, as well as key fuelling hub locations identified through conversations with ITM Power and Scottish Government.
- Co-location of electrolysers with existing petrol stations that have large HGV demand will be an important factor, particularly between 2020 and 2030, where the increased presence of hydrogen fleets will drive demand.
- After 2035, smaller petrol stations will potentially also have hydrogen refuelling stations. These small-scale electrolysers could have a capacity of less than a 1MW, so pockets 1MW of hydrogen electrolysis capacity could be distributed across several Electricity Supply Areas in the North of Scotland licence area.

- Existing hydrogen refuelling stations could be upgraded to 800kg/day (or 26,880kWh/day), especially if they are used as depots or hub fuelling locations, which would increase their electrical import capacity to between 2 and 5 MW.
- The other factors that will affect deployment at a local level could include:
    - The location of major ports and marine/shipping activity
    - Rail depots that supply stretches of the rail network that have been potentially earmarked to convert to hydrogen fuelled trains
    - The ambition of local authorities within the licence area to invest in hydrogen electrolysis as a low carbon technology
    - Industrial and commercial clusters

Figure 45 Petrol stations in the North of Scotland licence area, weighted by annual HGV demand

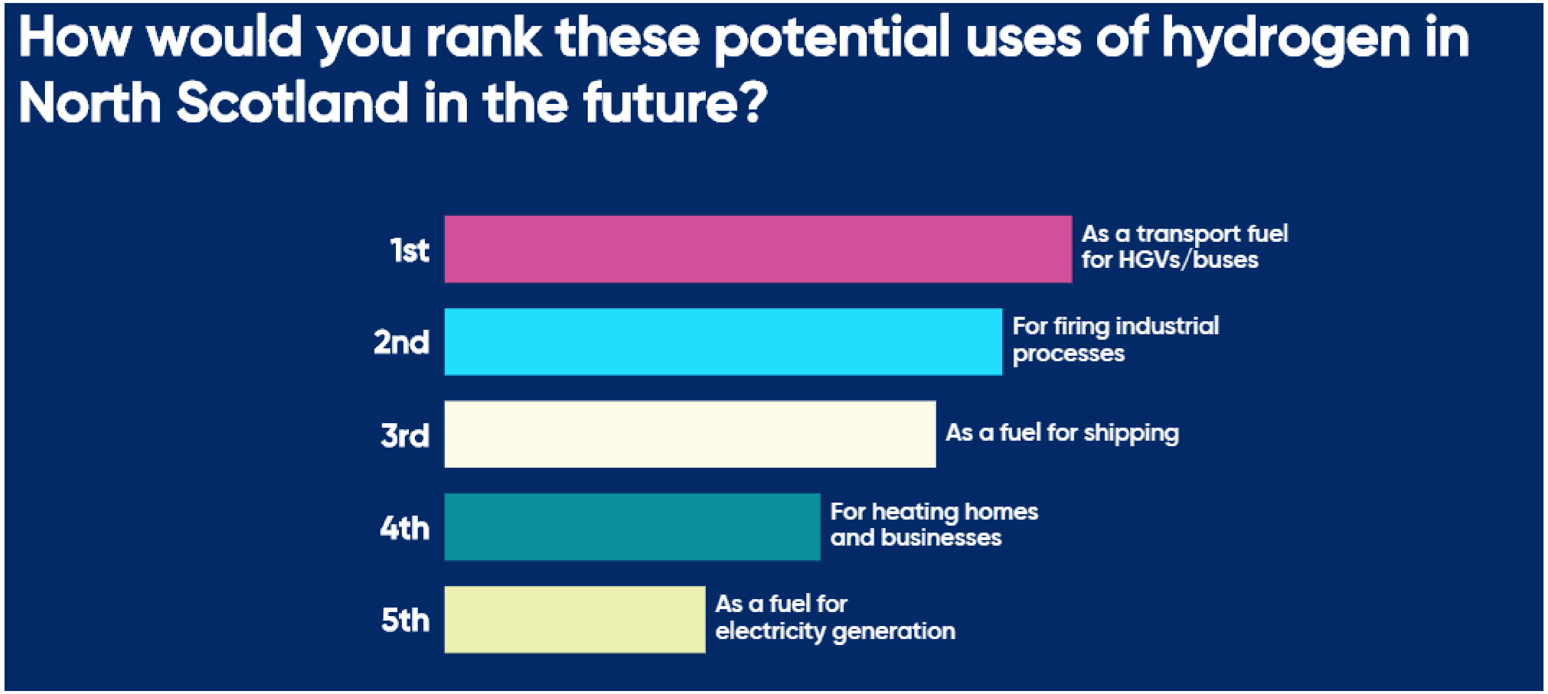


Overview of stakeholder and regional input:

As part of the DFES stakeholder engagement process, Regen delivered a series of webinars with SSEN and the Energy Systems Catapult across August and September. Part of these webinars included discussing some of the key technology sectors in the scope of the DFES, including hydrogen. Participants fed back that transport fuel was the main potential future use of hydrogen. This feedback influenced the DFES analysis and cemented some of the assumptions made around hydrogen refuelling stations as a key factor influencing the development of electrolysis capacity.

