SPT RIIO T2 Planning Scenarios
2019 Update

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Contact

Luke Humphry (Luke.Humphry@baringa.com +44 203 853 1676)

James Greenleaf (james.greenleaf@baringa.com +44 203 327 4220)

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1 Introduction

1.1 Background

SP Energy Networks (SPEN) is preparing its investment plans for the SP Transmission (SPT) network in advance of the upcoming RIIO-T2 price control period, with support from Baringa Partners, supported by Element Energy.

In 2018 Baringa and Element prepared planning scenarios for the SPT area, based on the National Grid (NG) 2018 Future Energy Scenarios (FES). SPEN have used the 2018 FES based scenarios as the basis for much of their RIIO-T2 investment planning. However, recognising that industry expectations for supply and demand have continued to evolve over the last 12 months, SPEN have engaged Baringa and Element to update the SPT area scenario analysis with the 2019 FES (published July 2019), to understand the changes that arise from these most recent assumptions.

1.2 Purpose of this report

This short report documents the methodology and results coming from our analysis using the 2019 FES. The aim of this report is to outline key differences in methodology, input assumptions, and results between the 2019 scenarios and 2018 scenarios. In many cases the differences are very minor, in which case we have stated so explicitly. Where there are significant differences we have given more detail.

1.3 Structure of this report

The structure of this report matches that of the 2018 scenarios report ("SPT RIIO T2 Planning Scenarios") to allow for easy cross referencing between the reports. In brief, the structure is as follows:

- Section 2 describes the core principles associated with the scenario methodology followed by a detailed description of the methodology for developing the evolution of:
  - Demand
  - Distribution-level supply
  - Transmission-level supply
  - Integration of supply and demand and consideration of flexibility requirements
- Section 3 provides the scenario results based on the 2019 FES data including results for:
  - Demand
  - Distribution-level supply
  - Net GSP supply/demand positions at Winter Peak and Summer Minimum (AM)
  - Transmission-level supply
  - Implications for system flexibility

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The report is accompanied by a supporting Excel results workbook. This contains the full breakdown of results for each scenario, supply/demand element, by year and GSP (where relevant).

2 Scenario development methodology

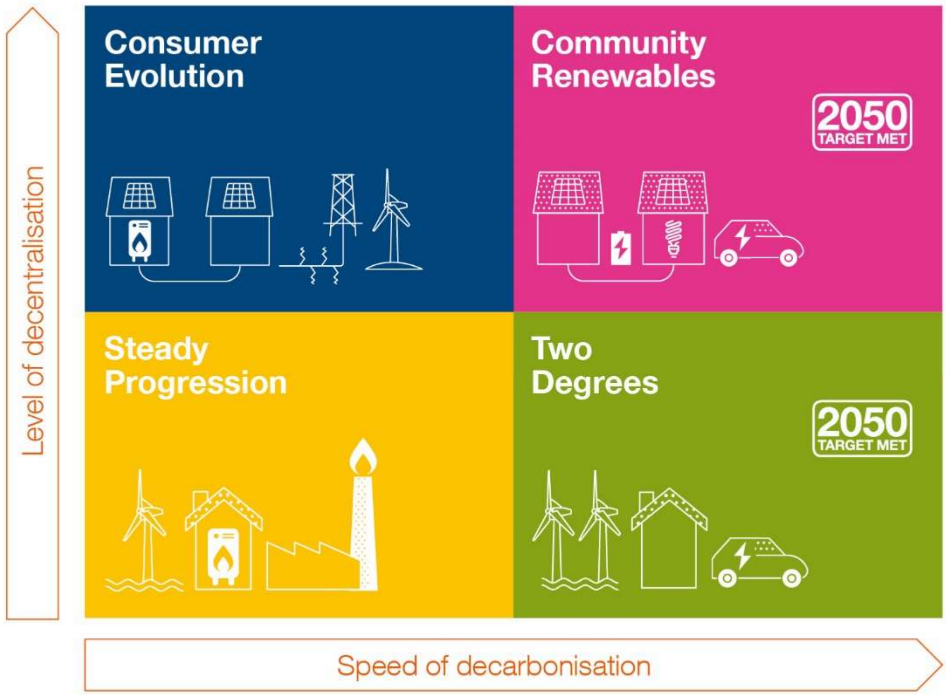
2.1 High level principles

In this 2019 update we have followed a very similar approach to that used in 2018, adhering to the same high level principles, and therefore only adapting the approach where the FES data required.

2.1.1 Use of FES

For this 2019 update we have used the National Grid Electricity System Operator (NG ESO) 2019 Future Energy Scenarios[1]. The scenarios for 2019 are the same as for 2018, as shown in Figure 1.

Figure 1 Future Energy Scenarios 2019[2]



The key difference between the assumptions used for the scenarios in 2019 (vs 2018) are given below, for GB as a whole:

Steady Progression (SP)

- Higher hydrogen supply with roll-out of blended hydrogen into the gas network.
- Increased offshore wind capacity and decreased nuclear capacity, as well as lower thermal efficiency is common across all scenarios

[1] http://fes.nationalgrid.com/

[2] Image reproduced with permission of National Grid

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Consumer Evolution (CE)

- Now the lowest peak and annual electricity demand scenario
- No small modular nuclear reactors
- Increased offshore wind capacity and decreased nuclear capacity, as well as lower thermal efficiency is common across all scenarios

Two Degrees (TD)

- Now the highest peak and annual electricity demand scenario
- Higher hydrogen demand for heat and commercial transport and hydrogen from electrolysis introduced
- Small modular nuclear reactors introduced
- Increased offshore wind capacity and decreased nuclear capacity, as well as lower thermal efficiency is common across all scenarios

Community Renewables (CR)

- Larger role for district heat and hybrid heat pumps
- Earlier growth in electricity storage capacity
- Reduced solar capacity
- Increased offshore wind capacity and decreased nuclear capacity, as well as lower thermal efficiency is common across all scenarios

2.1.2 Macro Assumptions

The NG FES 2019 include several macro assumptions that influence the scenarios. In the main these have been left unchanged when developing scenarios for the SPT area. The key assumptions in terms of driving changes supply and demand that have been inherited from the NG FES are:

- **Population Growth:** In the 2019 FES a population growth from 64.7 million in 2018 to 70.7 million in 2050 is assumed across all scenarios.
  - Little change from FES 2018
- **Energy efficiency:** In the 2019 FES efficiency improvements are lower than in the 2018 FES, reflecting a lack of clear policy in this area, notably thermal efficiency of buildings. There is more variation between scenarios (previously CR and TD had high efficiency improvements, and CE and SP had low improvements), with a CR seeing highest improvements, TD high, CE medium and SP low.
  - Lower overall efficiency improvements and more variation between scenarios than in FES 2018

- **Economic Outlook:** I&C demand in the FES 2019 is modelled assuming Gross Domestic Product (GDP) grows at a rate of 1.9% for the high growth scenarios (CR and TD) and 0.9% for the low growth scenarios (CE and SP).
  - Little change from FES 2018
- **EV population:** The EV uptake in the FES is influenced by the UK government's target for nearly all new cars and vans sold by 2040 to be zero emission[3]. Two of the FES scenarios (CR and TD) comply with this target and show strong EV uptake (meeting the Scottish Government target of 100% of vehicles sales to be EVs by 2032), for the other two scenarios uptake is lower, but EVs are still expected to become dominant after 2040.
  - Little change from FES 2018.
- **Supply technology load factors:** The FES uses load factor assumptions for the expected output of supply and storage technologies at different times of the year. These assumptions are based on observed output from recent years, and are selected to reflect stress on the system at periods of peak and minimum net demand.
  - Little change from FES 2018

In developing the SP FES the following additional high level assumptions have been made:

- **Grid Supply Points:** The SP FES 2019 use the same GSP sites as the FES 2018, without assuming any splitting or new GSP sites.
  - No change from FES 2018
- **Network constraints not a barrier to change:** Changes in supply and demand technologies have been applied without consideration of current or future network constraints.
  - No change from FES 2018

2.1.3 Stakeholder engagement

Following the publication of the previous scenarios for 2018, feedback was provided by a number of stakeholders through the formal consultation process that SPT undertook as well as through various bilateral meetings.

The table below lists the key comments received and how SPT have responded to these.

Stakeholder feedback	How SPT have reflected this
Strong support for the use of scenarios and the FES as the basis for informing SPT business plan on some of the key changes going forward	SPT have continued to use the FES for this refresh and the overall structure is consistent with the previous approach. This approach helps to ensure consistency with other industry processes which also rely on this data and ensures a consistent approach.

[3] https://www.gov.uk/government/news/plan-for-roadside-no2-concentrations-published

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Small scale gas turbines are likely to play a greater role in the future network but are not considered in the FES	Small scale gas turbines are included in the scenarios as controllable distributed generation. SPT will continue to monitor this with SGN as the gas network operator in Scotland to ensure consistency and effective whole system planning.
Levels of solar generation may be substantially higher than the FES	SPT have maintained projections to be consistent with the FES but modelled the potential impact of greater volumes of solar generation on the network. SPT are confident the mechanisms they have will allow them to flex their plans to accommodate this should it happen. SPT have also incorporated a number of GSP upgrades at sites which are currently constrained. Over the course of RIIO-T2, SPT will continue to work closely with SP Distribution to ensure the transmission network can cater for any changes which are beyond SPT current projections.
The scenarios did not consider economic factors which may impact the future pathways	Assumptions are made on the future economic trends as part of the FES which SPT have maintained in their analysis. Some of the changes which will be required will depend on policy and economic factors but SPT have not sought to take a view on these to reduce the number of variables.
It is not reasonable to select a single scenario due to the level of uncertainty and the plans should consider how they can adapt to the different scenarios	SPT have continued to use all four scenarios to test their plans that they can adapt to different outcomes. The Energy Networks Association have developed a common scenario for RIIO-T2 which SPT have reflected in their business plan.
Support for the assumptions relating to flexibility of demand	The FES has updated its assumptions for flexible demand following further research and SPT have incorporated this into their analysis. These changes include assumptions behind the size of vehicle batteries, the charging pattern of electric vehicles and other elements of demand response from both domestic and industrial and commercial customers.
The scenarios did not consider the changes required for black start resiliency, system security or staff.	SPT have considered these separately in their business plan as changes they need to make as a consequence of the different scenarios rather than input variables to the scenarios.

2.1.4 Technologies considered

We have considered the same supply and demand technologies as for the SPT FES 2018, described in the 2018 report (“SPT RIIO T2 Planning Scenarios”) and shown in Figure 2.

Figure 2 Technologies considered

Demand and behind the meter supply	Distribution connected supply	Transmission connected supply
• Domestic • Industrial and Commercial (I&C) • Heat Pumps (Domestic) • District Heating (large scale heat pumps) • Electric Vehicles • Vehicle-to-grid • Behind the meter PV • Home battery storage	• Wind • PV • Hydro • CHP - Renewable - Non-Renewable • Controllable - Renewable - Non-Renewable • Storage	• All likely technologies considered

2.2 Overview of SPT’s licence area and GSPs

We have used the same definition of grid supply points (GSPs) to represent the SPT area as used for the 2018 analysis.

2.3 Demand and behind the meter supply

2.3.1 Introduction

In the 2019 analysis we have broadly used the same methodology and data sources as for the 2018 analysis. Where updates to the approach have been made, they are briefly described in the following.

2.3.2 FES data availability

The 2019 FES data was made available in the same format as the 2018 FES data, at GSP level. We have used the same sources of additional data to supplement the FES data, and the same mapping tool to convert data at local authority (LA) level to GSP level (this mapping tool is described in the 2018 SPT FES report).

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To ensure we are working with the best data, we have updated the mapping tool with the latest version of the postcode level domestic electricity consumption data[4] as well as with the latest Department for Transport (DfT)[5] and Feed-in Tariff[6] (FiT) data.

2.3.3 Domestic demand

In the 2019 FES a new approach was used by NG to determine the underlying demand at GSP level based on SPD's estimation of distributed generation as presented in the Week 24 data. While this approach is reasonable, it causes inconsistencies between the 2018 and 2019 analysis which do not reflect real changing conditions (for example, FES summer minimum demand in 2018 for SPD area goes up by ~150MW, where SPEN data shows a small reduction in demand from 2017 to 2018 outturn). We have therefore decided to stick to the original FES approach for this study and rescaled the domestic and I&C demand to match the 2018 levels from the 2018 analysis.

Furthermore, it is worth noting that the non-residential EV demand was no longer included in the commercial demand in the 2019 FES, and therefore no longer had to be removed before calculating the domestic demand.

2.3.4 I&C demand

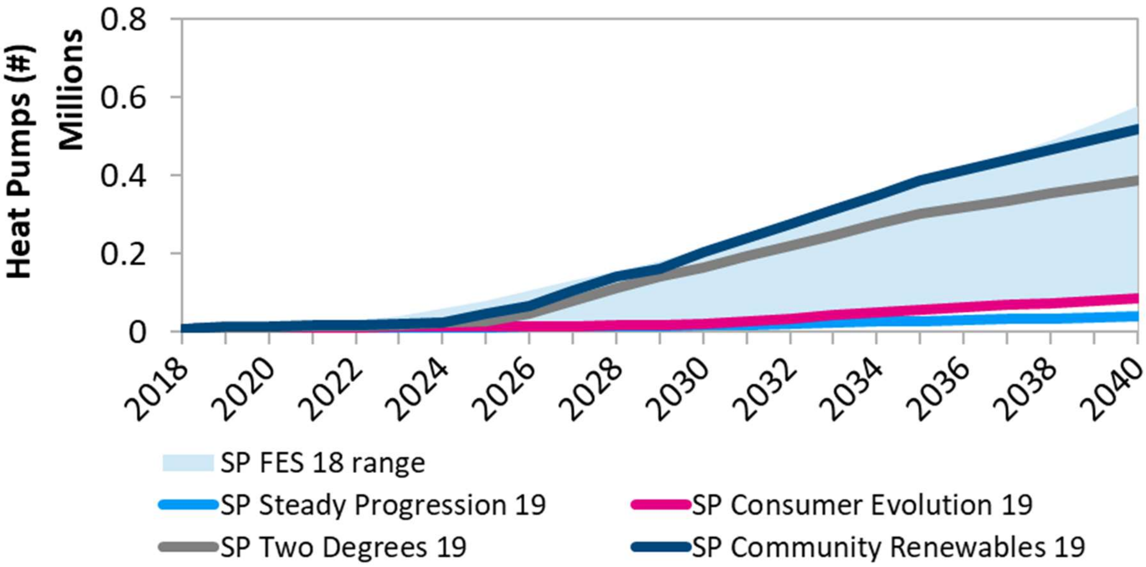
As mentioned above, the I&C demand was rescaled to match the 2018 value from the 2018 FES analysis. Furthermore, the non-residential EV demand did not have to be subtracted from the I&C demand, so the model was adjusted accordingly.

2.3.5 Heat Pumps

The approach used for the uptake of heat pumps has not changed, and the range in uptake is comparable to last year, as shows in Figure 3. It is worth noting that there is a larger spread between the low- and high decarbonisation scenarios in the 2019 FES.

[4] https://www.gov.uk/government/collections/sub-national-electricity-consumption-data#postcode-level-data: Postcode level electricity statistics: 2017 (experimental)
[5] https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01
[6] https://www.gov.uk/government/collections/feed-in-tariff-statistics

Figure 3 SPT uptake of Heat Pumps



The approach used for the spatial allocation of heat pumps has changed somewhat as compared to the 2018 analysis, based on the Committee on Climate Change's (CCC)[7] recommendation that from 2025 onwards no new homes should be connected to the gas grid.

In the 2018 analysis heat pumps were allocated to GSPs based on their off-gas percentage and their new-build rate, applying equal weights (50%) to both parameters. In the 2019 analysis the weighting applied to the new build rate has been increased to 67%. As a result, the uptake of heat pumps now generally favours urban GSPs over rural GSPs.

2.3.6 District Heating

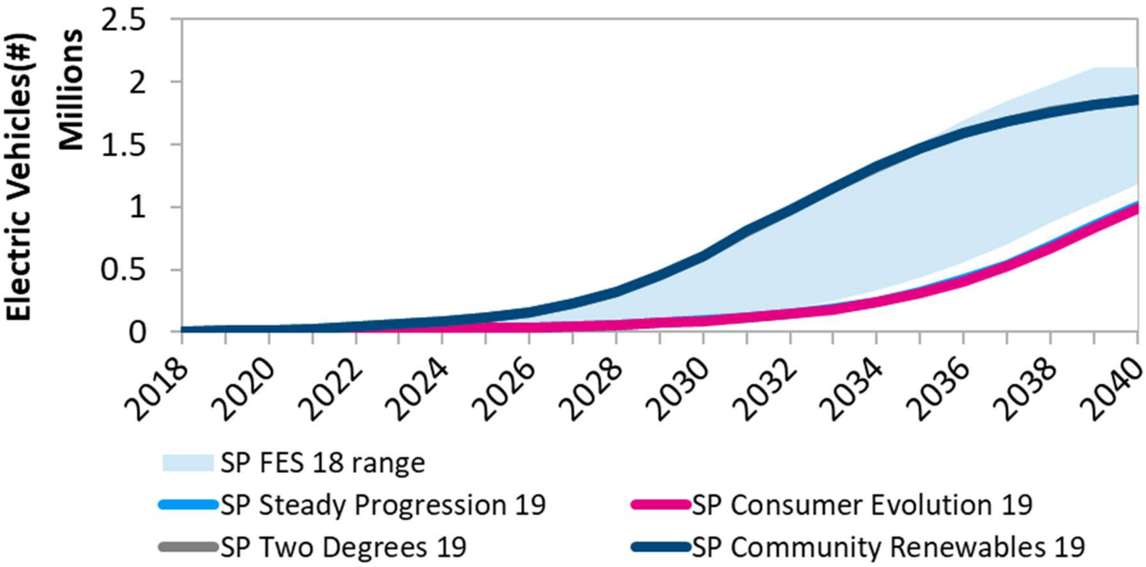
There has been no change in the approach used for the 2018 analysis.

2.3.7 Electric Vehicles

No changes have been made to our approach used for the 2018 analysis, but several changes have been made to the FES 2019 regarding EVs, which affect our analysis. The number of EVs is very similar to that in the 2018 FES (see Figure 4) but large changes have been made to the assumed charging profiles and the locations of charging.

[7] https://www.theccc.org.uk/wp-content/uploads/2019/02/UK-housing-Fit-for-the-future-CCC-2019.pdf

Figure 4 SPT uptake of Electric Vehicles



The updated charging profiles (as shown in Appendix A) indicate that the network peak demand does not overlap with the EV peak demand, and therefore the demand per vehicle at peak time has reduced by approximately 50%. This has a large impact on the total EV demand per scenario produced by our model.

The changed assumptions regarding the split between charging location types (i.e. residential and non-residential charging) across the different scenarios has affected our outputs in two ways. Firstly, charging at the different location types causes peaks at different times of the day, which has changed the EV peak demand across the scenarios. Secondly, as flexible charging is only deemed suitable for residential charging, the scenarios with higher shares of non-residential charging exhibit a smaller flexible EV load.

For the spatial allocation of EVs to GSPs a new methodology was trialled in the 2019 NG FES based on a nearest-neighbour approach. However, the resulting EV clusters were found to be unrealistically strong at a GSP level, and therefore we have used our own mapping of EVs for the initial year GSP allocation. Our mapping is based on Department for Transport (DfT)[8] data on the uptake of EVs at LA level, allocated to each GSP as described in Section 2.3.2 in the 2018 report. In last year's analysis, our mapping of EVs provided very similar values as the 2018 FES, which means that by using our values the 2019 methodology has effectively remained unchanged to the 2018 SP FES.

2.3.8 Vehicle-to-grid

There has been no change in the approach used for the 2018 analysis.

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[8] https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01

2.3.9 Behind the Meter PV

There been no change in the approach used for the 2018 analysis. Noting the historically low levels of BtM PV in the SPT region when compared with the GB average, consideration was given to increasing the capacity of BtM PV compared with the NG FES (which uses a GB wide growth rate). However, given recent removal of the domestic FiT for solar and without a Scotland specific replacement, and also the poorer conditions for solar in the SPT area, we have not altered the previous methodology – and so assume the same growth rate as the rest of GB. This means that the SPT area lags behind the rest of GB in terms of assumed rooftop penetration.

It should be noted that due to the low load factor for BtM PV at winter peak and summer minimum (AM) the impact on the network of changes to the BtM PV capacity is very limited.

2.3.10 Home battery storage

There has been no change in the approach used for the 2018 analysis.

2.3.11 Flexibility

2.3.11.1 Introduction

There has been no change in the approach used for the 2018 analysis, but it should be noted that the FES 2019 has made some changes to the flexibility assumptions.

2.3.11.2 Domestic

In the case of domestic demand, the range across the scenarios has become somewhat smaller, but most importantly the flexibility assumed for the Consumer Evolution scenario is now stronger than for the Two Degrees scenario to reflect the higher level of customer engagement in the Consumer Evolution scenario.

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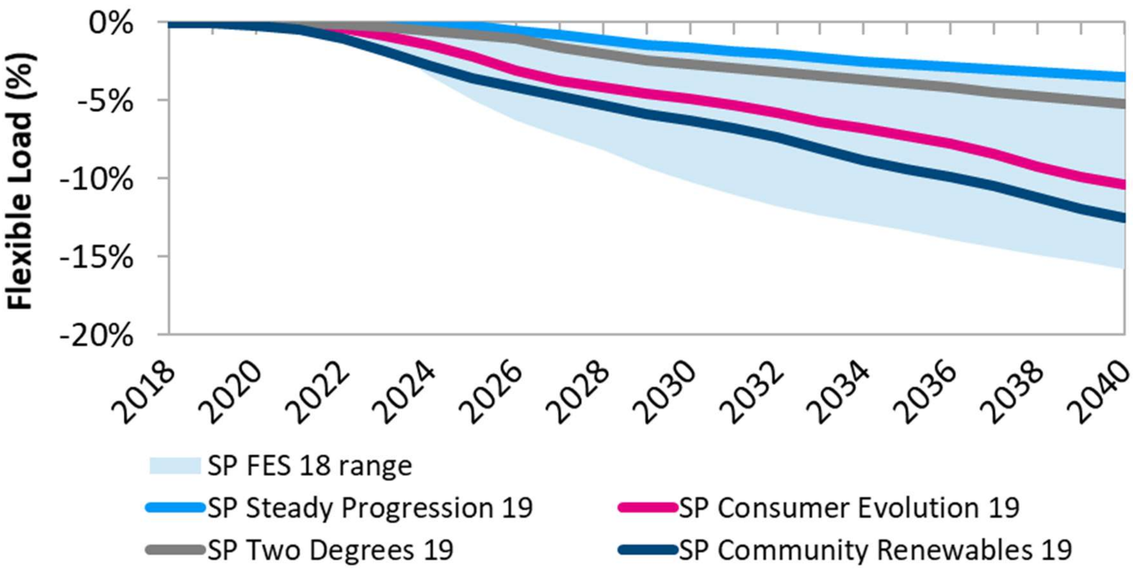
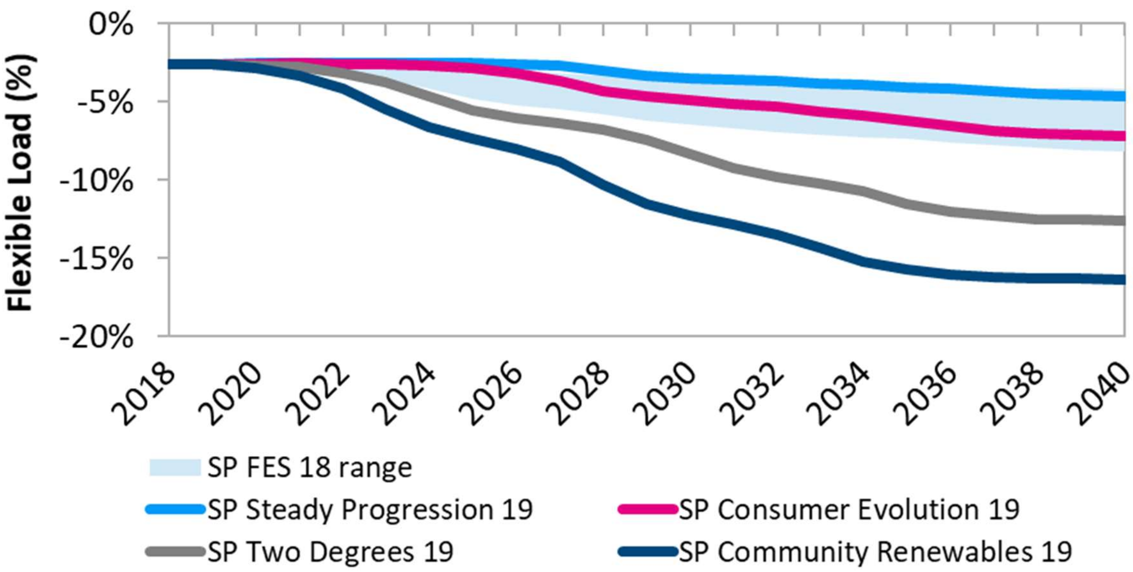
Figure 5 Flexibility of domestic demand



2.3.11.3 I&C

The assumed flexibility of I&C demand has significantly increased in the 2019 FES, in particular for the two high decarbonisation scenarios for which the percentage doubled.

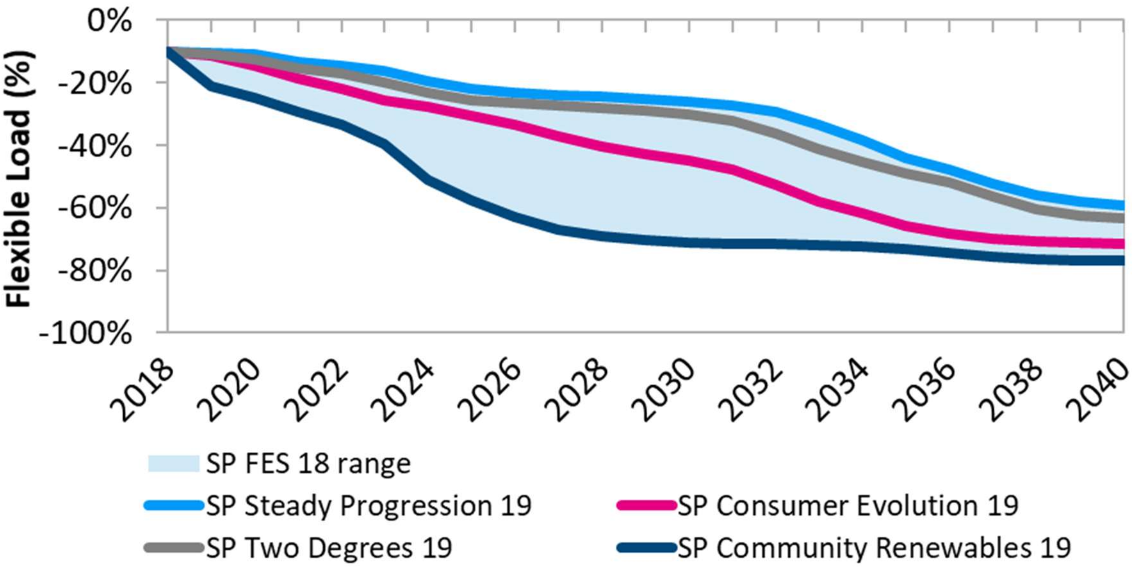
Figure 6 Flexibility of I&C demand



2.3.11.4 Electric Vehicles

The range of EV flexibility assumptions across the scenarios is exactly the same in the 2019 FES as it was in the 2018 FES, but again the flexibility assumed for the Consumer Evolution scenario is now stronger than for the Two Degrees scenario to reflect the higher level of customer engagement in the Consumer Evolution scenario.

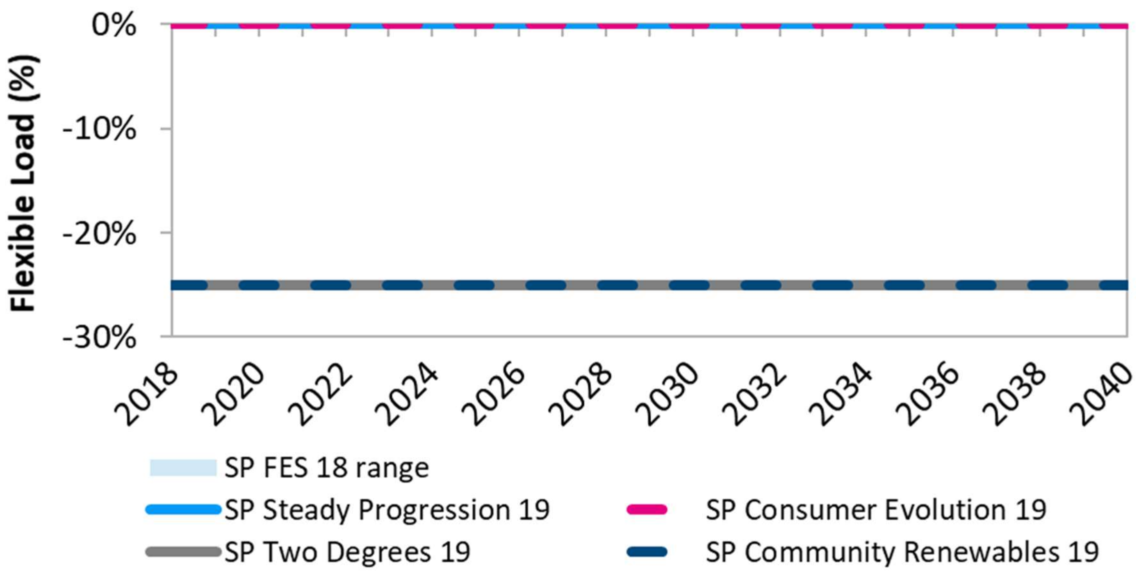
Figure 7 Flexibility of EV demand



2.3.11.5 Heat Pumps

Whereas no flexibility of HP demand was assumed in the 2018 FES, in the 2019 FES it has been assumed that in the two high decarbonisation scenarios 25% of households will have thermal storage which will enable them to avoid 100% of the HP peak demand. This required no change of our methodology but did provide a flexible load which was previously not included.

Figure 8 Flexibility of HP demand



2.3.12 Summary

As the 2019 NG FES was based on the same framework as the 2018 NG FES, only a limited number of methodology changes were required to accommodate the new input data. However, as described above, the changes in the 2019 FES have resulted in significant changes to demand and flexibility, which will be treated in Section 3.2

2.4 Distribution connected supply/storage

2.4.1 Introduction

In the 2019 analysis we have broadly used the same methodology and data sources as for the 2018 analysis. In this section we describe the few distribution connected technologies where changes have been made.

2.4.2 Overall approach

No change to approach used in the 2018 analysis. The starting year has moved forward 1 year, so that year 2018 is considered “current”, 2019 and 2020 are considered “near term”, and 2021-2040 considered “long term”.

2.4.3 Current Capacity

No change to approach used in 2018. For most technologies we have used the FES capacities by GSP for 2018 directly, without alteration. For CHP and Controllable generation technologies we have used SPD primary data for embedded generation on their network, live as of June 2019.

2.4.4 Near Term Capacity

No major change to approach used in 2018. We use SPD's view of high probability projects, live as of June 2019, and compare with actual annual increases in embedded supply/storage capacities 2015-2018.

Using SPD's current view of future connections, and taking the sum of high ranked projects, an annual increase in embedded/storage capacity of 223MW is expected by SPD for the period 2019-2020.

Actual annual increases in embedded generation/storage for the SPT area from 2015 to 2018 range from 52WM/year to 259MW/year, with an average of 135MW/year, as shown in Table 1.

Table 1 Embedded generation/storage growth 2015-2018

	MW/year	Ranking
Actual capacity increase 2015-2016	259	High
Actual capacity increase 2016-2017	52	Low
Actual capacity increase 2017-2018	96	na
Average capacity increase 2015-2018	135	Medium

We have used the same methodology as in the 2018 analysis, varying the total annual growth rate based on the historical min/max/average applied to corresponding scenarios. We have changed the growth ranking of "Two Degrees" to be High growth, based on the growth level in the raw NG FES results, making 2 of the 4 scenarios have near term growth of 259MW/year, close to the level expected by SPD.

Table 2 Assumed near term growth in embedded capacity, 2019-2020

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Scenario	SP Growth Ranking	Rational	SP FES Assumption, MW/year	NG FES 2019 Assumption, MW/year
Community Renewables	High	High decarbonisation	259	83
Two Degrees	High	High decarbonisation	259	87
Steady Progression	Low	Low decarbonisation, Low decentralisation	52	36
Consumer Evolution	Medium	Low decarbonisation, High decentralisation	135	49

New capacity of each type is distributed over GSPs according to SPD's view of likely connecting projects, but with capacities scaled to match the annual increases outlined in Table 2.

2.4.5 Long Term Capacity

No change to approach used in 2018. Relative growth from the FES is applied to the SPT level capacity from 2021-2040.

2.4.6 Total SPT capacity over full horizon

As describe above, no major changes to current, near term and long term approach.

2.4.7 Capacity Siting

No change to approach used in 2018, for each embedded generation and storage technology. No changes to primary data sources.

2.4.8 Load factors

No change to approach used in 2018. We use technology load factors as per the NG FES 2019 GB assumptions, described in Appendix B, Table 5. There are some minor changes to load factors, the key difference being a small reduction in the assumed load factor of wind, as shown in Table 3.

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Table 3 DX wind load factor assumptions

	Winter Peak 2018	Winter Peak 2040	Summer Min (AM) 2018	Summer Min (AM) 2040
FES 2018	25%	25%	47%	47%
FES 2019	23%	23%	39%	39%

2.4.9 GSP net demand and supply

No change to approach used in 2018. Load factor and capacity assumptions are used to calculate supply volumes at Winter Peak and Summer Minimum (AM); by subtracting supply for demand net demand at each GSP can be calculated.

2.4.10 Summary

The methodology for distribution level supply and storage has not significantly changed between our 2018 and 2019 analysis.

2.5 Transmission connected supply/storage

In the 2019 analysis we have used the same methodology and data sources as for the 2018 analysis.

2.5.1 Approach for named sites

No change to approach used in 2018. We have taken the NG FES 2019 assumptions directly, without alteration.

3 Scenario results

3.1 Introduction

In this section we present the key SPT results using the 2019 FES input assumptions. Where we refer to scenarios we use the following scenario names:

Table 4 SPT scenario names, 2018 and 2019 analysis

2018 analysis	2019 analysis
SP Steady Progression	SP Steady Progression 19
SP Consumer Evolution	SP Consumer Evolution 19
SP Two Degrees	SP Two Degrees 19
SP Community Renewables	SP Community Renewables 19

We have a selected only a small subset of the results to show in this report, focussing on where are significant differences with the results from the 2018 analysis. The structure of the results sections is the same as the 2018 scenarios report; where differences between 2018 and 2019 results are minor we have stated so.

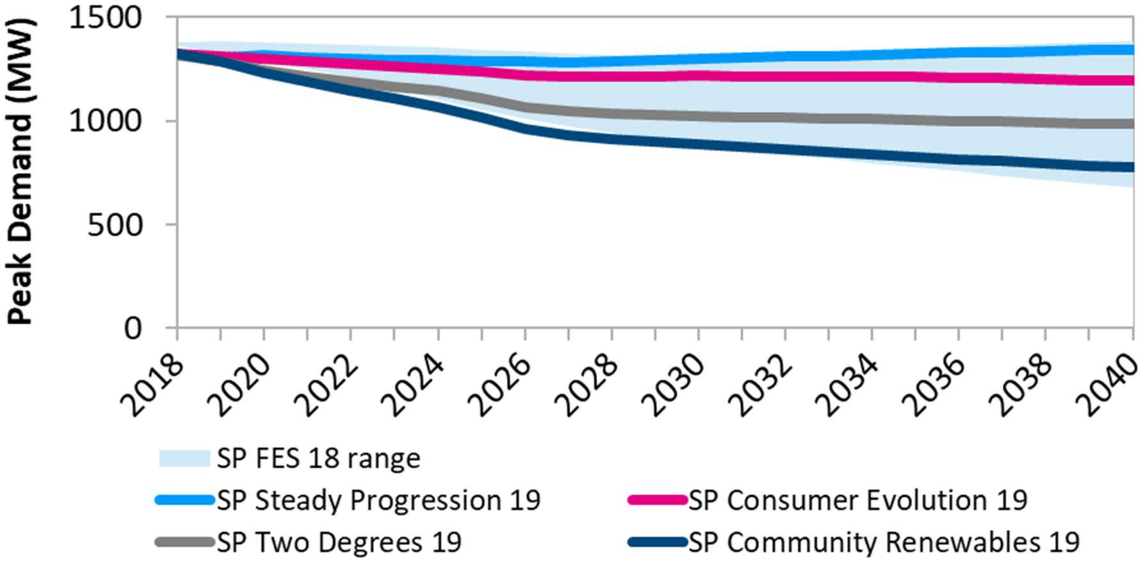
3.2 Demand and behind the meter supply

This section outlines the key differences in results between the 2018 and 2019 analysis, for demand and behind the meter supply.

3.2.1 Domestic demand

As shown in Figure 9 there are no major differences in the results, but it is worth noting that there is less reduction in underlying demand due to less ambitious energy efficiency improvements.

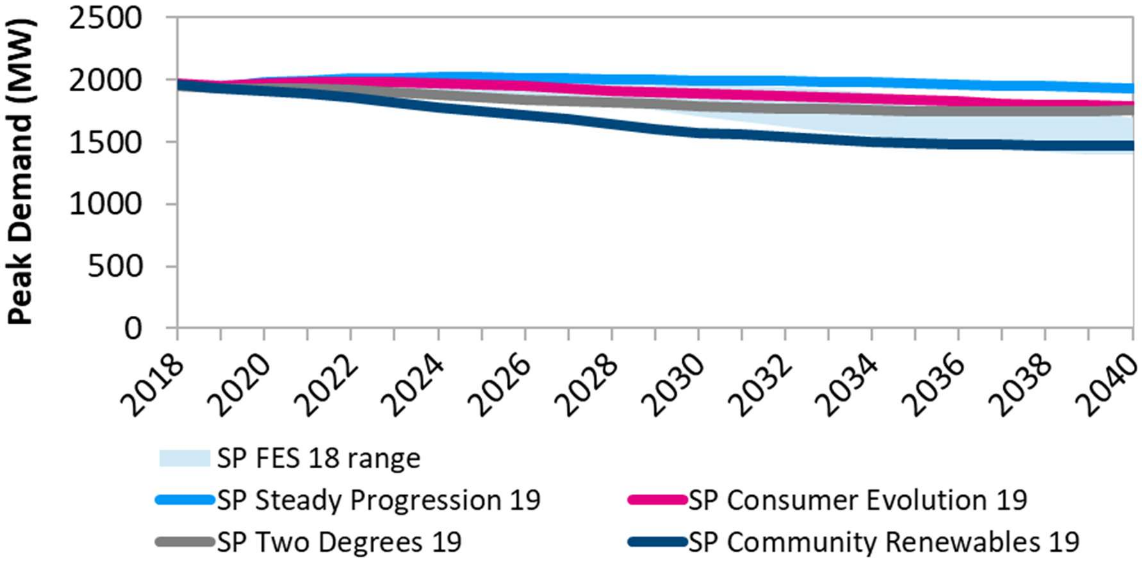
Figure 9 Total SPT underlying domestic demand (excluding HPs, EVs) at winter peak



3.2.2 I&C demand

As shown in Figure 10 there are some differences in the results. Lower energy price forecasts have reduced the incentive to reduce energy consumption, meaning that I&C demand in most scenarios remains constant, as compared to a significant reduction for all scenarios in the 2018 model.