Engagement with ITM Power highlighted the potential for electrolysis plants to be used to supply hydrogen refuelling stations, by delivering hydrogen by truck, and used for heating and electricity as a secondary application. Assuming much of this secondary capacity will be on the transmission network, this could see a lower capacity on the distribution network within the North of Scotland licence area.

Engagement with both the Scottish Government and ITM Power saw strong agreement with the modelling approach in the DFES to prioritise future deployment of hydrogen refuelling stations and to omit the hydrogen projects on the Scottish islands from the modelling projections, as not connecting to the distribution network. The potential for hydrogen trains to play an important role in Scotland's future was highlighted and the timescale was emphasised through the Rail Services Decarbonisation Action Plan.



References and data sources:

Online trial project research, FES 2020 data workbook, Scottish Government and Transport Scotland policy, ITM Power product specifications.

[xxxv] Scottish government Rail Services Decarbonisation Action Plan: https://www.transport.gov.scot/media/47906/rail-services-decarbonisation-action-plan.pdf
[xxxvi] https://www.bbc.co.uk/news/science-environment-51366123
[xxxvii] https://www.gov.uk/government/collections/total-final-energy-consumption-at-sub-national-level
[xxxviii] https://www.surfnturf.org.uk/
[xxxix] https://www.nationalgrideso.com/document/173821/download
[xl] Scotland's Climate Change Bill: https://www.legislation.gov.uk/asp/2019/15/enacted
[xli] See Scottish Government's Hydrogen Policy Statement: https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/
[xlii] https://www.aberdeencity.gov.uk/services/environment/h2-aberdeen
[xliii] https://www.boconline.co.uk/en/images/Case%20study%20Kittybrewster%20Aberdeen%20hydrogen%20refuelling%20station_tcm410-563229.pdf
[xliv] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf
[xlv] H2Mobility project: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/192440/13-799-uk-h2-mobility-phase-1-results.pdf
[xlvi] https://www.heraldscotland.com/business_hq/18792033.scotland-track-hydrogen-powered-railways-revolution/
[xlvii] https://www.itm-power.com/products
[xlviii] https://www.bighit.eu/
[xlix] https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

18. New property developments in the North of Scotland licence area

Summary of modelling assumptions and results.

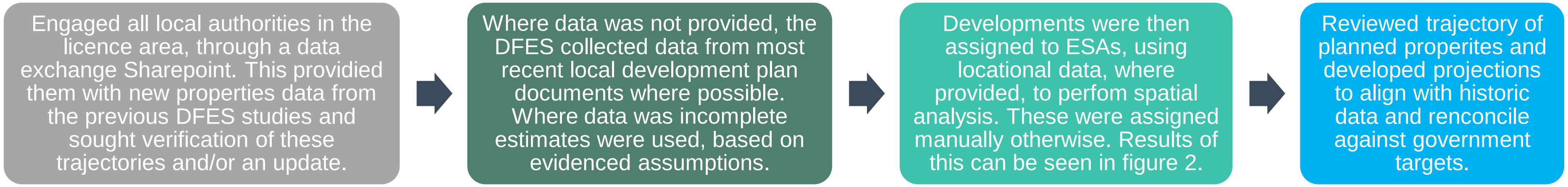
Specification:

New property developments can have a significant impact on local electricity demand and therefore, forecasts of new house and commercial and industrial (C&I) builds have been included in the DFES analysis for the North Scotland licence area. Local authorities within the licence area were contacted to aid the collation of planned new properties, through a data exchange Sharepoint. The information fed back from the local authorities was collated into a central projection for new housing and C&I properties. Engagement with local authorities is a key aspect of the DFES' stakeholder evidence around not just property developments, but also local energy strategy. The ESO FES 2020 does not have an equivalent projection for property developments and therefore there is no technology building block.

Summary:

Domestic housing and non-domestic commercial and industrial property growth projections were created using the methodology outlined below. The new property development analysis for DFES 2020 built on and updated the analysis that was previously completed in the SSEN licence areas in 2019.