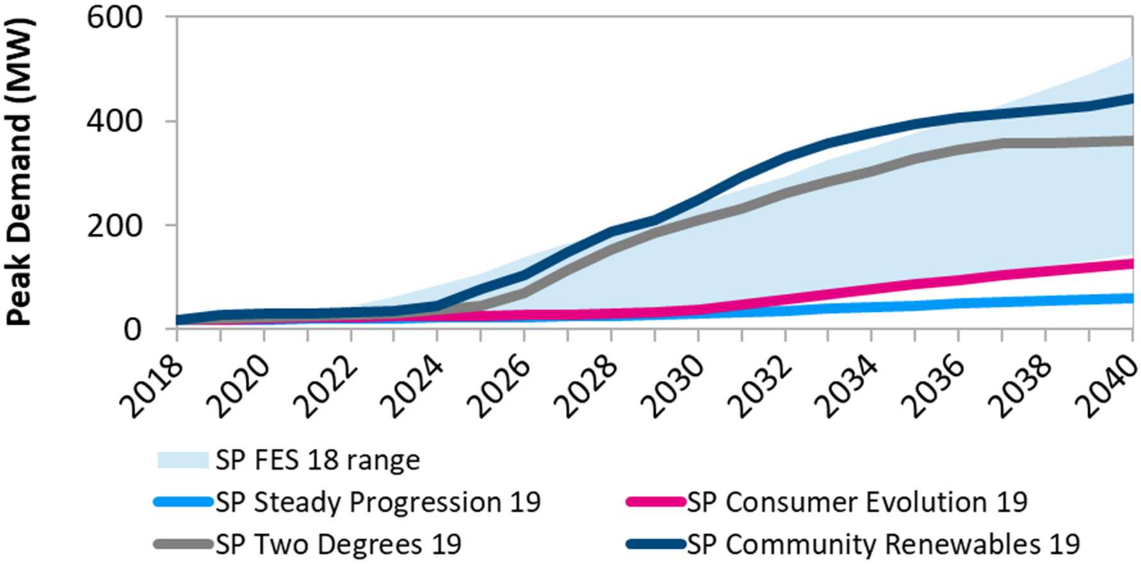
Figure 10 Total SPT underlying I&C demand at winter peak



3.2.3 Heat pumps

As shown in Figure 11 there are no key differences in the results. The range of HP peak demand across the scenarios is similar, with a slightly larger spread across the low and high decarbonisation scenarios.

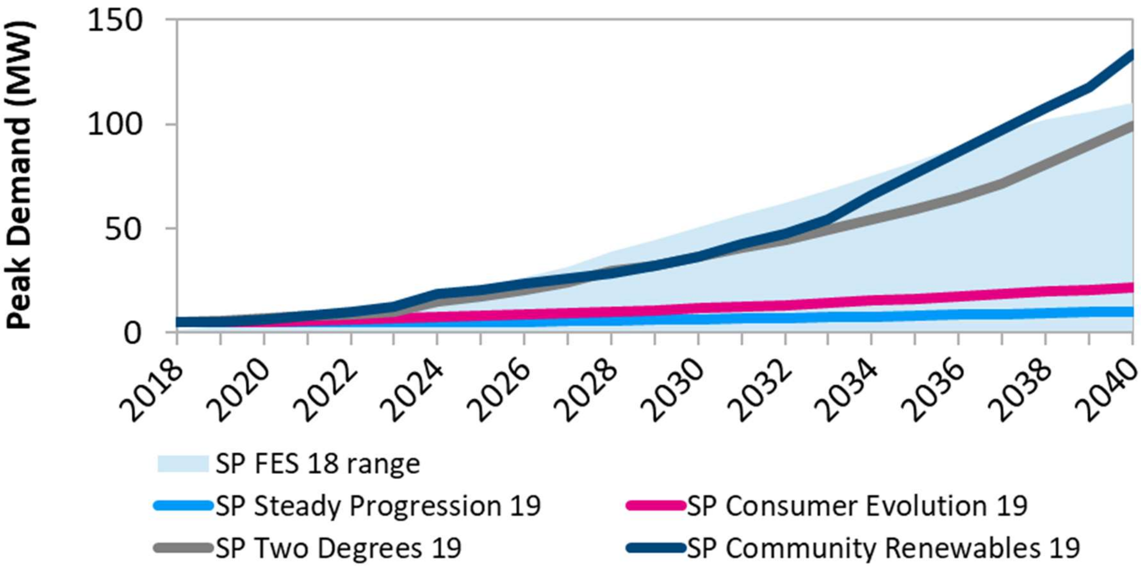
Figure 11 Total SPT underlying HP demand at winter peak



3.2.4 District Heating

As shown in Figure 12 there are no key differences in the results.

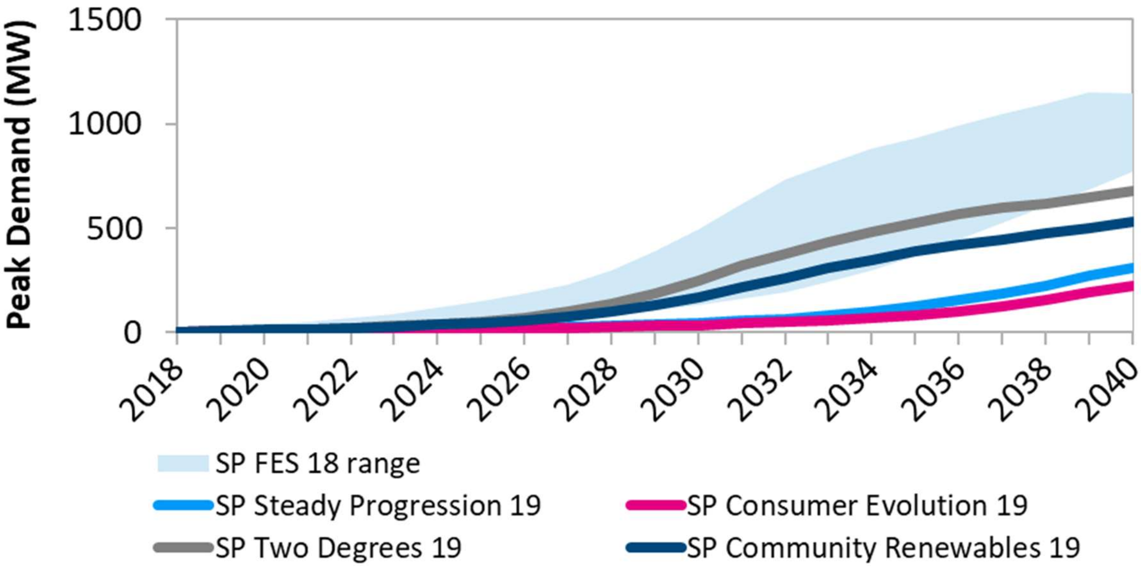
Figure 12 Total SPT DH demand at winter peak



3.2.5 Electric Vehicles

The updated charging profiles and assumptions around locational charging described in Section 2.3.7 had a strong impact on the EV peak demand, as shown in Figure 13.

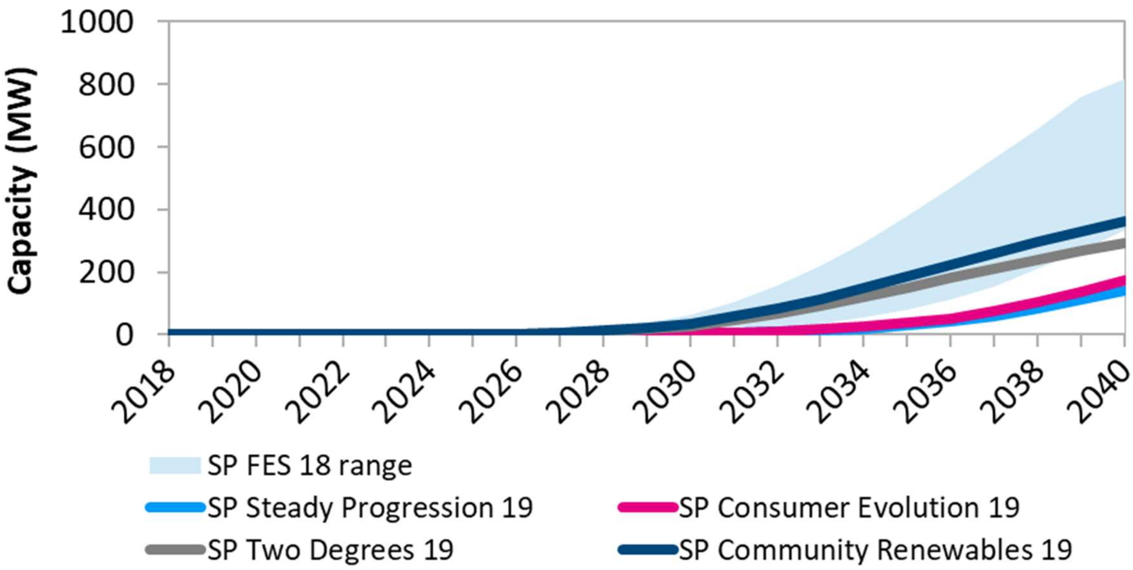
Figure 13 Total SPT underlying EV demand at winter peak



3.2.6 Vehicle-to-Grid

In line with the assumption that less people are plugged in at the time of peak, the V2G capacity in the 2019 FES has been significantly reduced, as shown in Figure 14.

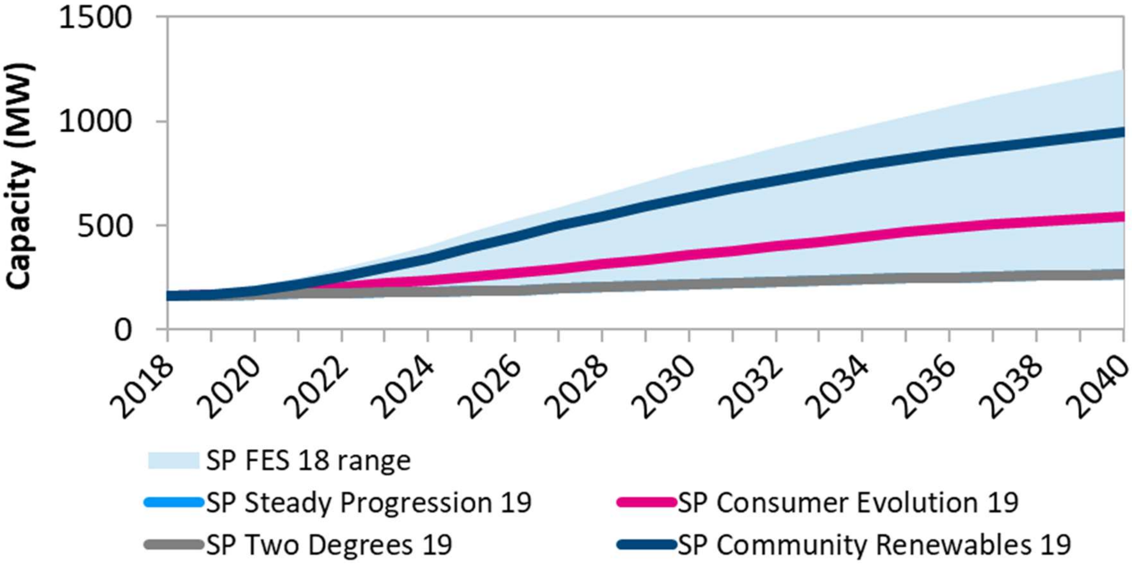
Figure 14 Total SPT V2G capacity



3.2.7 Behind the meter PV

As shown in Figure 15 there are no large differences in the results to 2030, though the high scenario is significantly lower by 2040 than previously projected.

Figure 15 Total SPT behind the meter PV capacity



3.2.8 Domestic Battery Storage

As shown in Figure 16 the range across the scenarios is similar to last year, although there is one significant difference between the results. Whereas the Consumer Evolution scenario had an uptake similar to the Community Renewables scenarios in the 2018 FES, it has now been assumed to have negligible uptake.

It should also be noted in the Community Renewables scenario the uptake of behind the meter storage capacity is no longer expected to decelerate as much after 2036 which results in a significant increase in capacity at 2040.

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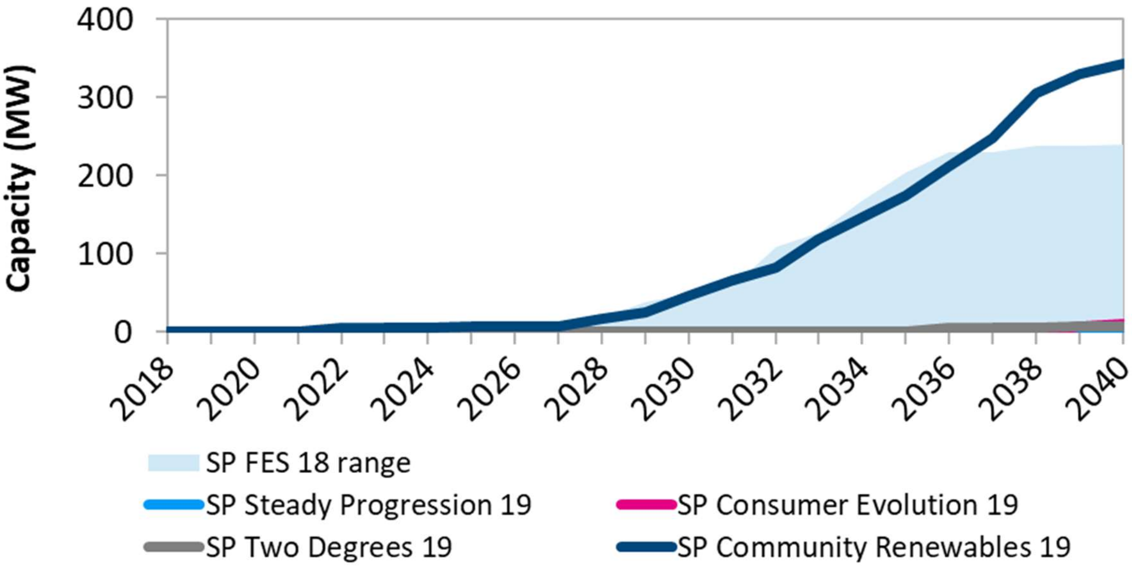
Figure 16 Total SPT behind the meter storage capacity

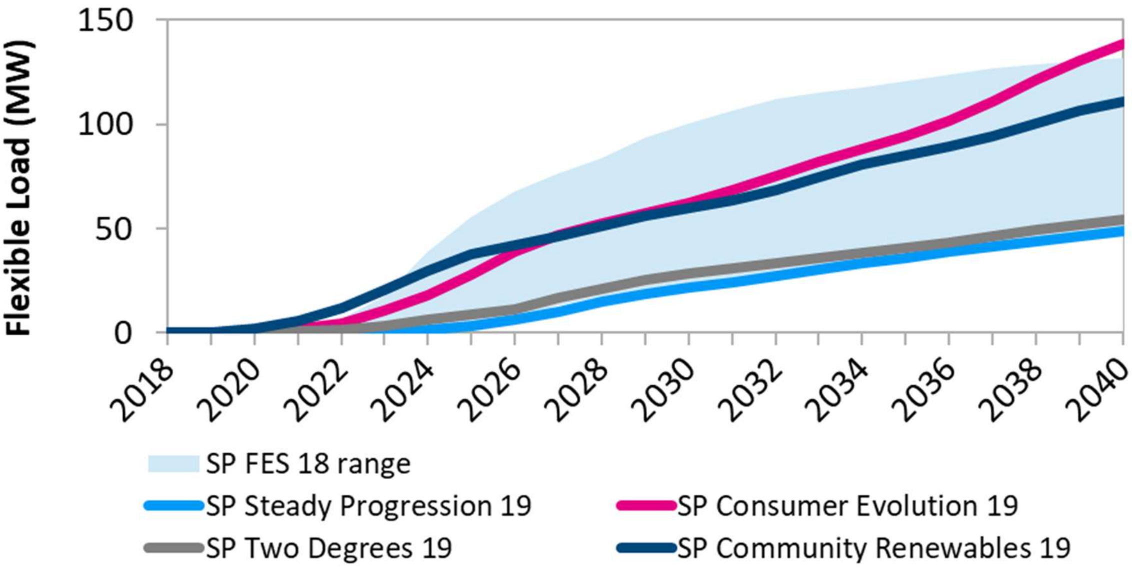


3.2.9 Flexibility

3.2.9.1 Domestic

As shown in Figure 17 there is not a significant difference in the results through the T-2 period.

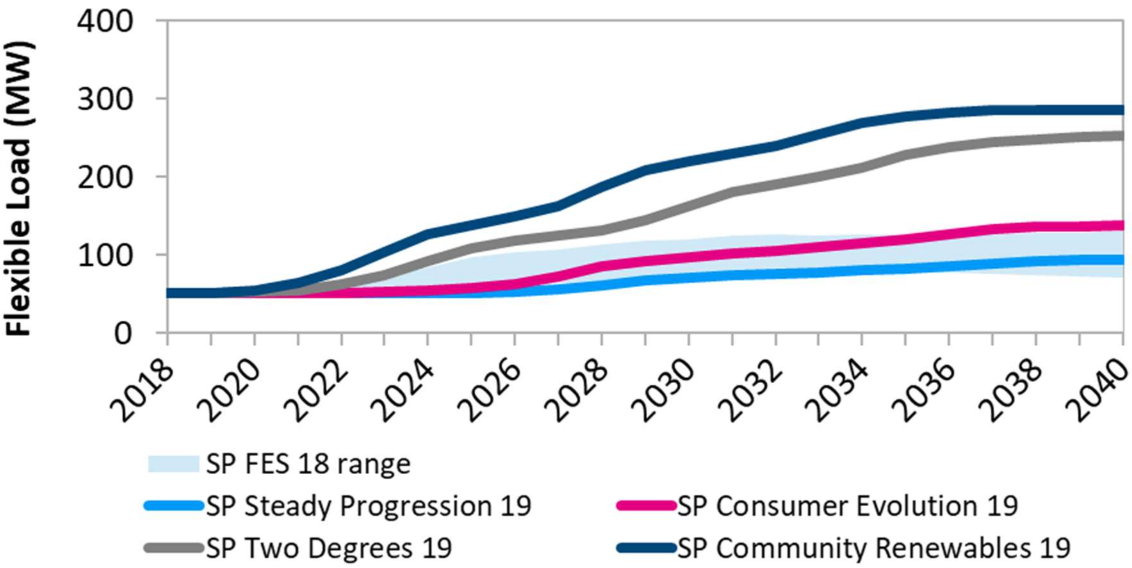
Figure 17 Flexibility of domestic demand at winter peak



3.2.9.2 I&C

Figure 18 shows that the changes regarding the flexibility of I&C demand, as well as the reduced incentive to reduce energy consumption, have a significant impact on the range of assumed flexible I&C load.

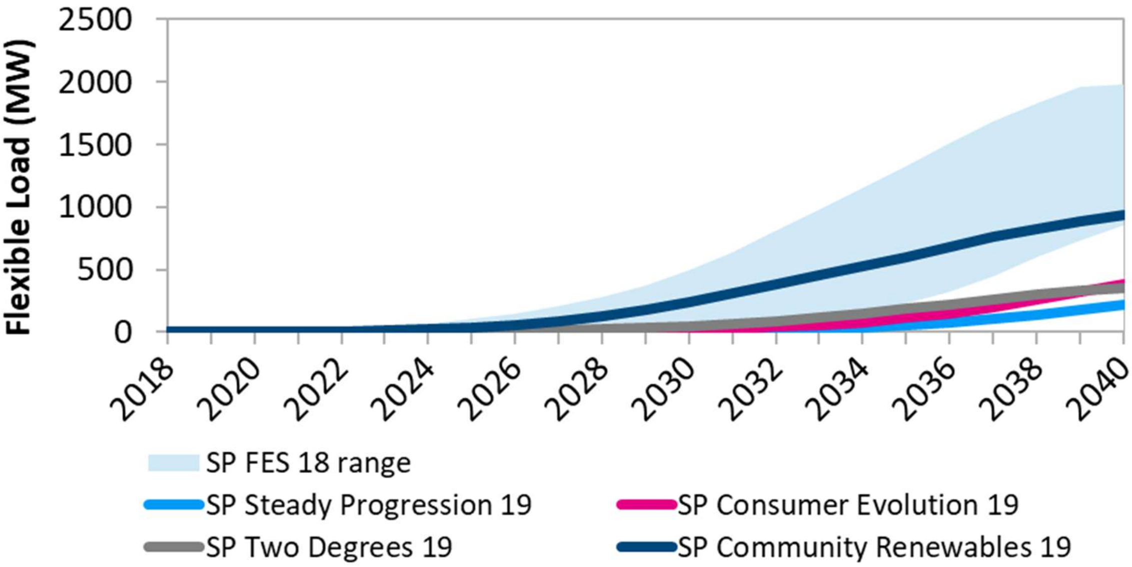
Figure 18 Flexibility of I&C demand at winter peak



3.2.9.3 Electric Vehicles

The strong reduction of EV demand at the time of peak as presented in Section 3.2.5 had a large impact on the flexible EV load, particularly because of the high levels of engagement (60-80%) assumed. This reduced level of assumed flexible EV load (Figure 19) is an important change in the results, as it means there is significantly less uncertainty around the expected demand on the network as compared to last year’s analysis.

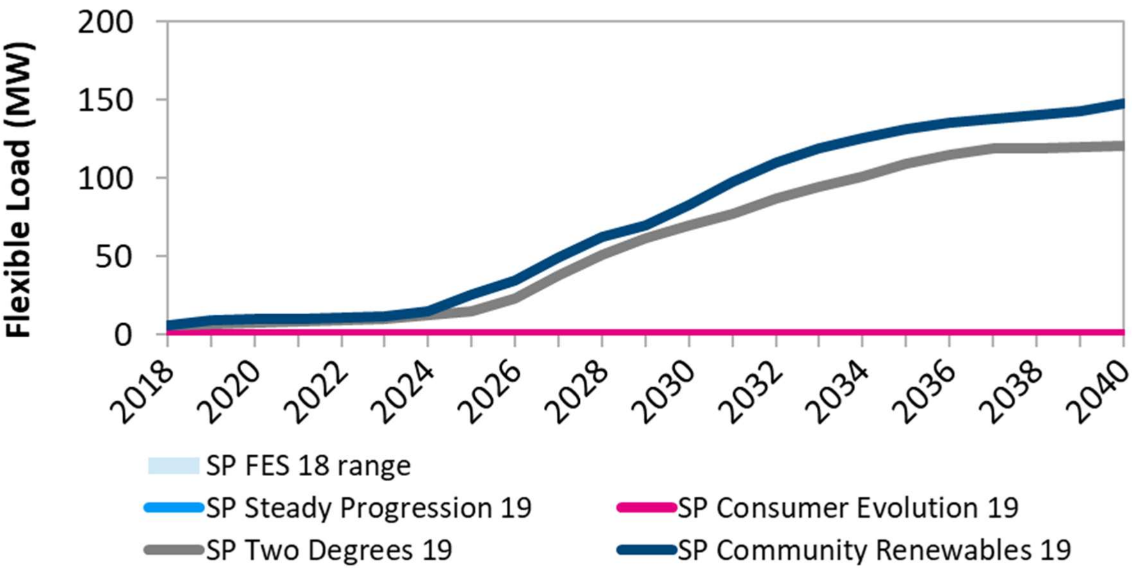
Figure 19 Flexibility of EV demand at winter peak



3.2.9.4 Heat Pumps

The flexibility of HP demand was not included in the 2018 analysis, so is a key change. However, due to the limited uptake of HPs, the total impact on the network is limited, as shown in Figure 20.

Figure 20 Flexibility of HP demand at winter peak

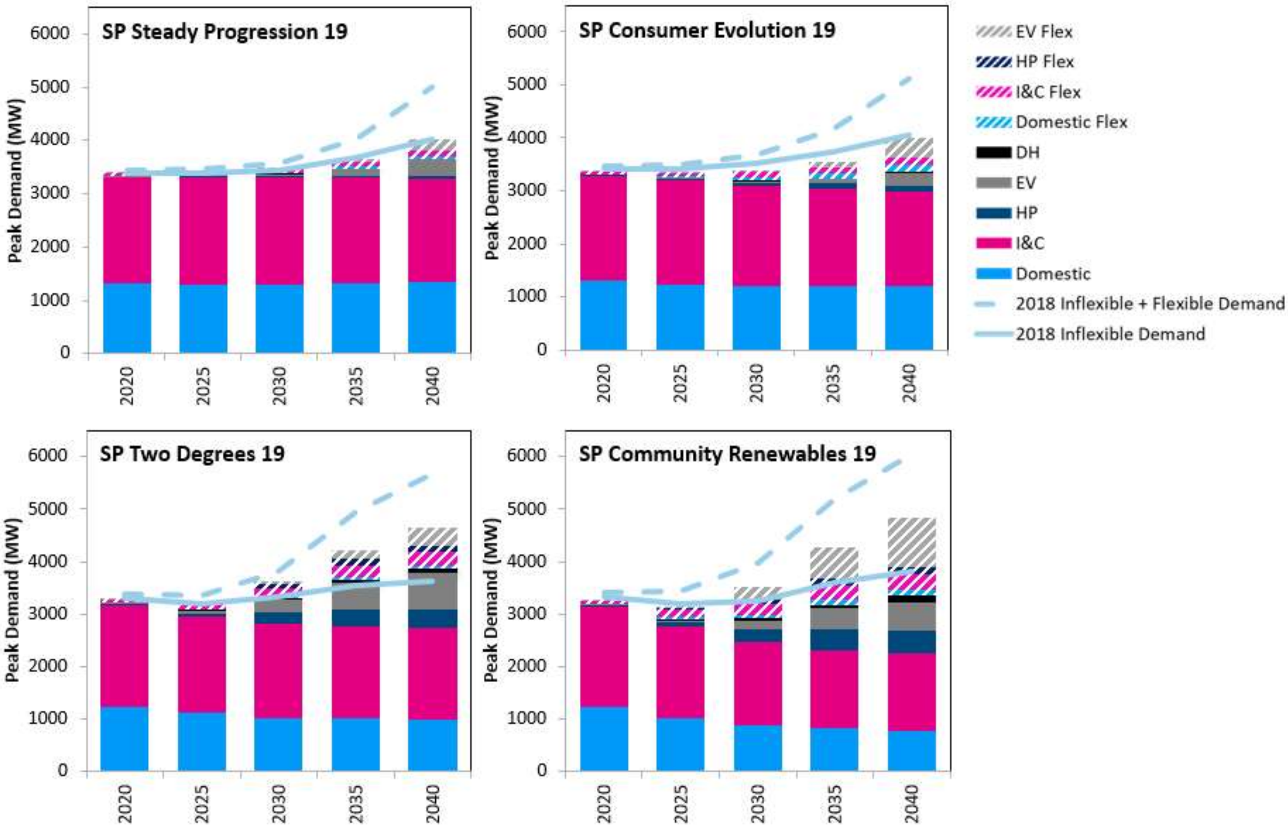


3.2.9.5 Total

Combining the flexible and inflexible demand gives us an understanding of what the total demand on the network would have been if no flexibility were assumed, as is shown in Figure 21 for all scenarios.

Similar to last year, the increase in flexibility of demand results in peak load on the network that is not expected to change much towards 2040. It is however important to note that in the 2019 analysis the levels of assumed flexible demand are significantly smaller than in the 2018 analysis, which means there is less uncertainty in the forecast related to the extent to which the flexible demand is realised. For comparison, the inflexible and the total demand (inflexible + flexible) of the 2018 analysis are included as respectively solid and dashed lines in Figure 21.

Figure 21 Total SPT inflexible and flexible underlying demand at winter peak



3.2.10 Metered Demand

After calculating the total underlying demand, the model subtracts the load provided by behind the meter batteries and the PV generation (based on the FES assumptions for PV load factor and battery operation) to determine the metered demand, which is shown in Figure 22 (winter peak) and Figure 23 (summer minimum).

There has not been a significant increase in behind the meter PV generation and home storage, and therefore the difference between the underlying demand and the metered demand (after subtracting behind the meter supply) is still small.

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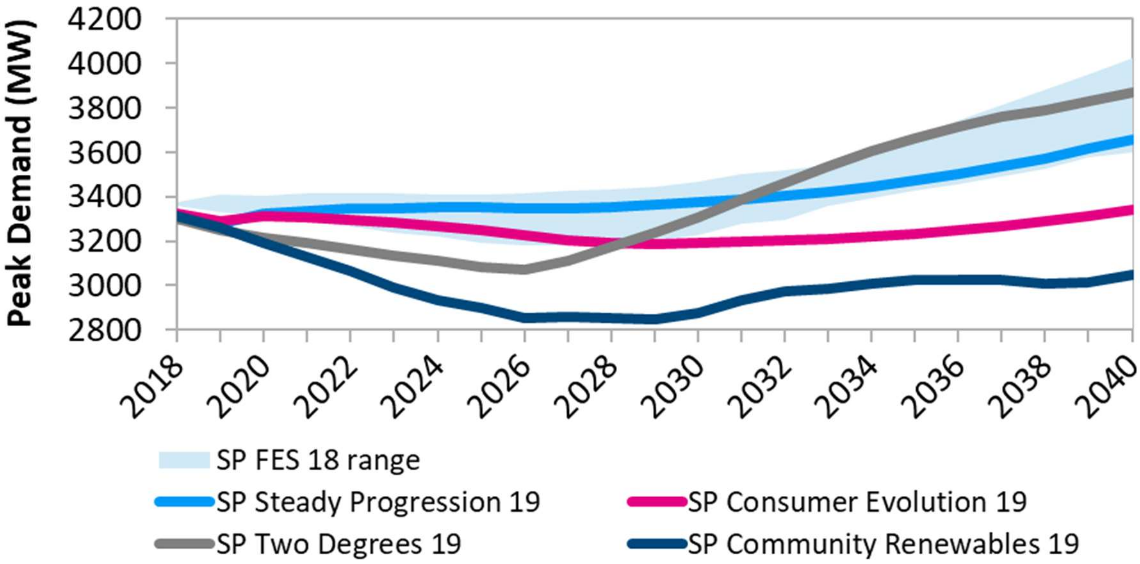
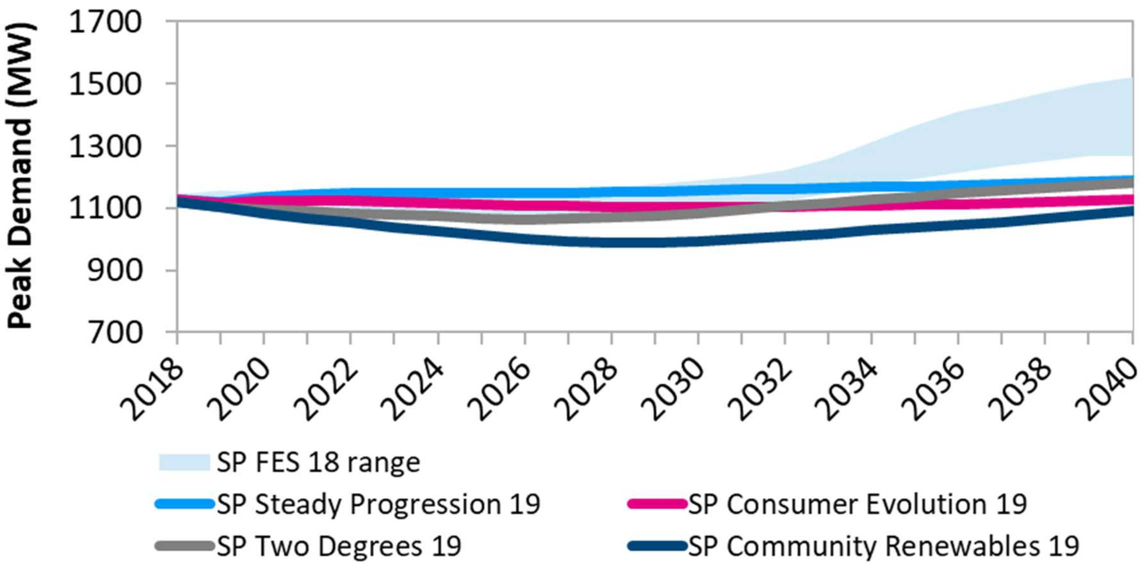
Figure 22 Total SPT metered demand at winter peak



There are a few key changes in the results shown in Figure 22 and Figure 23. Firstly, the 2019 FES scenarios present a significantly broader range than the 2018 FES – particularly in the early years but also towards 2040. NG indicated that they received stakeholder feedback that requested a wider variety across the scenarios in the earlier years, which is consistent with the 2019 scenarios shown in the figures. Secondly, for all scenarios in the 2019 FES the summer minimum demand is expected to remain fairly constant over the entire modelled period, in contrast to a significant increase after 2030 in the 2018 FES. This difference is mainly due to the reduced impact from EV charging in the 2019 analysis, a result of NG using updated charging profiles.

Figure 23 Total SPT metered demand at summer minimum



3.2.11 Summary

We conclude that although there have been significant changes to the demand and behind the meter generation in the 2019 FES, the actual change in network impact is limited. The decrease in EV demand has been partially offset by the increase in domestic and I&C demand, which means the total underlying network demand has not changed significantly.

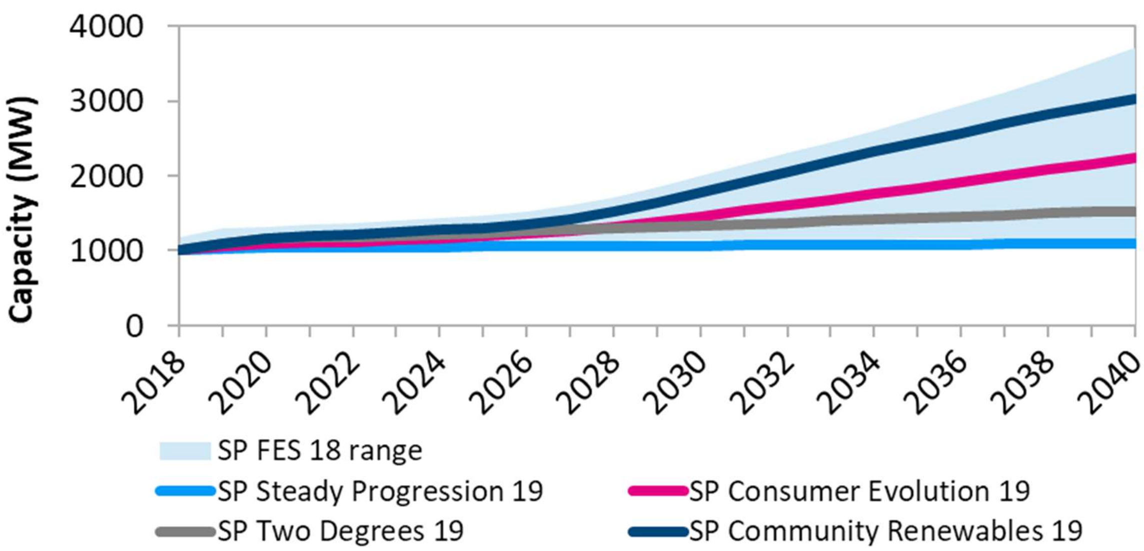
Perhaps the most important change in the results is the strong reduction in assumed flexible EV load related to the reduced EV demand. By being less dependent on the customer engagement, the scenarios also present less uncertainty around the impact of flexibility on the results, as was shown in Figure 21. However, scenario uncertainty has increased, with greater range over the level of demand that the 4 scenarios cover.

3.3 Distribution connected supply/storage

3.3.1 Wind

Distribution level wind is one the key supply technologies in terms of the volume of capacity expected to connect during the T2 period and beyond. Figure 24 shows projections using this year's analysis; it can be seen that the range of scenarios is close to that projected in the 2018 SPT FES.

Figure 24 Total SPT distribution connected Wind, capacity (MW)



3.3.2 PV

The range in PV capacities across the 2019 SPT FES is far higher than for the 2018 SPT FES, with much increased capacity in the high decarbonisation scenarios. This follows stakeholder feedback to NG about the limited range in the 2018 FES. The relative growth of PV in the SPT area (2019 SPT FES) is

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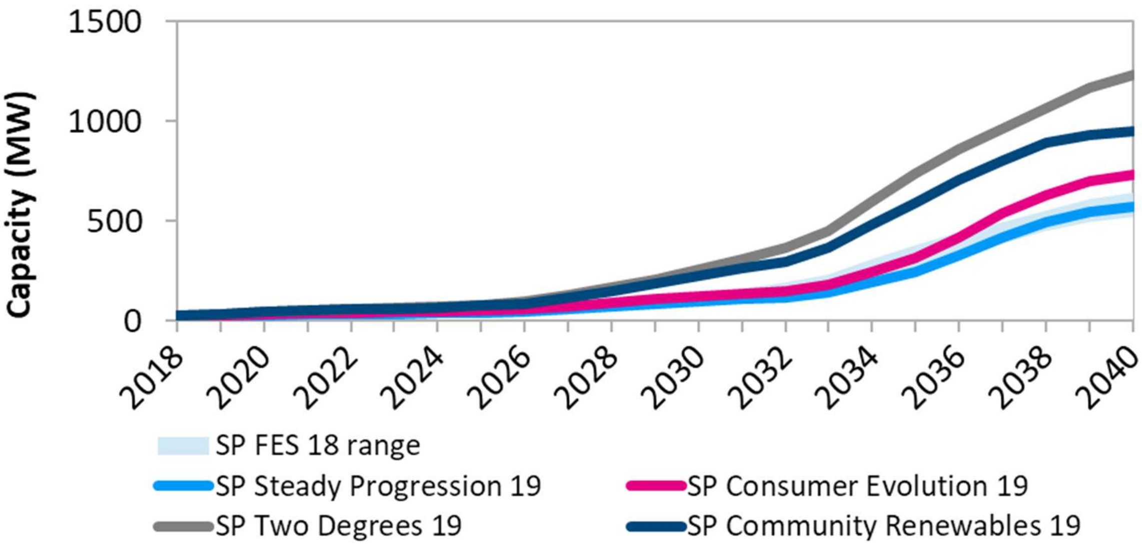
significantly faster than for the rest of GB (2019 NG FES), reflecting an assumption that growth has initially come in the south of GB and this will extend northwards. Despite higher relative growth for the SPT area, SPT remains a fairly low density area for PV, ~20% of that of the rest of GB.

It should be noted that distribution connected PV has a relatively limited impact on the SPT network, due to its generally very low load factor

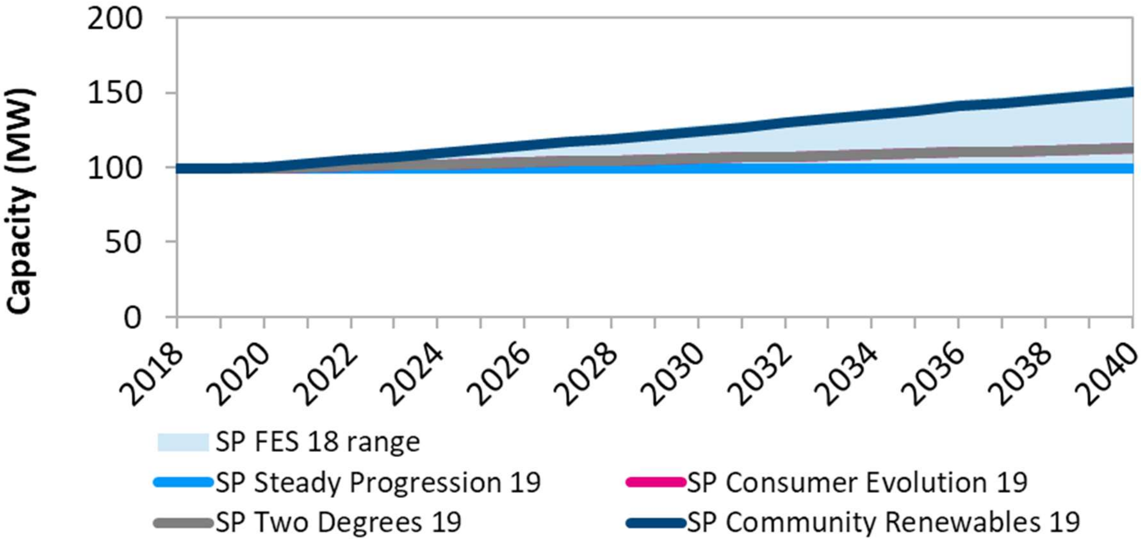
Figure 25 Total SPT distribution connected PV, capacity (MW)



3.3.3 Hydro

There is limited growth for distribution connected hydro capacity, consistent with the previous projections within the 2018 SP FES.