Figure 46 – Summary of methodology for the assessment of new developments

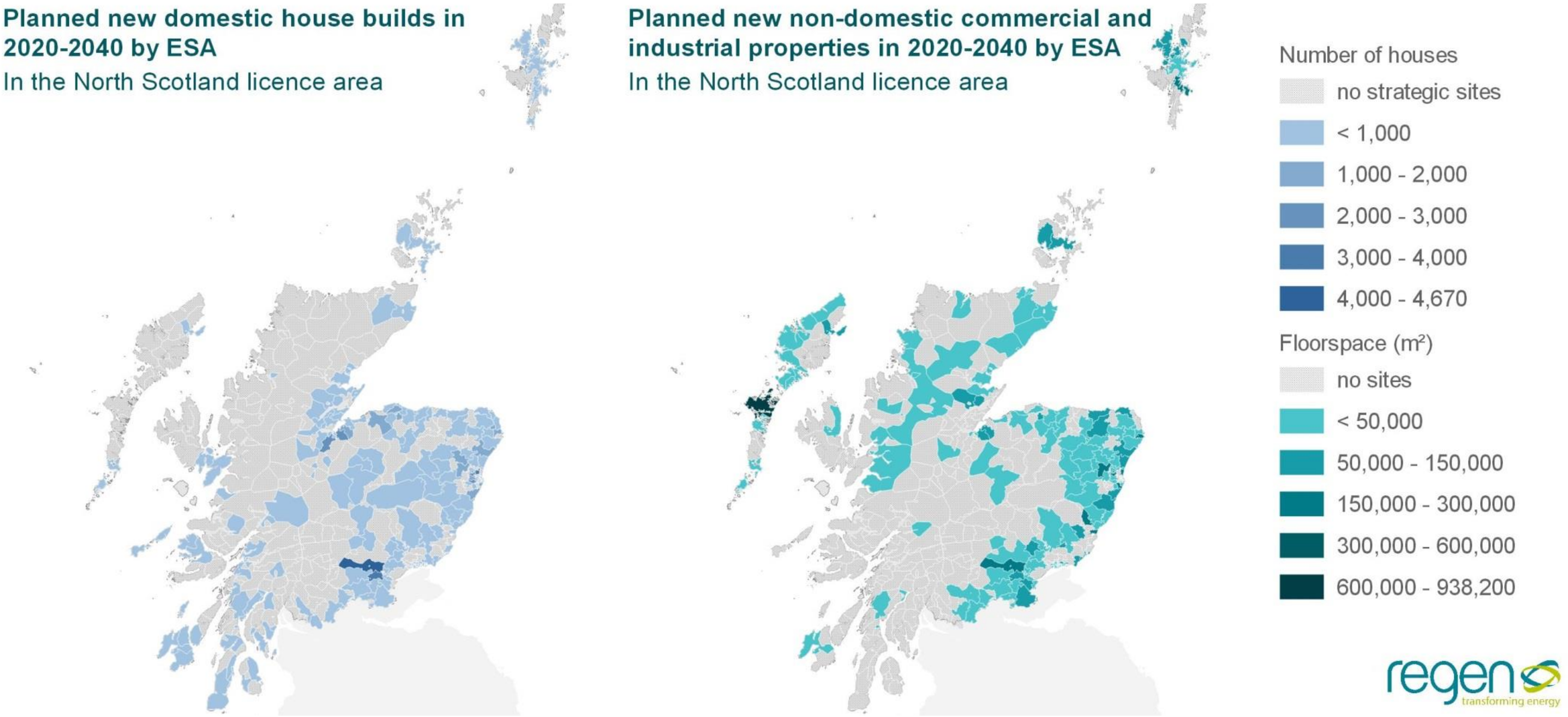


In this year's DFES analysis, new properties data was refreshed through a Sharepoint data exchange between Regen and all local authorities within the licence area. Approximately half of the local authorities in the North Scotland licence area updated the databases themselves, which requested information around location, likely use, development stage, size (e.g. number of homes or C&I floorspace) and expected completion years. Some local authorities sent information separately via email and, where there was no response, the database was updated using published planning documents for that local authority area.

Only strategic domestic housing developments were recorded, which are defined as 20 homes or more for the North Scotland licence area, unless otherwise flagged by the local authority. Non-strategic developments, which make up a small proportion of new builds, were estimated and also included in the projection.