Figure 26 Total SPT distribution connected Hydro, capacity (MW)

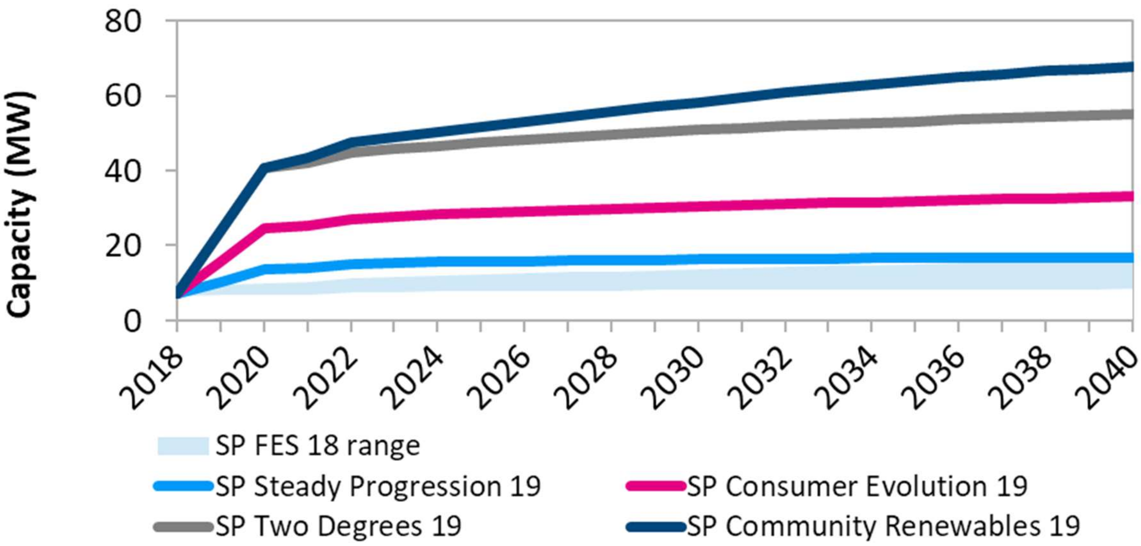


3.3.4 CHP

3.3.4.1 Renewable CHP

Due to new near term project data, the expected growth in capacity of renewable CHP to 2021 has increased significantly. Growth thereafter is similar in % terms, but starting from the much higher view of capacities in 2020. Absolute levels are very low for this type of generation capacity, reaching 15-60MW by 2030.

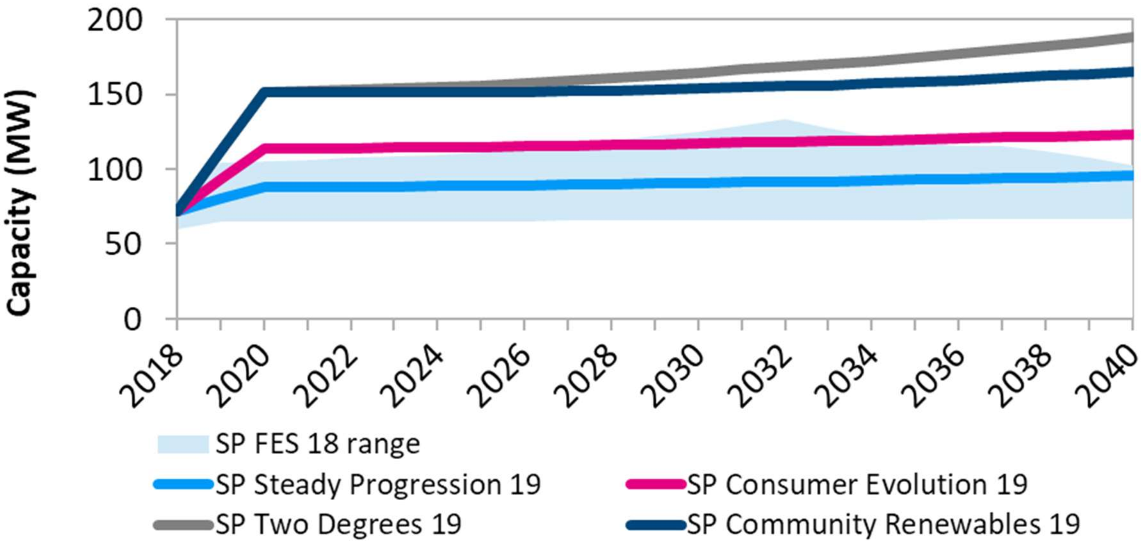
Figure 27 Total SPT distribution connected Renewable CHP, capacity (MW)



3.3.4.2 Non-Renewable CHP

Non-renewable CHP is similar to Renewable CHP, in that due to new near term project data the expected growth in capacity of renewable CHP to 2020 has increased in the 2019 SP FES. There is modest growth thereafter, but starting from the much higher view of capacities in 2020.

Figure 28 Total SPT distribution connected Non-Renewable CHP, capacity (MW)



3.3.5 Controllable plant

3.3.5.1 Renewable Controllable

There is limited near term growth expected for Renewable Controllable plant (eg biomass, landfill gas), a reduction on the near term growth expected in the 2018 SP FES. This results in lower long term growth projections in the 2019 SP FES, though within the same range as previously projected.

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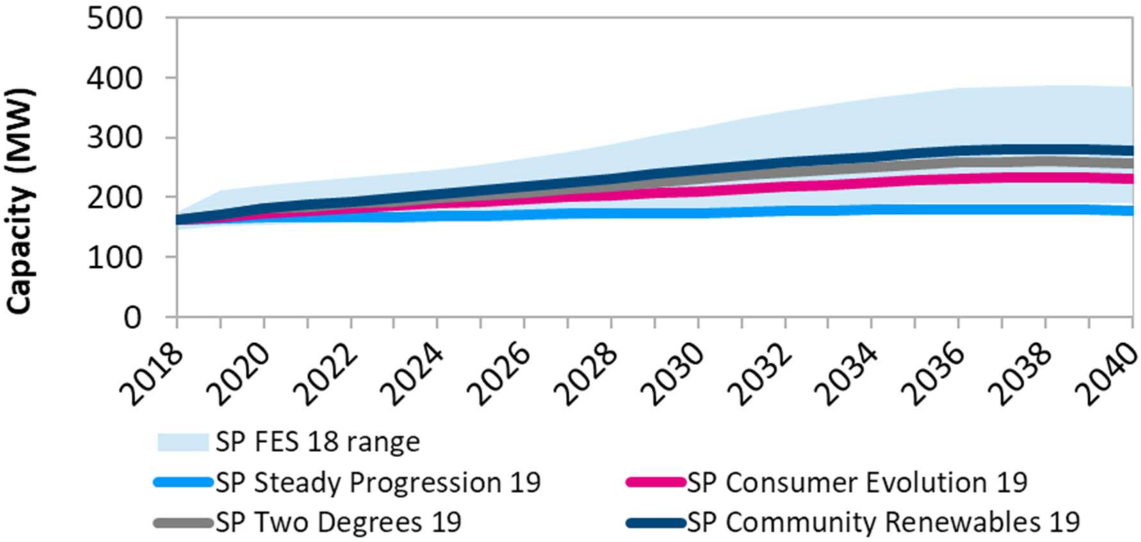
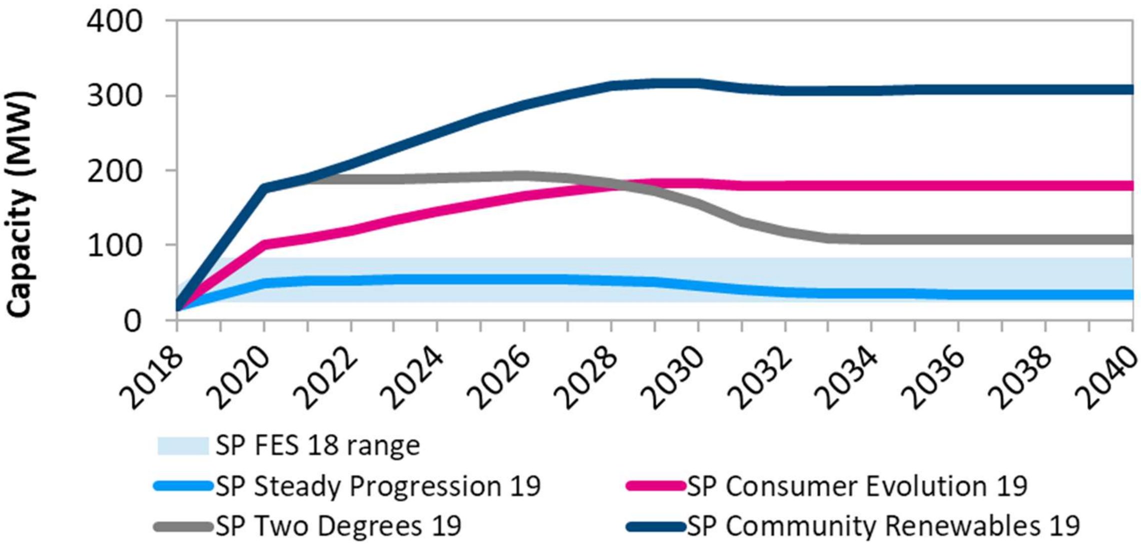
Figure 29 Total SPT distribution connected Renewable Controllable, capacity (MW)



3.3.5.2 Non-Renewable Controllable

Non-Renewable plant (eg diesel or oil engines) are expected to have higher near term growth than previously expected due new near term project data. The resulting range in capacities is far higher than in last year's analysis. At an SPT aggregated level the increase in Non-renewable Controllable plant is balanced by the decrease in Renewable Controllable capacities, though there will be some bigger variations in individual GSPs.

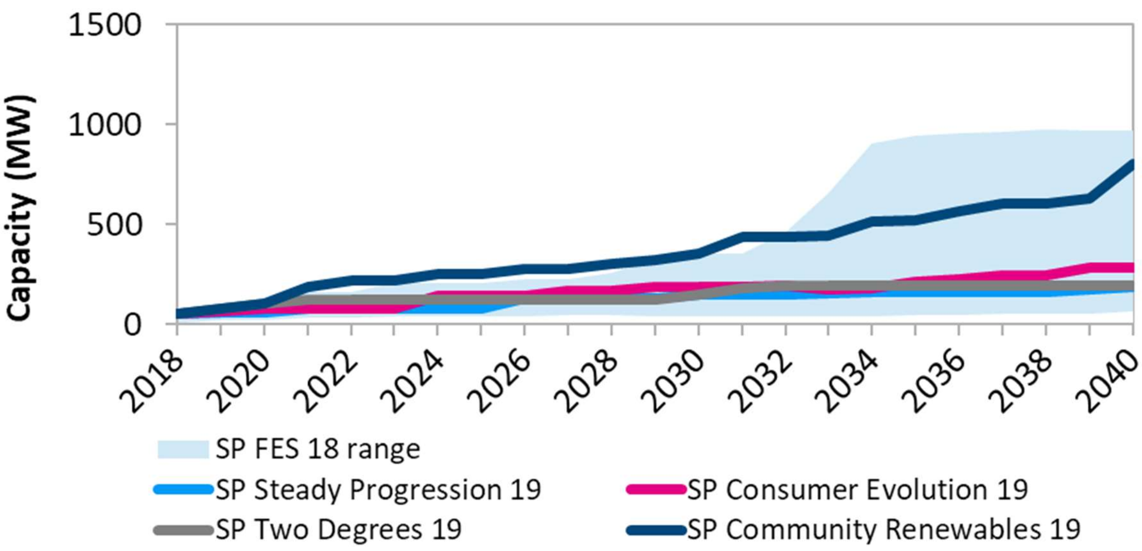
Figure 30 Total SPT distribution connected Non-Renewable Controllable, capacity (MW)



3.3.6 Storage

Throughout the T2 period the range of storage capacities across the 2019 SP FES is similar to that assumed in the 2018 SP FES. In the mid 2030s the 2019 SP FES assumes steady growth in the higher scenarios, but in the 2018 SP FES a boom then stagnation is assumed.

Figure 31 Total SPT distribution connected storage, capacity (MW)



3.3.7 Total Distribution connected supply

There are differences in the capacity of individual technologies when comparing the 2018 and 2019 SP FES, but the aggregate impact on expected supply is fairly limited. Figure 32 and Figure 33 show the expected output of all distribution connected technologies at winter peak and summer minimum periods respectively. The 2019 SP FES broadly lie within the range of the previous 2018 SP FES. The main differences are that the 2019 Community Renewables scenario is somewhat higher at winter peak compared with the 2018 projection over the T2 period (+200MW in 2026, primarily due to higher projections of Non-Renewable Controllable capacity), and that summer minimum supply is expected to be slightly lower in all scenarios (-150MW on average in 2026, primarily due to a decreased load factor assumption for DX wind).

Figure 32 Total SPT distribution connected supply, expected output at peak (MW)

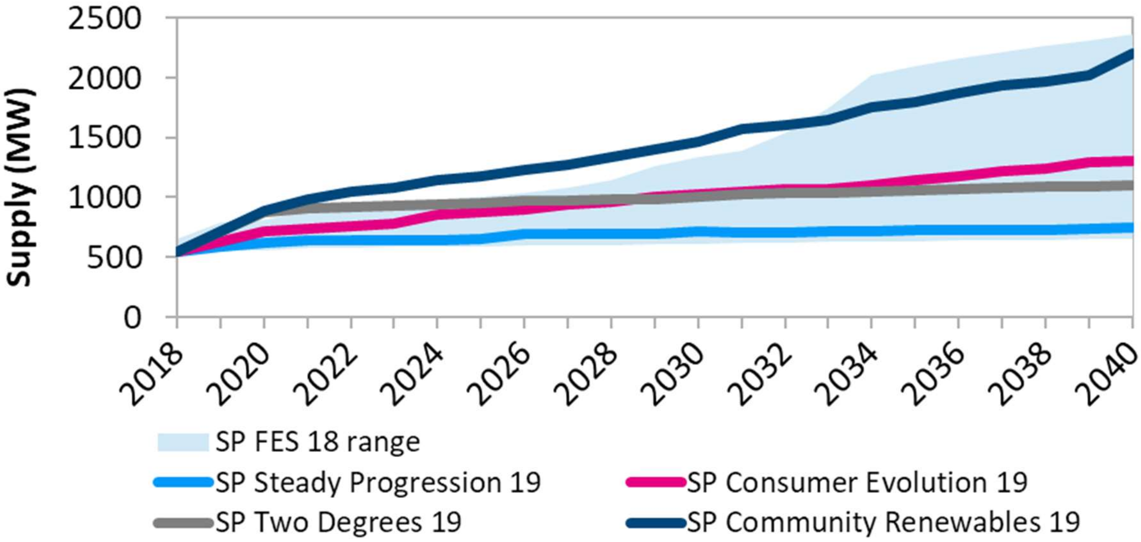
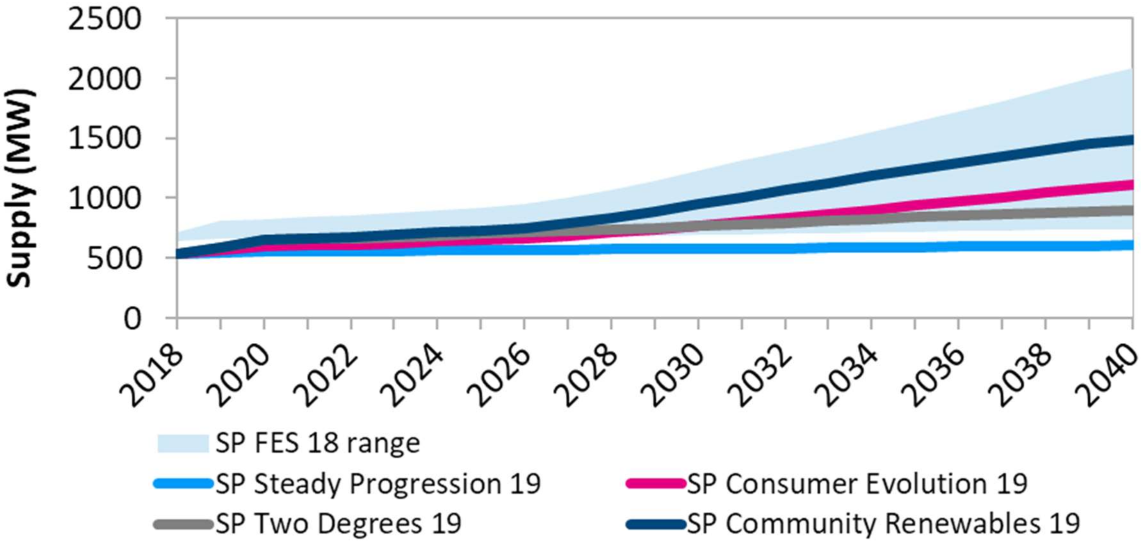


Figure 33 Total SPT distribution connected supply, expected output at Summer Minimum (AM) (MW)



3.4 GSP level net demand results

Net demand from supply and demand technologies on the distribution network is seen on the SPT network through GSPs. In this section we calculate net demand by subtracting expected supply (covered in Section 3.3) from the metered demand (covered in Section 3.2).

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3.4.1 GSP net demand

The net demand at Winter Peak and Summer Minimum respectively are shown in Figure 34 and Figure 35 respectively.

Peak GSP demand is a key driver of investment on the SPT network, and the 2019 SP FES are close to the previous 2018 SP FES range, with limited increases in net demand expected. During the T2 period the range of net demand projections is higher in the 2019 scenarios, reflecting an intentional increase in medium term uncertainty included in the 2019 FES, following stakeholder feedback to NG.

Projections of net demand at Summer Minimum are slightly higher in the 2019 SP FES, primarily due a reduction in the summer load factor for distribution connected wind generation.

Figure 34 Total SPT net demand, Winter Peak (MW)

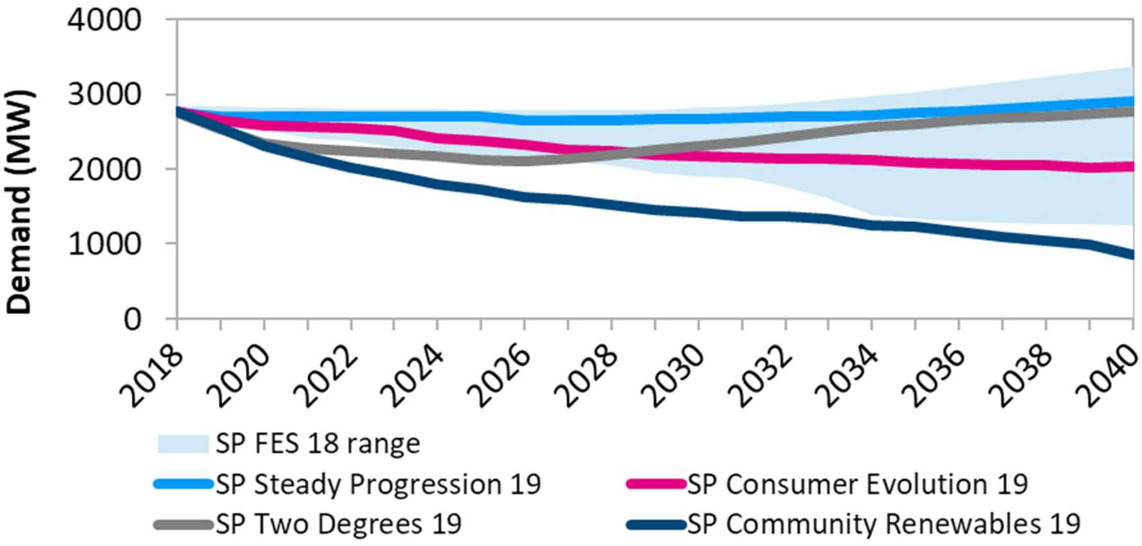
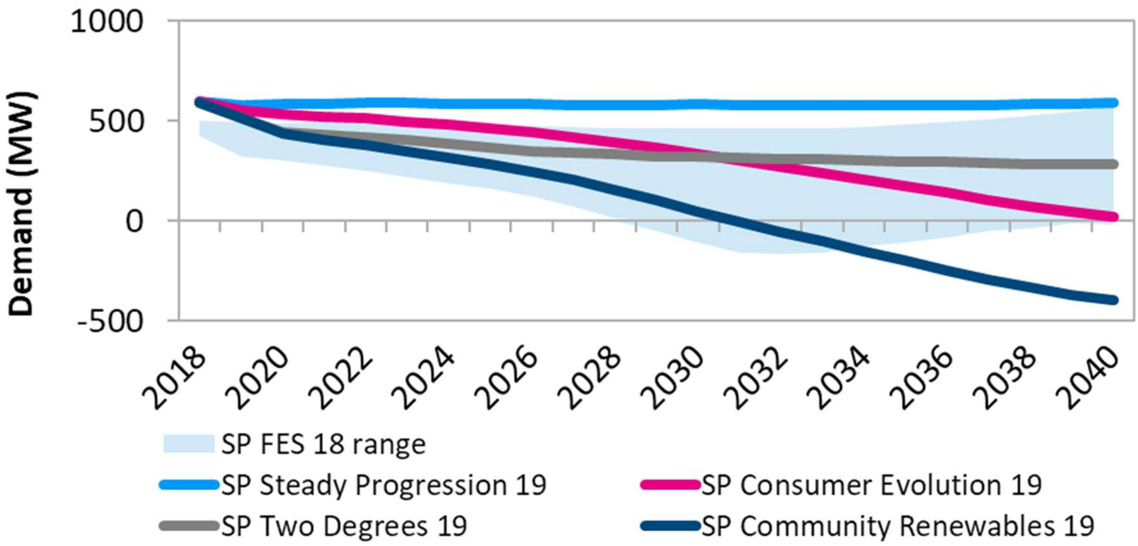


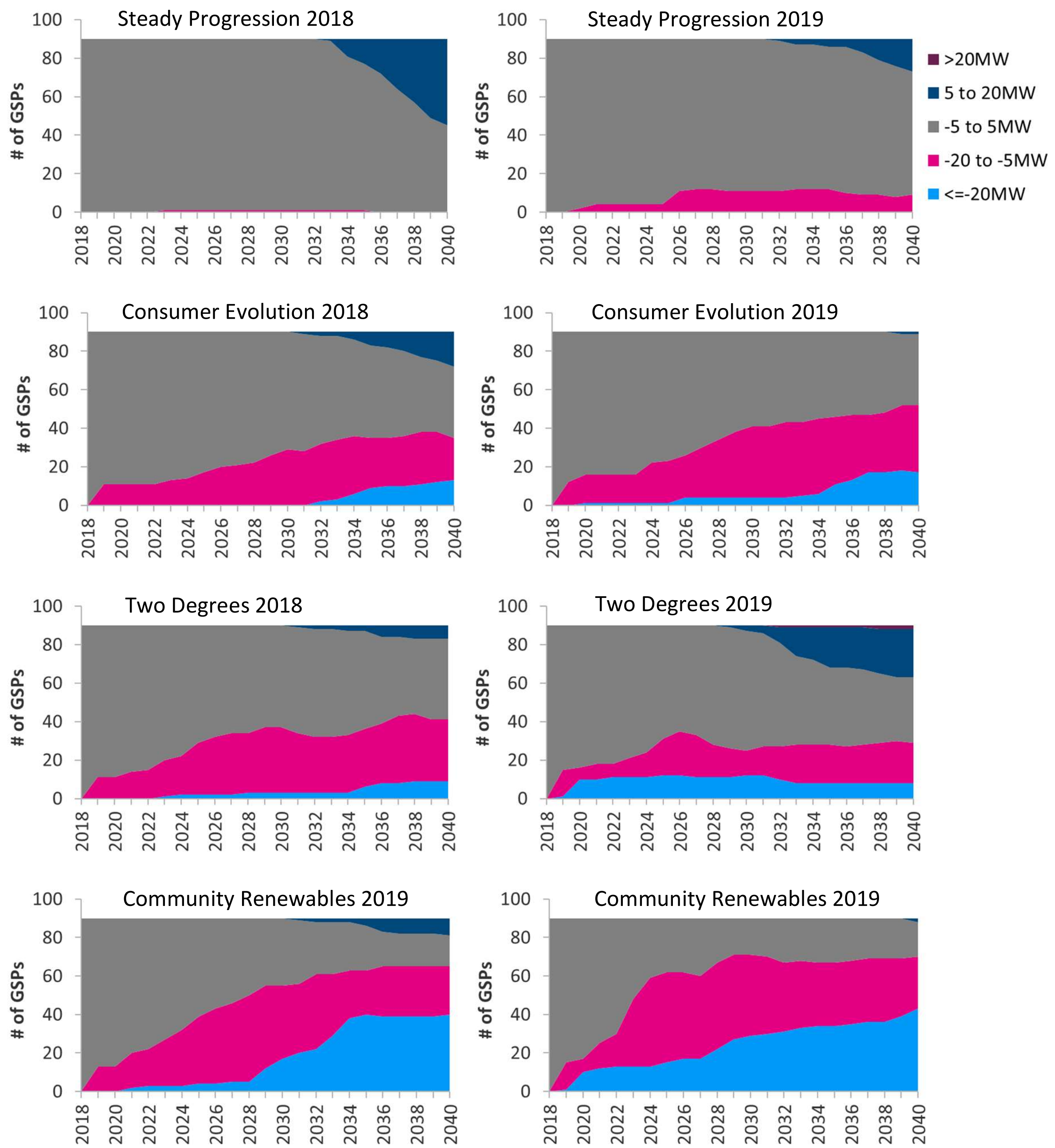
Figure 35 Total SPT net demand, Summer Minimum (AM) (MW)



3.4.2 Impact on individual GSPs

The analysis above has focused on projections for the SPT level as a whole. Our analysis goes down to GSP level, and supply/demand projections at this granularity have been used by SPEN to inform their investment plan. Figure 36 shows the change in GSP net demand for each GSP over time, with a comparison of the 2018 SP FES and the 2019 SP FES. It can be seen that the level of change in net demand is quite similar between the 2018 and 2019 analysis; in most scenarios there is a slight increase in the number of GSPs experiencing a negative change in net demand in the 2019 analysis, though in Two Degrees there is an increase in GSPs experiencing a positive change.

Figure 36 Change in net demand per GSP from 2018, all scenarios (MW)



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3.5 Transmission connected supply/storage

The capacity of generators and storage connected directly to the SPT network has been aggregated by plant type and is shown in Figure 37 to Figure 40. For the SPT area we supply capacity results for named plant, but these have been aggregated here for clarity.

Figure 41 shows the total transmission capacity over all scenarios. It can be seen that there is a slightly higher range over the 2019 SP FES, reflecting increased uncertainty. Some of this increased uncertainty is due the two nuclear plant at Hunterston and Torness. Hunterston has experienced recent outages which make its future availability uncertain, adding to previous uncertainty around decommissioning dates in the 2020s. Further uncertainty comes from capacity projections for onshore and offshore wind – these are slightly higher on average in the 2019 SP FES, but with a greater range across the 4 scenarios.

Figure 37 Total SPT transmission connected generation capacity, Steady Progression (MW)

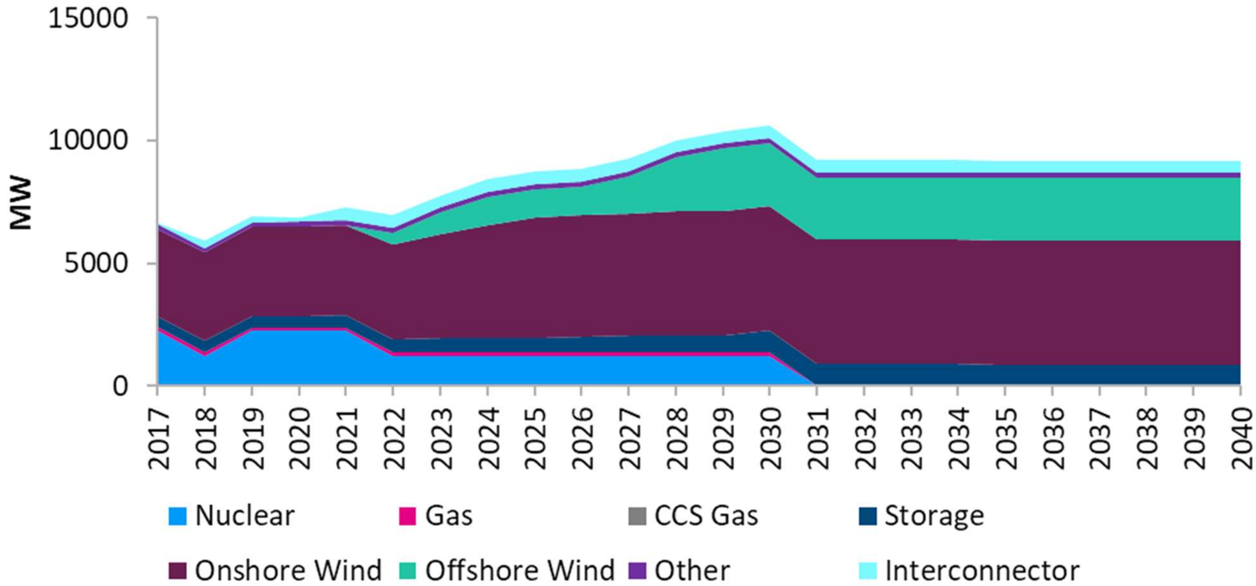

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Figure 38 Total SPT transmission connected generation capacity, Consumer Evolution (MW)

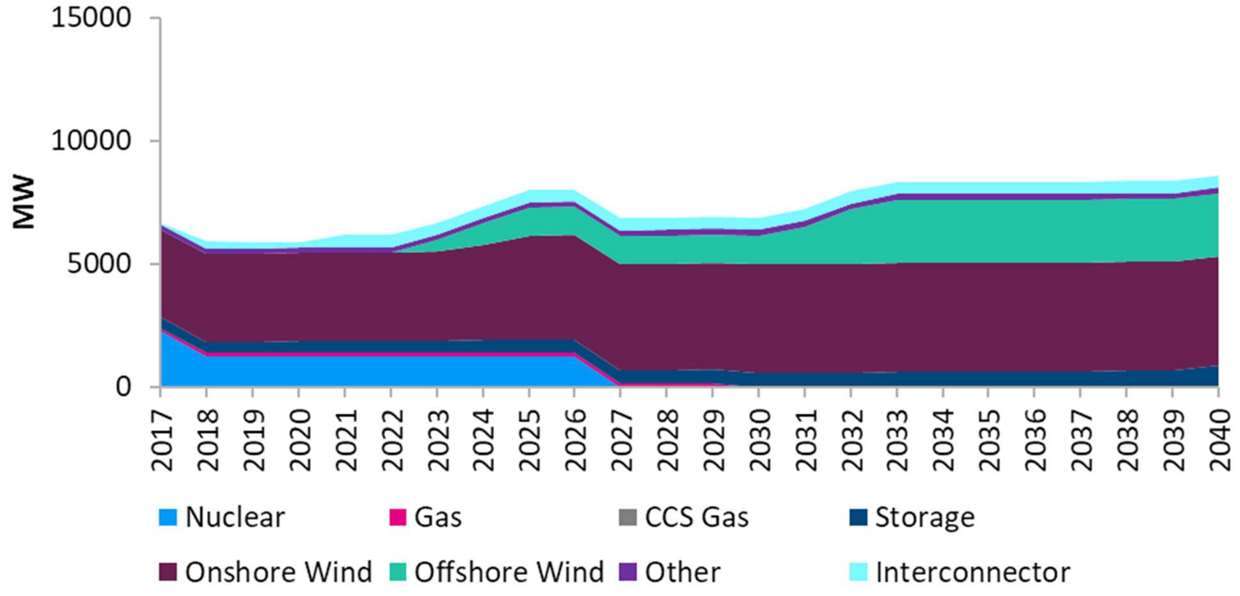

Figure 39 Total SPT transmission connected generation capacity, Two Degrees (MW)

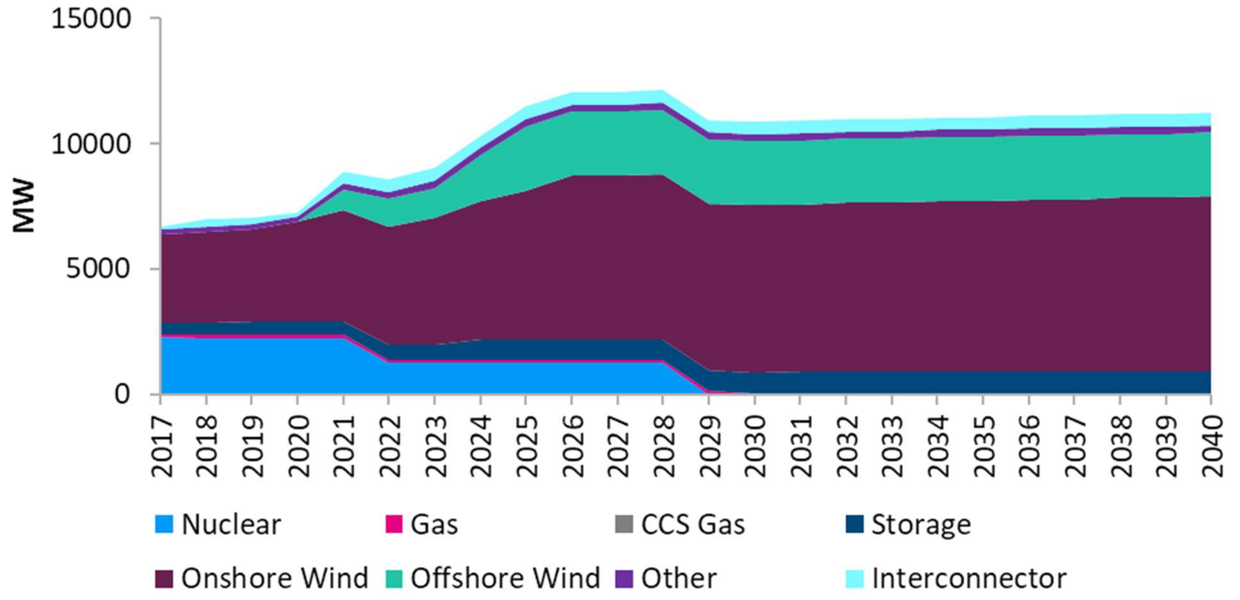

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Figure 40 Total SPT transmission connected generation capacity, Community Renewables (MW)

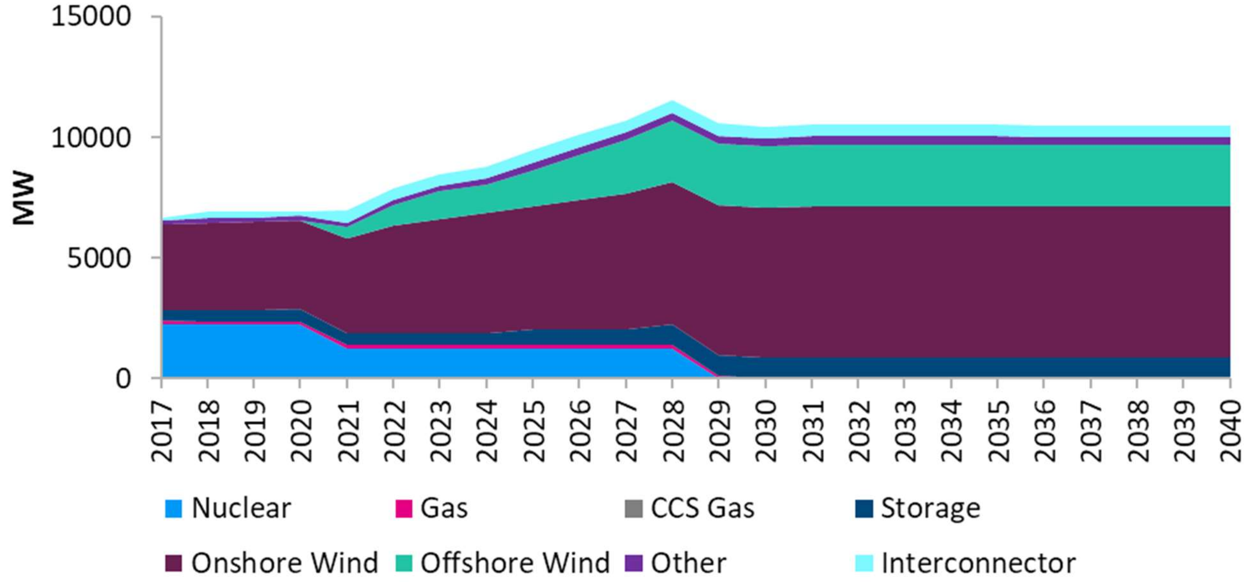
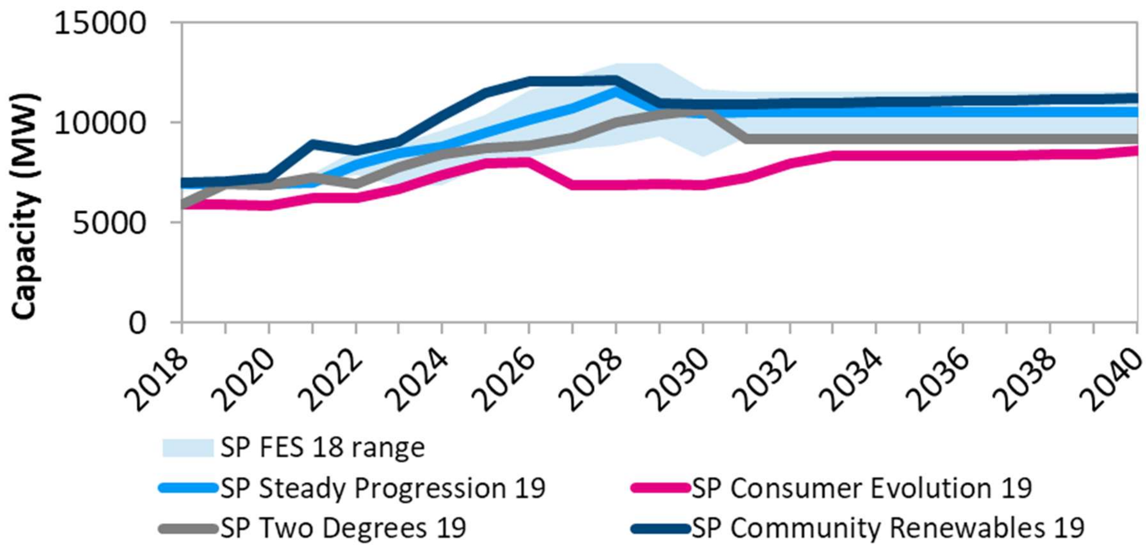


Figure 41 Total SPT level transmission level generation and storage capacity (MW)



3.6 Conclusions

We have used the 2019 NG FES to produce load planning scenarios for the SPT network. We have used a very similar methodology to that used previously to create 2018 SP FES, updating data sources where appropriate.