- There are no assumptions within the ESO FES 2020 regarding property construction. Hence, in the DFES a single projection is used.
- Reflecting potential delays in roll-out of new properties, and a noted "optimism bias" in development plans, the model shifts a proportion of the planned properties to subsequent years.
- For housing developments, the projection is initially comparable to the average number of new builds per year from 2001 onwards which is approximately six thousand houses over the licence area[l]. The profile then drops, which follows the National Records of Scotland household projections[li]. With the projection being based on known new housing developments, the rate of new builds drops significantly after 2030 when the projections become of less value.
- No statistical data is available for non-domestic developments.

Figure 47 – Distribution of planned property developments over licence area



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

Classification of new property development	Near-term projections of known new developments up to 2030			Projections of known new developments beyond 2030 to 2050			
	2020	2025	2030	2035	2040	2045	2050
Domestic (number of homes)	5,399	30,948	50,233	63,297	71,332	73,861	74,629
Non-Domestic (floor space/ m^2)	642,879	4,452,457	7,980,927	10,258,340	11,075,843	11,248,880	11,262,780

Projection results:

Baseline (2020)

There is a total of approximately 5.4 thousand new houses, (of which 0.2 thousand are non-strategic), and 643 thousand m^2 of new non-domestic developments in the North Scotland licence area in 2020. This is slightly lower than the historic average of 6.2 thousand houses for the licence area[1]. The COVID-19 pandemic has had a notable impact on housing development in 2020, with quarterly new build rates in the second quarter of 2020 falling to their lowest level since the year 2000[lii]. This introduces uncertainty for the housing builds due to have been completed this year and planned in the coming years.

- The Craigton (Aberdeen City) ESA has the highest number of domestic housing developments in 2020 with 247 new homes.
- The Gremista 11kV Switchroom (Shetland Islands) ESA has the largest area of non-domestic floorspace in 2020 with 86 thousand m^2 of specifically new office, factory and warehouse space.

The developments in this year are made up of 90% of the planned new developments. 10% of the domestic and non-domestic developments were delayed to following years.

Near term (2021 – 2030)

There is a total of approximately 45 thousand new houses and 7,902 thousand m^2 new non-domestic developments in the North Scotland licence area over the near term. Hence, over 50 thousand new homes are projected to be completed by 2030, as labelled in Figure 48. The new developments are evenly spread across the decade, but most densely at the start and reducing on average by 160 new houses. It is estimated from National Records of Scotland projections that the net number of new houses is expected to fall by around 200 houses a year over the period in the licence area[1]. Refer to the net new houses projection in Figure 48.

- ESAs identified as having a significant number of new homes in the near term are Redgorton (Perth and Kinross), Craigton (Aberdeen City), and Stoneywood (Aberdeen City) which are expected to around 1.7,1.6 and 1.6 thousand homes respectively over the 10 years. For these ESAs, this is the result of a consistent addition of one to two hundred new homes a year, with higher rates of development seen towards the end of the decade.
- Bridge of Don (Aberdeen City) attains the most new non-domestic floorspace with 600 thousand m^2 for offices, factories and warehouses.
- Of the planned new houses and non-domestic developments an increasing fraction of the developments are delayed to following years ranging from 80 down to 50%.

Beyond 2030 (2031 – 2050)

The data after 2030 has limited value as a licence area projection. While there are known/planned developments in the pipeline after 2030, their aggregation is significantly lower than a level of development which should be expected. This is a reflection of the modelling method being predominantly based on new developments with document plans for which there are few beyond 2030.