The results presented here show the following key insights:

- For most technology types there is a modest change in capacity and output assumptions coming from the 2019 SP FES compared with the 2018 SP FES
- In general, there is an increase in the range of capacities covered by the 4 scenarios, a result of stakeholder feedback to National Grid to increase the uncertainty of the scenarios
- Key areas which see larger changes in capacity/output assumptions are:
  - Reduced efficiency reductions, particularly in I&C demand
  - More heat pumps now sited in areas of domestic new build (typically urban)
  - Peak EV demand significantly lower due to updated charging profile assumptions
  - Much higher % of I&C load assumed to be flexible
  - Large share of flexible heat pump load in the high decarbonisation scenarios assumed for the first time
  - Reduced distribution connected DX wind load factor at summer minimum
  - Increased mean and range of distribution PV capacity projections
- When calculating the change in net demand at an individual GSP level, the differences between the 2019 SP FES and 2018 SP FES are fairly modest
  - Though there will be some large differences at individual GSPs
- Flexible demand assumptions remain key to the need to reinforce (or not), but with lower uncertainty

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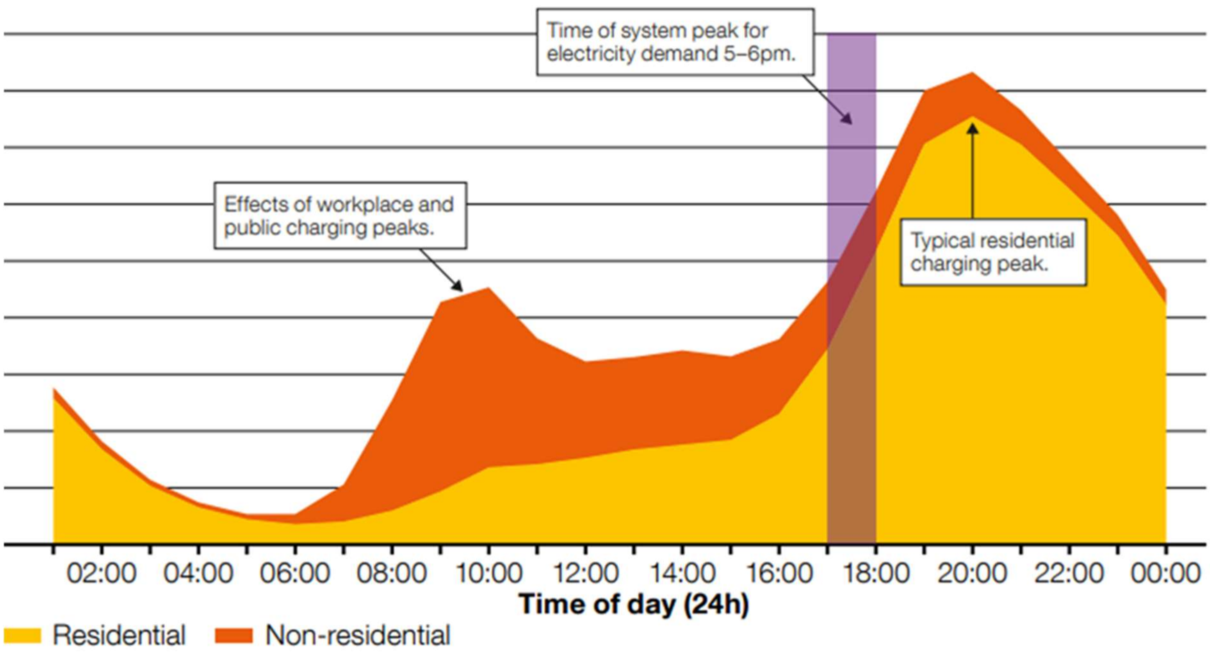
Appendix A Charging Profiles

NG commissioned a Network Innovation Allowance project to develop a better understanding of current EV charging profiles, which has allowed them to significantly improve the modelling of EV charging. An important learning of the project has been that the typical charging peak does not overlap with the system peak, which strongly affects the impact of EV peak demand on the electricity network.

Figure 42 Typical weekday profile assumed in the 2019 FES



Appendix B Load Factor Assumptions

We have taken annual load factors from the FES 2019. Most technologies show stable load factors across scenarios and years. The exceptions are the thermal renewable technologies (CHP and controllable). The variation is due to these high level technologies being formed from the aggregation of a number more granular technologies, each with a different load factor. As the mix of granular technologies changes, so the overall load factor does too. Here we show load factors from the start and end of the horizon only, but we use annually changing values in the scenario model itself.

Table 5 Distribution connected supply technology load factor assumptions

Technology	Scenario	Winter Peak		Summer Minimum (AM)	
		2017	2040	2017	2040
Wind (DX)	All	23%	23%	39%	39%
PV (DX)	All	0%	0%	2%	2%
Hydro (DX)	All	85%	85%	17%	17%
CHP Renewable (DX)	Community Renewables	70%	76%	59%	62%
	Two Degrees	70%	76%	59%	62%
	Steady Progression	70%	75%	59%	63%
	Consumer Evolution	70%	75%	59%	63%
CHP Non-Renewable (DX)	All	74%	74%	33%	33%
Controllable Renewable (DX)	Community Renewables	71%	81%	55%	58%
	Two Degrees	71%	80%	55%	60%
	Steady Progression	71%	80%	55%	59%
	Consumer Evolution	71%	77%	55%	60%
Controllable Non-Renewable (DX)	All	95%	95%	0%	0%
Storage (DX)	All	87%	87%	0%	0%

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SPT RIIO T2 Planning Scenarios

2018 Update

CLIENT: SPEN

DATE: 11/10/2018

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4.0	11/10/2018	Updated following SPEN comments	LH, SvL, JG	Luke Humphry

Contact

Luke Humphry (Luke.Humphry@baringa.com +44 203 853 1676)

James Greenleaf (james.greenleaf@baringa.com +44 203 327 4220)

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Glossary

Table 1 Acronyms

Acronym	Description
BtM	Behind the Meter
CHP	Combined Heat and Power
DH	District Heating
DX	Distribution
DNO	Distribution Network Operator
DSO	Distribution System Operator
EV	Electric Vehicle
FES	Future Energy Scenarios
GSP	Grid Supply Point
HP	Heat Pump
LV	Low Voltage
NG	National Grid
RES-E	Electrical Renewable Energy Supply
SSEN	Scottish and Southern Electricity Networks
SPD	SP Distribution
SPEN	SP Energy Networks
SPT	SP Transmission
TX	Transmission

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Executive Summary

Introduction

SP Energy Networks (SPEN) is developing its investment plans for the SP Transmission (SPT) network for the upcoming RIIO-T2 price control period.

As part of developing these plans, SPEN undertakes a number of pieces of analysis including the framing of planning scenarios to help understand the future evolution of energy supply and demand on its network. SPEN has commissioned Baringa Partners, supported by Element Energy, to help develop these scenarios. While the main focus of these scenarios is the period of the RIIO-T2 price control period (assumed to be 2021-2026), the scenarios go from 2017 to 2040, to allow SPEN to ensure the SPT network is technically prepared for changes in load that may come after the RIIO-T2 period.

SPEN have specified that the SPT planning scenarios must be holistic from a whole energy systems perspective, and need to consider all supply and demand within the SPT area (disaggregated down to individual Grid Supply Point level) including:

- Transmission and distribution network connected generators (and storage)
- Transmission and distribution network connected consumers
- “Behind the meter” generators (e.g. small scale solar or storage)

The scenario development methodology has been informed by a number of underlying principles, including the need for them to be:

- Simple and transparent so that they are accessible to other parties, including Ofgem
- Be informed by a broad range of stakeholder feedback.

Methodology

The SPT planning scenarios use the four National Grid (NG) 2018 Future Energy Scenarios[1] (FES) as their starting point. The NG FES are a widely used set of annually updated scenarios, providing a range of credible pathways for the GB energy system out to 2050. The FES focus predominantly on gas and electricity sectors, whilst also considering the wider set of energy system options that affect these (e.g. the role of bioenergy or district heating) to create holistic whole energy system scenarios.

The 2018 FES have been used to produce the result in this report. The four scenarios vary over two dimensions, as shown in Figure 1:

- **Level of Decentralisation:** how close the production and management of energy is to the end consumer

[1] https://www.nationalgrid.com/uk/publications/future-energy-scenarios-fes

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- **Speed of Decarbonisation:** how quickly reductions in carbon emissions across all sectors are seen, and whether the UK meets the Government's target of an 80% reduction by 2050

Figure 1 Future Energy Scenarios 2018[2]

Level of decentralisation

2050 carbon reduction target is not met

Consumer Evolution

Electricity demand	Moderate-high demand: high for electric vehicles (EVs) and moderate efficiency gains
Transport	Most cars are EVs by 2040; some gas used in commercial vehicles
Heat	Gas boilers dominate; moderate levels of thermal efficiency
Electricity supply	Small scale renewables and gas; small modular reactors from 2030s
Gas supply	Highest shale gas, developing strongly from 2020s

Steady Progression

Electricity demand	Moderate-high demand: high for EVs and moderate efficiency gains
Transport	Most cars are EVs by 2040; some gas used in commercial vehicles
Heat	Gas boilers dominate; moderate levels of thermal efficiency
Electricity supply	Offshore wind, nuclear and gas; carbon capture utilisation and storage (CCUS) gas generation from late 2030s
Gas supply	UK Continental Shelf still producing in 2050; some shale gas

2050 carbon reduction target is met

Community Renewables

Electricity demand	Highest demand: high for EVs, high for heating and good efficiency gains
Transport	Most cars are EVs by 2033; greatest use of gas in commercial vehicles but superseded from mid 2040s by hydrogen (from electrolysis)
Heat	Heat pumps dominate; high levels of thermal efficiency
Electricity supply	Highest solar and onshore wind
Gas supply	Highest green gas development from 2030s

Two Degrees

Electricity demand	Lowest demand: high for EVs, low for heating and good efficiency gains
Transport	Most cars are EVs by 2033; high level of gas used for commercial vehicles but superseded from mid 2040s by hydrogen
Heat	Hydrogen from steam methane reforming from 2030s, and some district heat; high levels of thermal efficiency
Electricity supply	Offshore wind, nuclear, large scale storage and interconnectors; CCUS gas generation from 2030
Gas supply	Some green gas, incl. biomethane and BioSNG; highest import dependency

Speed of decarbonisation

The FES give results on a GB wide basis, built up of assumptions that are split geographically at a much more granular level. However, many of the methodologies used to create the spatially

[2] Image reproduced with permission of National Grid

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disaggregated data are simplistic, or are suitable for GB on average and no do not reflect conditions in the SPT area.

The approach taken in developing the SPT planning scenarios has been to:

- Use the overall growth in demand and supply for the SPT area as a whole in the NG FES
- Split aggregated supply and demand categories into more granular technology types using a number of simple and transparent methodologies
- Split total SPT area capacities by GSP using a number of simple and transparent methodologies

A number of alternate sources of data have been used to inform the methodologies used, including:

- SPEN internal information of local areas (customer numbers, generation connections, etc)
- External publicly available data
- Feedback from a wide range of internal SPEN and external stakeholders (e.g. other network operators, Scottish Government) on both the methodology and data used.

Scenario Results

The key output from this work is a databook detailing the resulting capacity of demand and supply technologies at each location and grid level of the SPT area. These detailed results will be used by SPEN as the inputs to other detailed modelling tools to understand where investment may be required on the SPT network.

Focusing on the SPT area as a whole, the following insights come from the SPT FES:

- **Demand**
  - Underlying demand from conventional end uses is expected to reduce in all scenarios, with population growth offset by improvements in efficiency (lighting, appliances etc).
  - However, electrification of heat (through heat pumps) and transport (through electric vehicles) may considerably increase demand on the SPD network, particularly in the Two Degrees and Community Renewables scenarios
  - The assumption for how much demand (particularly EV demand) can be "Flexible" (i.e. can be managed such that it does not draw power in peak periods) is key in calculating the metered peak load on the SPD and SPT networks
  - *If* new sources of underlying demand can be managed "flexibly", total underlying demand may remain fairly constant in all scenarios (though with some individual GSPs experiencing greater levels of change in underlying demand)

> *1 million electric vehicles* expected by 2033 (TD and CR scenarios) to 2039 (SP and CP scenarios)

> Unmanaged EV demand could add *3000MW* to the SPT network by 2040 (TD scenario), but if managed this may be reduced to just *500MW*

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- Figure 2 shows the breakdown of underlying demand at the SPT level across all scenarios

- **Behind the meter supply/storage**
  - Growth in BtM PV has a large variation across the SPT FES, with potentially 1250MW of installed capacity in the Community Renewables scenario by 2040
  - Impact of PV on network is low, given low expected output in peak periods
  - Home storage technologies not expected to be seen in SPT area until after RIIO-T2 period, and in relatively low numbers thereafter

Figure 2 Total SPT inflexible and flexible underlying demand (MW)

- **Distribution connected supply/storage**
  - The key technology in terms of additional supply and storage capacity on the SPD network is wind, increasing by potentially 2700MW by 2040 in the Community Renewables scenario (Figure 3)

Total distribution connected supply capacity may *double by 2030* in the TD and CR scenarios

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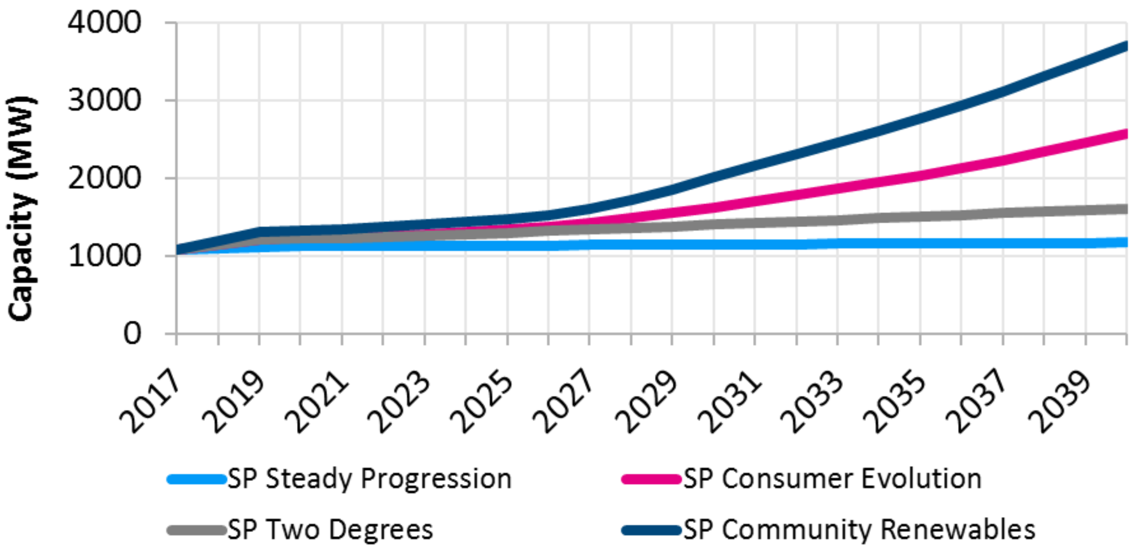
- Capacity increases in distribution connected wind are expected to be modest in all scenarios until after the RIIO-T2 period, after which point strong growth is seen in the Two Degrees and Community Renewables scenarios

Figure 3 Total SPT Distribution Connected Wind capacity (MW)



- **Key technologies**
  - On the demand side, the largest changes come from domestic demand (potential for reductions due to increased efficiency) and electric vehicles (potential for large increases if not managed). There is expected to be less of an impact from heat pumps.
  - On the supply side, the key technologies are wind (providing intermittent energy output in most periods) and flexible storage and controllable thermal generation (providing power in peak periods, as shown in Figure 4), with large impact on net transmission demand and large variation across scenarios

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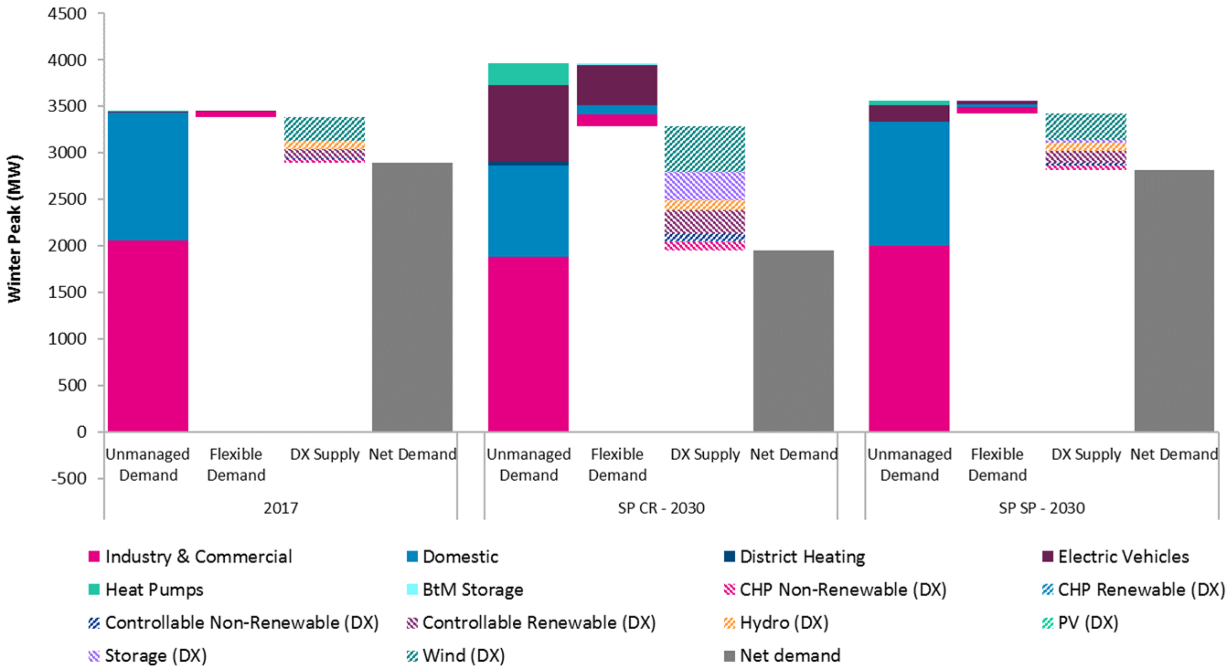
Figure 4 Key drivers of expected transmission net demand at winter peak



- **GSP net Demand and Supply**
  - In peak periods, the total net demand/supply balance for all SPT GSPs remains fairly flat over the RIIO-T2 period in all scenarios, with increasing net demand observed thereafter
  - At the Summer Minimum (AM) period there is a trend towards decreasing net demand in all scenarios, reaching a point of net supply to the SPT network by 2029 in the Community Renewables scenario and 2037 in the Consumer Evolution scenario.
  - There is significant variation in the net demand seen at certain GSPs in all scenarios (for example Two Degrees, Figure 5)
  - If flexible demand is not shifted from peak, the number of GSPs experiencing large changes in net demand increases significantly (Two Degrees, Figure 6)

Change in GSP load by 2030 varies from *-15% to +10%* when considering all locations and scenarios

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Figure 5 Change in net demand per GSP from 2017, Two Degrees (MW)

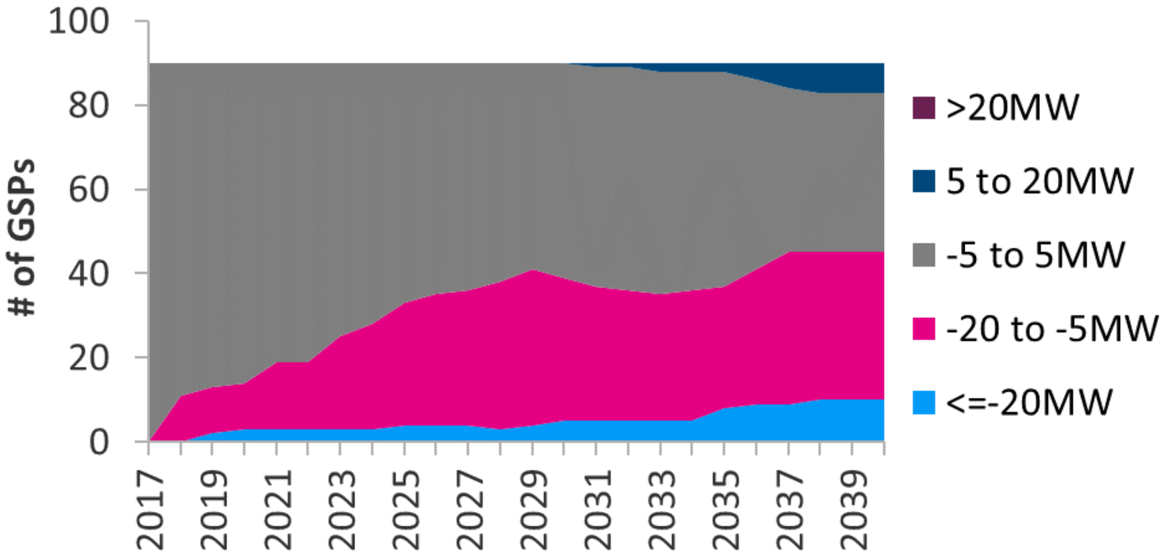
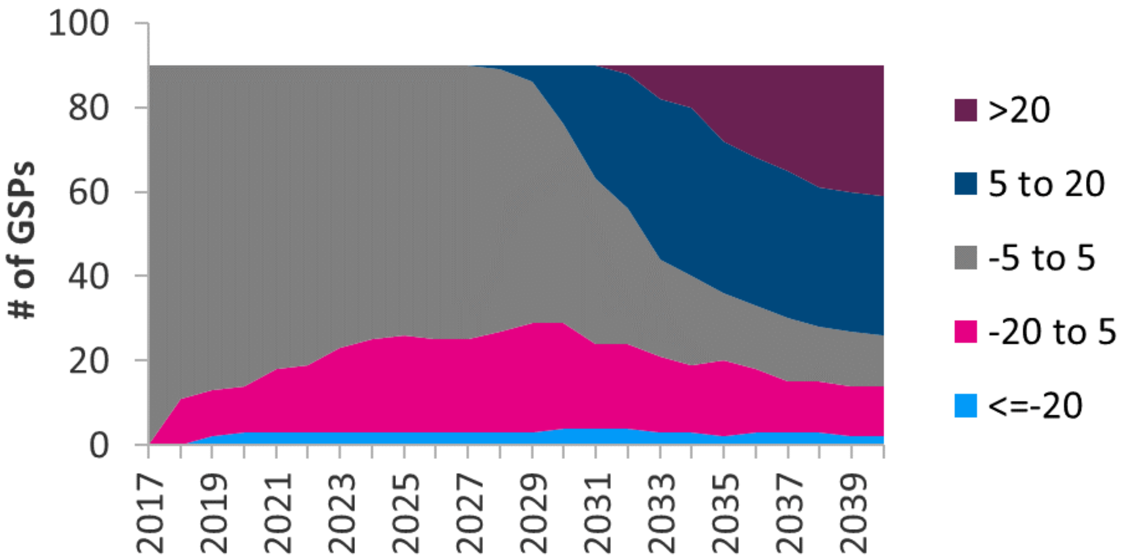


Figure 6 Change in net demand per GSP from 2017, Two Degrees – all demand inflexible (MW)



- **Transmission connected supply**
  - Remaining large thermal power plant capacity (Hunterston and Torness, both nuclear) expected to be off the system by the late 2020s in all scenarios
  - Bulk of capacity increases on SPT network expected to be wind, both onshore and offshore

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- A large range in wind capacities seen over the four scenarios, ranging from 3.3GW of additional capacity by 2030 in the Consumer Evolution scenario (Figure 7) to 5.6GW additional capacity in the Two Degrees scenario (Figure 8).