Figure 48 – Aggregated domestic housing properties over whole licence area

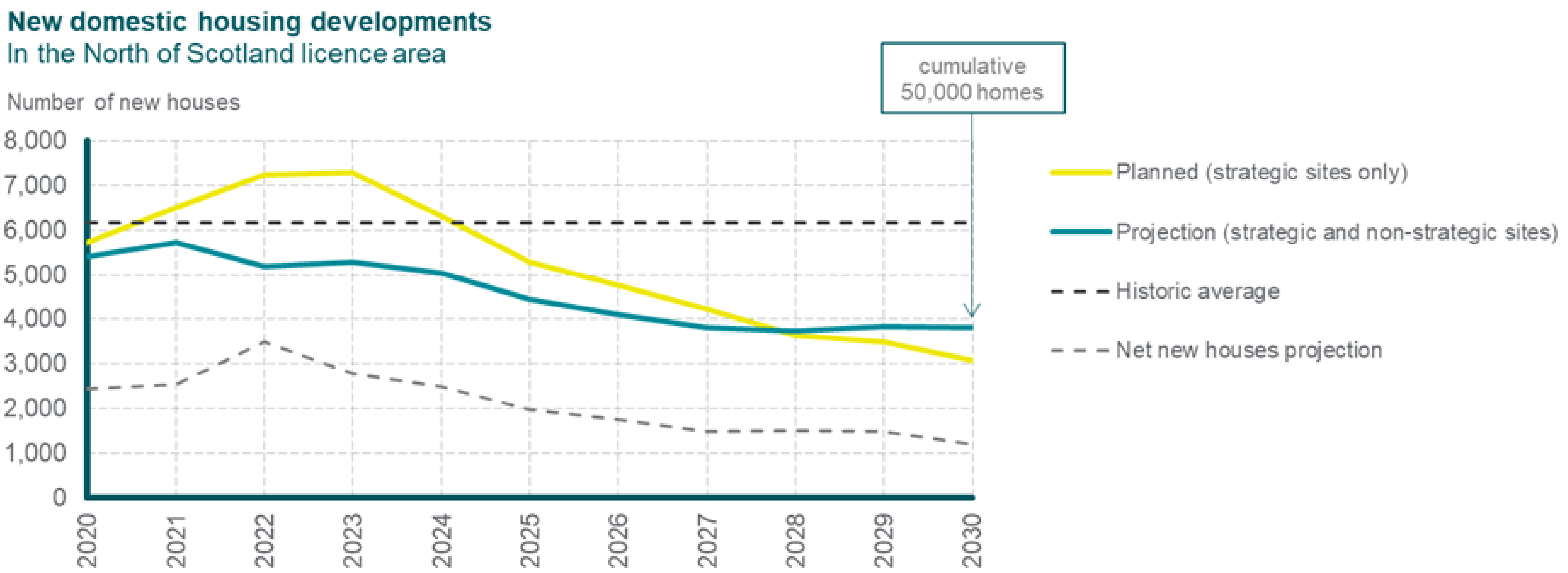
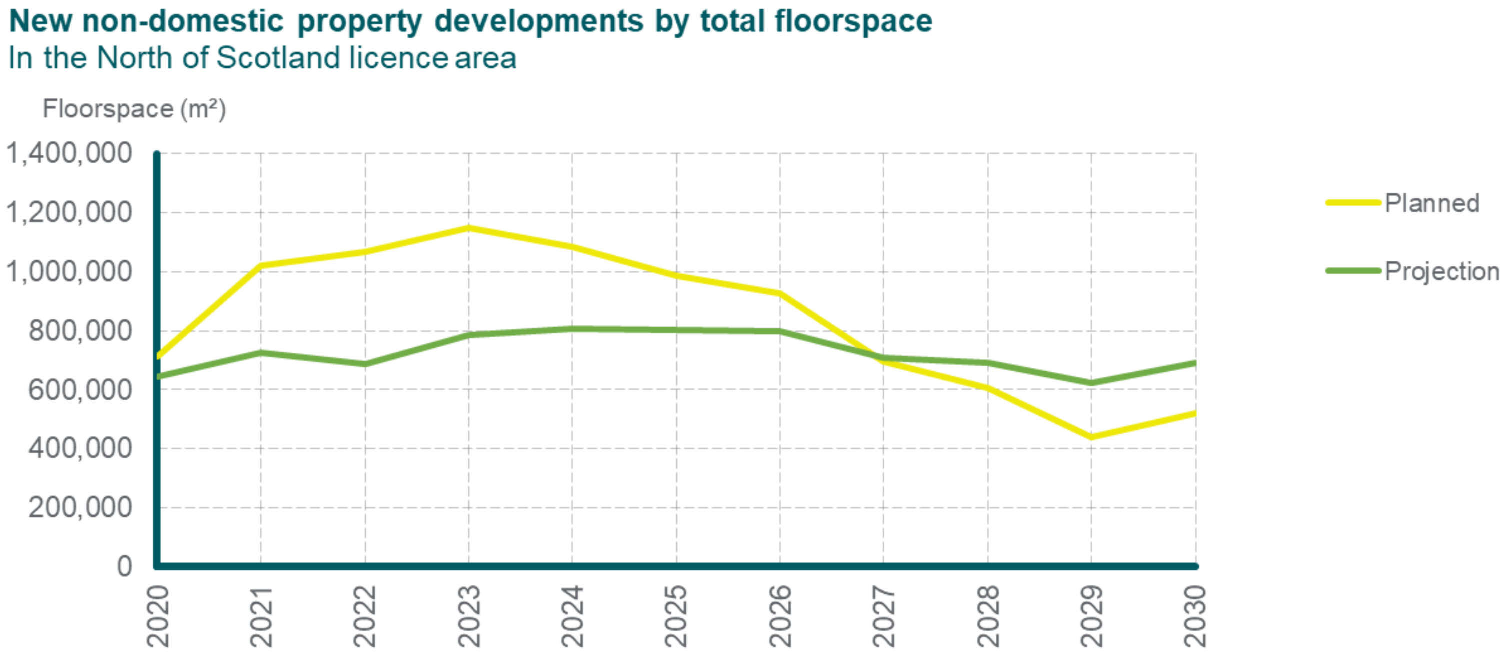


Figure 49 – Aggregated non-domestic commercial and industrial properties over whole licence area



Summary of Assumptions:

- Non-strategic developments make up 4% of the total homes built.
    - Previous new developments studies undertaken by Regen across multiple regions and licence areas suggest that approximately 4% of planned new homes are in developments of fewer than 20 homes.
- The delay profile applied to the planned developments is detailed in the following table, where the delayed developments are spread over subsequent years;

Property type	2020	2021	2022	2023	2024	2025	2026	2027 onwards
Domestic	10%	20%	40%	40%	40%	45%	45%	50%
Non-Domestic	10%	30%	40%	40%	40%	40%	40%	40%

- Developments in the near term have full planning permission or have already begun construction, whereas the plans for later developments are less prescriptive. The likeliness of delay therefore increases further in later years.
- The delayed housing developments are spread in increments of 5% over the subsequent years. For example, of the planned new houses in 2020, 5% are delayed to 2021 and 5% are delayed to 2022.
- The delayed commercial/industrial properties are spread in increments of 2% and 3% for the first two years respectively and 5% thereafter.

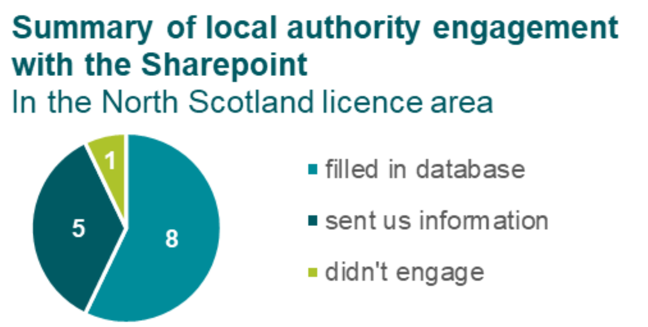
- Where a build plan is not provided one is extrapolated based on a maximum build rate of 20,000 m^2 of floorspace a year and the development stage, i.e. those with full planning permission were scheduled to start in the next 5 years and those with outline permission were scheduled to start after 6 years.
- If the floorspace was not provided it was estimated from the site area based on the category type (office, factory or retail etc.)
    - For example, previous new development studies undertaken by Regen across multiple regions and licence areas suggest that the floorspace to site area ratio can be approximated as 4 for offices and retail, and 3 for factories.
- The historic average is taken from the years 2001-2019 from an aggregation of the local authorities in the licence area[1]. Where local authorities are partially in the licence area, a fraction proportional to the area within the licence area is taken.

Local authority engagement overview:

A previous study of the licence area undertook detailed data collection from local authorities. For this study, it was opted to refresh the data, by sharing it with the authorities using a Sharepoint, which over half the local authorities successfully updated themselves. This process significantly reduced the data processing time.

Only one local authority, Stirling Council, did not engage. See the appendix at the end of this section for a specific record of local authority engagement.

Figure 50 – Local authority data exchange engagement



Appendix: Record of local authority engagement with Sharepoint

LA name	Notification for domestic data change in Sharepoint	Notification for non-domestic data change in Sharepoint	Any evidence of engagement?
Aberdeen City	Y	Y	Y
Aberdeenshire	Y	Y	Y
Angus			Y
Argyll and Bute	Y		Y
Dundee City	Y	Y	Y
Highland	Y	Y	Y
Moray			Y
Na h-Eileanan Siar	Y	Y	Y
North Ayrshire			Y
Orkney Islands	Y		Y
Perth and Kinross	Y	Y	Y
Shetland Islands			Y
Stirling			
West Dunbartonshire			Y

References:

SSEN new developments sharepoint data exchange with local authorities

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[i] See Scottish Government Housing Statistics by licence area: https://www.gov.scot/publications/housing-statistics-for-scotland-new-house-building/
[ii] See National Records of Scotland Household Projections for Scotland, principal projection: https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/households/household-projections/2018-based-household-projections/list-of-data-tables
[iii] See MHCLG Housing supply indicators January to June 2020: https://www.gov.uk/government/statistics/housing-supply-indicators-of-new-supply-england-january-to-june-2020

19. Domestic air conditioning in the North of Scotland licence area

Summary of modelling assumptions and results.

Technology specification:

The analysis covers domestic air conditioning (AC) units in the North of Scotland licence area.

The National Grid FES 2020 does not give a projection for the number of installations or the total capacity (MW) of domestic AC units. However, the FES 2020 does give a projection for residential AC consumption and some usage assumptions from which the number of units can be derived.

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

Total number of homes with air conditioning units	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	1,434	1,445	2,951	5,716	16,102	26,010	52,252	105,095
System Transformation		1,445	2,669	4,678	8,562	17,428	26,480	48,200
Consumer Transformation		1,445	2,668	4,676	8,547	17,397	26,352	47,971
Leading the Way		1,445	1,487	1,522	1,562	1,602	1,642	1,682

Overview of technology projections in the licence area:

- The baseline of existing domestic AC units has been based on an assumption that nationally, c.1% of homes on average across GB currently have AC units[liii]. These AC units are likely to mostly be in flats and apartment buildings. With both a lower population density (including less multi-occupancy buildings) and a colder climate in North Scotland, (resulting in fewer degree-days above 18.5°C that would require cooling) this national average figure has been reduced to 0.2% of homes in the North of Scotland licence area with an AC unit. As a very rough assumption, this equates to just over 1,400 AC units in the baseline year.
- Based on the National Grid FES 2020 residential energy consumption datasets, domestic AC unit capacity (kW) and assumptions around operating hours, the DFES analysis has projected a significant range of results for AC deployment across the scenarios by 2050:
    - The highest number is seen in **Steady Progression**, with just over 105,000 units (c.12% of all homes in the licence area).
    - The lowest number is seen in **Leading the Way**, with just under 1,700 units (c.0.2% of all homes in the licence area).

Methodology and assumptions:

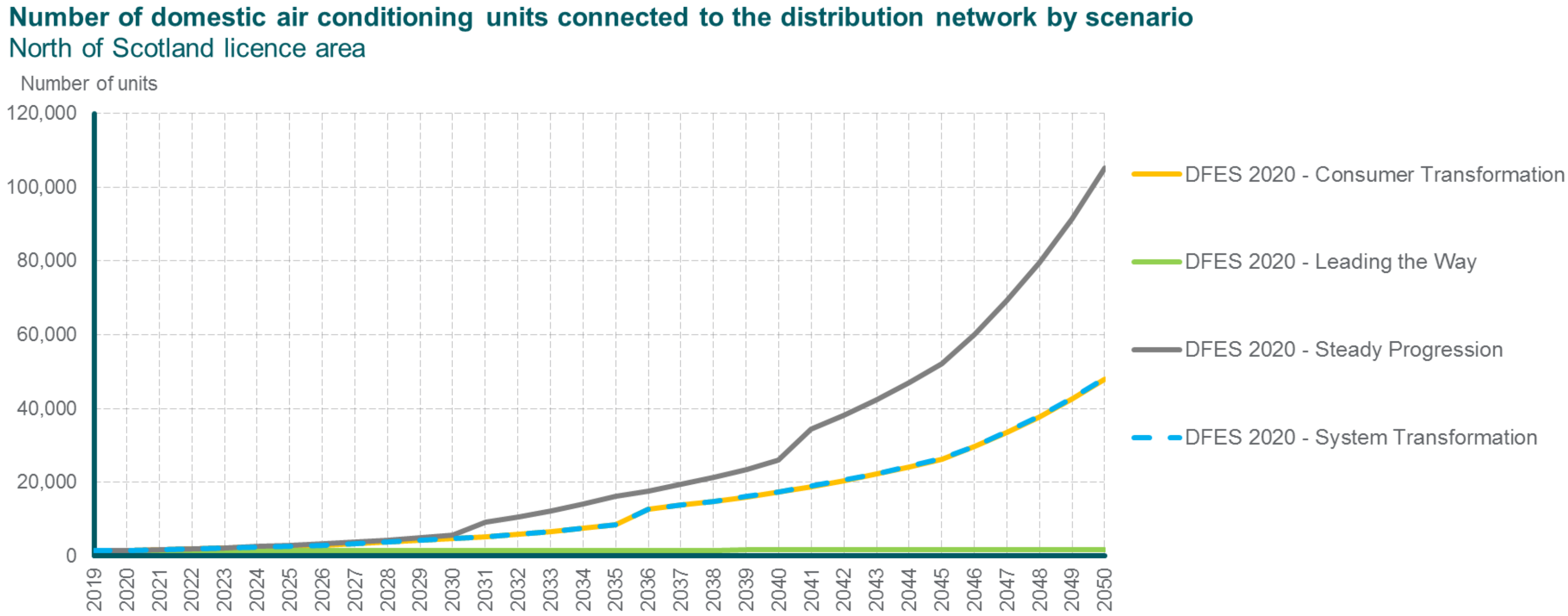
- There is no absolute projection of the number of domestic AC units in the National Grid FES 2020 data workbook. Therefore, the following data sources were used to determine the DFES projections out to 2050 in the licence area.
    - The FES 2020 scenario projections for total GB annual energy consumption (GWh) from domestic AC out to 2050
    - The FES 2020 assumptions around domestic AC unit load (stated to be 2.7kW, undiversified) and annual operating hours
    - A total count of GB domestic properties out to 2050, based upon a summation of FES 2020 domestic heating technology projections
- After an inflation was applied to the number of operating hours out to 2050 (reflecting higher temperatures across GB by 2050), the FES 2020 data was combined to provide a set of national GB figures for the percentage of homes with AC units, under each scenario, out to 2050:

Percentage of GB homes with domestic air conditioning units	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	1%	1%	2%	4%	7%	12%	19%	38%
System Transformation		1%	2%	3%	5%	8%	12%	21%
Consumer Transformation		1%	2%	3%	5%	8%	12%	21%
Leading the Way		1%	1%	1%	1%	1%	1%	1%

- Analysis was then undertaken of the population density[liv] (as a proxy for multi-occupancy buildings) and cooling degree-days in the North of Scotland licence[lv] area. This analysis showed:
    - The licence area has a very low proportion of UK population overall (c.2.3%) and is the licence area with the lowest percentage of population density that is greater than 100 people per hectare.
    - The licence area was the region with generally the fewest degree-days above 18.5°C that would require cooling
- This analysis resulted in applying two dampening factors to the FES 2020 percentage figures for GB homes with domestic AC units, to reflect the low population density and colder climate present in the licence area.
- This resulted in the percentage of homes with AC units to be adjusted to the following:

Percentage of GB homes with domestic air conditioning units	Baseline	2020	2025	2030	2035	2040	2045	2050
Steady Progression	0.2%	0.2%	0.4%	0.8%	2.1%	3.3%	6.5%	12.9%
System Transformation		0.2%	0.4%	0.6%	1.1%	2.2%	3.3%	5.9%
Consumer Transformation		0.2%	0.4%	0.6%	1.1%	2.2%	3.3%	5.9%
Leading the Way		0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%

Figure 51: Domestic air conditioning units in the North of Scotland licence area by scenario



Reconciliation with National Grid FES 2020:

There is no FES 2020 regional data to directly compare the DFES results to. However, the DFES analysis has been based on the FES 2020 scenario projections for total annual energy consumption of GB domestic AC, assumptions around unit capacity (in kW) and operating hours and the total number of domestic properties with any heating technology across GB out to 2050.

Factors that will affect deployment at a local level:

- In the baseline and in the near term, domestic AC is distributed to high density urban areas where heat island effects are more common, as well as homes with high levels of affluence.
- Under **Leading the Way**, where domestic AC uptake is very limited, location remains consistent throughout the timeframe to 2050.
- Under **System Transformation** and **Consumer Transformation**, domestic AC becomes more common in less affluent and less dense areas over time. However, more affluent and denser urban areas still see the majority of domestic AC units installed by 2050.
- Under **Steady Progression**, domestic AC becomes much more common as households react to rising temperatures. While affluence and building density has an impact throughout the scenario to 2050, the impact of these factors reduces over time.

Relevant assumptions from National Grid FES 2020:

Assumption number	3.1.2 Uptake of Residential Air Conditioning (was Summer household temperatures)
Steady Progression	Low willingness to change means society takes the easiest route to maintain comfort levels, therefore increased levels of air con.
System Transformation Consumer Transformation	Medium air con as society takes a mix of actions to maintain comfort levels (mix of air con, tolerance of higher temperatures, changes to building design).
Leading the Way	Low air con as society changes to minimise uptake (e.g. personal tolerance of higher temperatures, changes to building design)

References:

National Grid FES 2020 data workbook, UK Census data, Stark degree-days data.

[liii] See National Grid FES 2020 Data workbook, ED2 worksheet Data Item for Residential Air Conditioning: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents
[liv] Based on analysis census data: https://www.nomisweb.co.uk/census/2011/qs102uk
[lv] Sourced from 'Degree Days for Free' datasets provided by Stark: https://poweredby.stark.co.uk/SEO/SEO.aspx