Figure 7 Total SPT transmission connected generation, Consumer Evolution (MW)

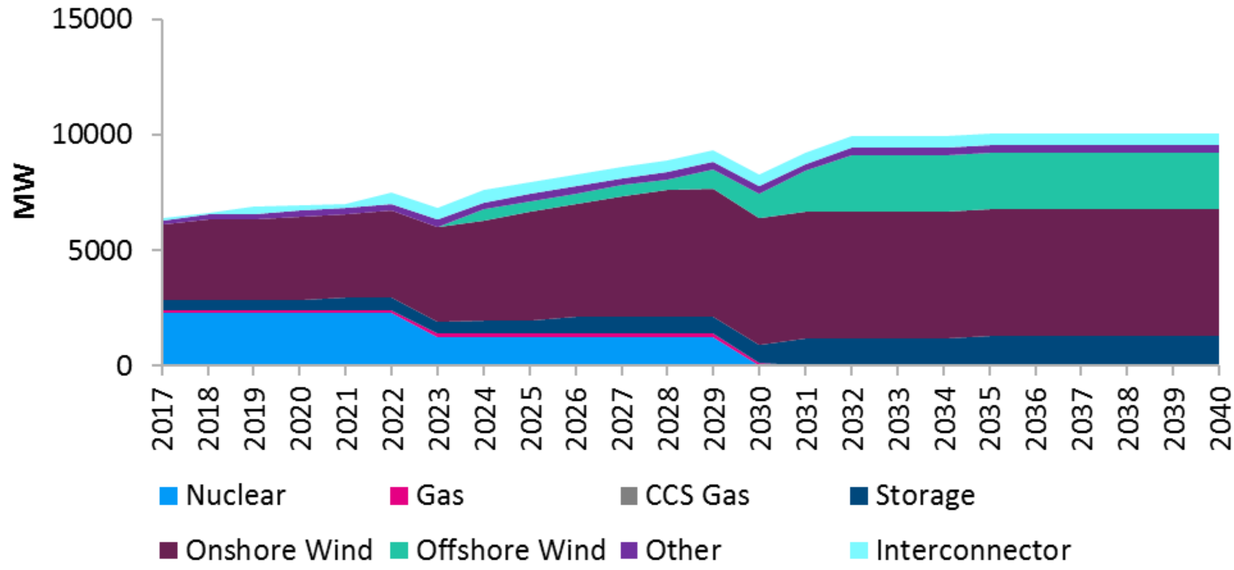
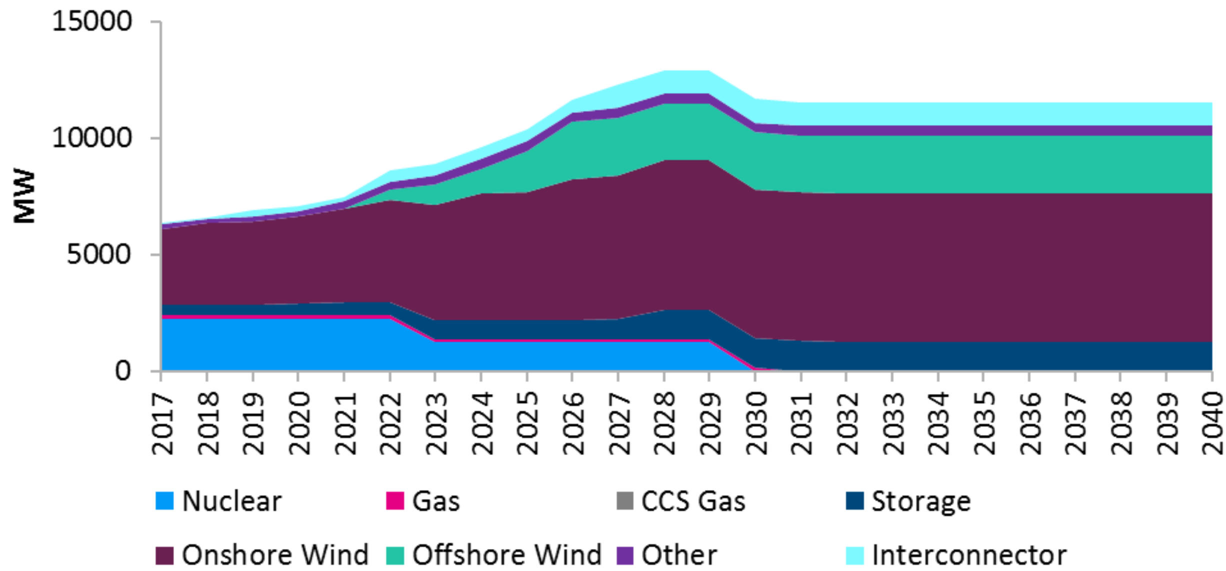


Figure 8 Total SPT transmission connected generation, Two Degrees (MW)



- **Alignment with government targets**

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- When combined with results for the rest of the UK from the NG FES, the SPT scenarios imply that the UK Government’s target of an 80% emissions reduction by 2050 is met in the faster decarbonisation scenarios (Two Degrees and Community Renewables)
- The faster decarbonisation scenarios broadly match the Scottish Government’s ambitions for renewable electricity generation and electric vehicle uptake, while the slower decarbonisation scenarios fall short
- All scenarios have lower uptake of heat pumps than is implied by the Scottish Government ambitions for low carbon heat

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1 Introduction

1.1 Background

SP Energy Networks (SPEN) is developing its investment plans for the SP Transmission (SPT) network for the upcoming RIIO-T2 price control period, which is assumed to run from 2021 to 2026 in accordance with Ofgem's latest proposal[3]. These plans will seek to accommodate all supply and demand customers, help facilitate overarching decarbonisation objectives, and target investments only where needed to keep costs low for end-users.

As part of developing these plans, SPEN undertakes a number of pieces of analysis including the framing of planning scenarios to help understand the future evolution of energy supply and demand on its network, which is the focus of this report. SPEN has commissioned Baringa Partners, supported by Element Energy, to help develop these scenarios.

The scenarios are intended to be holistic and need to consider all supply and demand within the SPT area, disaggregated down to individual Grid Supply Point (GSP) level, including:

- Transmission and distribution network connected generators (and storage)
- Transmission and distribution network connected consumers
- "Behind the meter" generators (e.g. small scale solar or storage)

The development of the methodology and final scenarios has been informed by a number of underlying principles including the need for them to be:

- Simple and transparent so that they are accessible to other parties, including Ofgem
- Be informed by a broad range of stakeholder feedback.

The scenarios themselves use the four National Grid (NG) Future Energy Scenarios[4] (FES) as the starting point. The NG FES run from 2017 to 2050, however for this analysis scenarios are developed from 2017 to 2040 only, as this well covers the RIIO-T2 period. The FES already contain a spatial breakdown to SPT's licence area and GSPs within this[5]. However, this breakdown is generally based on simple GB-wide proxies and hence the core focus of this project has been to refine the initial FES so that they are better tailored to SPT's area. This has been undertaken via a number of routes including:

- Use of other, or supplementary, data sources
- Refinement of the methodology by which the overarching FES are disaggregated to GSP level
- Feedback from a wide range of internal SPEN and external stakeholders (e.g. other network operators, Scottish Government) on both the methodology and data used.

[3] Ofgem, RIIO-2 Framework Consultation, March 2018
[4] https://www.nationalgrid.com/uk/publications/future-energy-scenarios-fes
[5] This is not published as part of the main FES publication.

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1.2 Purpose of this report

This report describes the underlying methodology used to produce the SPT-specific scenarios along with a summary of results based on the 2018 FES data.

In developing the methodology outlined here, the process was first performed using the 2017 FES data. This led to a number of refinements to the data and methodology used, which is presented here for the 2018 FES and will form part of the SPT RIIO-T2 planning scenarios.

It is intended that the analysis presented in this document is repeated again with the 2019 FES data. However, given overall timescales for developing the SPT RIIO-T2 submission, it is envisaged that this final update will only indirectly inform the price control submission, for example, a qualitative discussion in the event of material differences compared to the 2018 analysis.

1.3 Structure of this report

The structure of this report is as follows:

- Section 2 describes the core principles associated with the scenario methodology followed by a detailed description of the methodology for developing the evolution of:
    - Demand
    - Distribution-level supply
    - Transmission-level supply
    - Integration of supply and demand and consideration of flexibility requirements
- Section 3 provides the scenario results based on the 2017 FES data including results for:
    - Demand
    - Distribution-level supply
    - Net GSP supply/demand positions at Winter Peak and Summer Minimum (AM)
    - Transmission-level supply
    - Implications for system flexibility
- Appendices contain the following supplementary information:
    - Appendix A – describes the stakeholder engagement undertaken during this project
    - Appendix B – summarises the feedback provided by stakeholders on initial results and methodology
    - Appendix C – summarises the key load factor assumptions for each supply/demand element (where relevant) as this is central to informing GSP net demand at Winter Peak and Summer Minimum (AM)

The report is accompanied by a supporting Excel results workbook. This contains the full breakdown of results for each scenario, supply/demand element, by year and GSP (where relevant).

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2 Scenario development methodology

2.1 High level principles

The purpose of developing load planning scenarios is to allow SPEN, in conjunction with other supporting analysis, to understand the investment required on the SPT network under a range of credible pathways of the electricity system in its area. Initially SPEN will test a broad range of scenarios, before using these results to understand where the key sensitivities are for its network, develop a central scenario and mechanisms for adapting to uncertainties. When developing scenarios the following high level principles have been adhered to:

- Scenarios cover a wide range of likely possible outcomes
- Scenarios are holistic and internally consistent
- Assumptions are based on publicly available sources or SPEN internal views
- Methodologies are simple, transparent, and credible
- Scenarios informed by engagement with industry, Government and other key stakeholders

2.1.1 Use of FES

National Grid, the Electricity System Operator (NG ESO) produces an annually updated set of energy scenarios for Great Britain, the Future Energy Scenarios[6] (FES). The FES are a range of credible pathways for the GB energy system out to 2050. They represent possible demands for, and sources of, gas and electricity, in an interlinked and holistic manner, whilst also considering the wider set of energy system options that affect these (e.g. the role of bioenergy or district heating). In developing the FES, NG ESO gathers feedback from a wide range of stakeholders on the assumptions and approach taken.

The FES are widely used by industry, academics and government, providing a regularly updated and internally consistent set of whole energy system scenarios. The scenarios are not projections of how the GB energy system will develop and no probabilities for the likelihood of each scenario are given. The scenarios can, however, be used to understand the impact of different potential futures and the sensitivity to different assumptions.

The FES are presented on a GB wide basis, though NG ESO makes assumptions for each transmission zone independently before aggregating this to the GB total. NG ESO collaborates with SPEN in developing many of the assumptions for the SPT area.

In developing load planning scenarios for SPT we have drawn heavily on the FES, as these are generally regarded as being one of the best set of holistic energy scenarios for GB. In some cases the assumptions in the FES for the SPT area have been used directly to develop the scenarios outlined in

[6] http://fes.nationalgrid.com/

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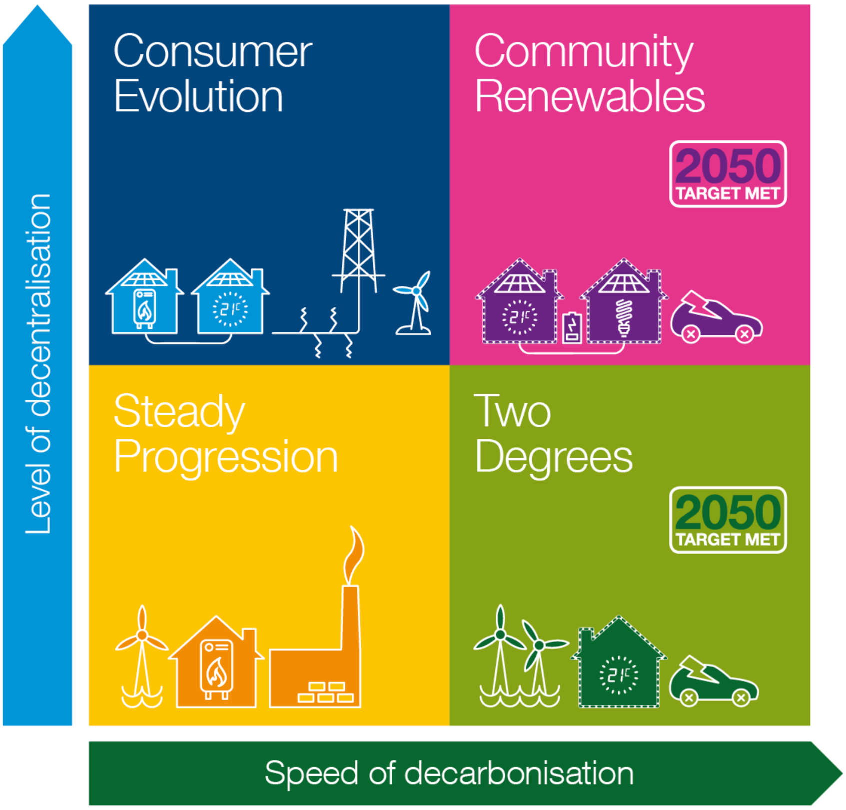
this document, either because they have been developed with SPEN or because they apply to GB and can reasonably be applied to SPT area.

However, in many areas the FES assumptions can be refined to better match local knowledge SPEN has of the SPT area, and where we can see reason to improve the assumptions we have done so, as documented in the following subsections.

In this report we have used the 2018 FES as the starting point, which has 4 scenarios as set out in Figure 9. The 2018 FES span two dimensions:

- **Level of Decentralisation:** how close the production and management of energy is to the end consumer
- **Speed of Decarbonisation:** how quickly reductions in carbon emissions across all sectors are seen, and whether the UK meets the Government's target of an 80% reduction by 2050

Figure 9 Future Energy Scenarios 2018[7]



[7] Image reproduced with permission of National Grid

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The following scenario descriptions have been reproduced with National Grid's permission from the FES 2018 main document:

Steady Progression

- This scenario is more centralised and makes progress towards, but does not meet, the 2050 decarbonisation target.
- Electricity demand: With a slower drive to decarbonisation, there are slower improvements in appliance efficiency and little electrification of heat. However, there is significant use of EVs, so smart technology is important for managing peak demand.
- Transport: The Government's aspiration for transport in 2040 is not met, though EVs are still the dominant choice for personal transport by 2050. There is also more of a role for natural gas-powered vehicles, particularly in the commercial sector.
- Heat: Most residential properties rely on gas boilers. There is limited use of heat pumps and smaller improvements in the thermal efficiency of houses. Decarbonisation of the heating sector is slow.
- Electricity supply: There is greater emphasis on large scale, rather than local, generation. There is development of nuclear power and offshore wind. Gas plays an important role in providing flexibility and gas-fired generation fitted with CCUS develops through the 2040s.
- Gas supply: Gas comes from the UKCS, Continental Europe, Norway and LNG, with additional supplies from shale gas.
- This scenario combines elements from Steady State and Slow Progression from FES 2017.

Consumer Evolution

- This is a more decentralised scenario which makes progress towards the decarbonisation target but fails to achieve the 80 per cent reduction by 2050.
- Electricity demand: There is a moderate rollout of smart charging of EVs. There are some improvements in energy efficiency with homes, businesses and communities focused and incentivised towards local generation, notably roof top solar, and local energy management.
- Transport: Private ownership of personal vehicles remains popular. The Government's aspiration for transport in 2040 is not met, though EVs are still the dominant choice for personal transport by 2050. There is a greater role for natural gas-powered vehicles, particularly in the commercial sector.
- Heat: Limited progress is made towards decarbonising heat. There are only small improvements in thermal efficiency. There is some progress in the rollout of heat pumps, but current heating technologies remain dominant.
- Electricity supply: Generation is focused on smaller scale renewables, with gas and batteries providing most of the system flexibility. Some new large scale nuclear power stations are built but there are also a number of small modular reactors. Greater emphasis on domestic and national energy solutions leads to lower levels of electricity interconnection.

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elementenergy

Baringa
Brighter together

- Gas supply: Gas from the UKCS, Continental Europe, Norway and LNG remains important in this scenario. However, by 2050, shale gas is the largest source of supply.
- This scenario builds on a blend of Consumer Power and Slow Progression from FES 2017.

Two Degrees

- In this scenario, NG explore how the decarbonisation target can be achieved using larger and more centralised technologies.
- Electricity demand: The use of hydrogen for heating helps reduce electricity demand, despite the widespread use of EVs. Smart technology is extensively used, alongside greater demand side actions to manage peak electricity demand. Appliances are more energy efficient to meet EU targets.
- Transport: The Government's 2040 transport aspiration is met. EVs become the most popular choice for personal transport. Increased use of public transport features in this scenario. For commercial vehicles, use of natural gas, and then hydrogen, become more widespread.
- Heat: As with Community Renewables, homes become more thermally efficient as there is a drive towards decarbonisation. By 2050 the dominant heat source is hydrogen, supported by a mixture of gas boilers, district heating and heat pumps.
- Electricity supply: Generation, such as offshore wind and nuclear, is based more on the transmission network. Flexibility is provided by interconnectors, larger scale storage and later, some large scale gas-fired plants fitted with CCUS technology.
- Gas supply: Gas from the UKCS, Norway and LNG remains important and NG explore the use of steam methane reforming to produce hydrogen. Some green gas is available.
- This scenario builds on Two Degrees from FES 2017, combined with hydrogen heating from the decarbonised gas sensitivity.

Community renewables

- In this scenario, NG explore how the 2050 decarbonisation target can be achieved through a more decentralised energy landscape.
- Electricity demand: With the drive towards decarbonisation, together with the high use of EVs and use of heat pumps, smart technology is used extensively to manage peak electricity demand. Appliance efficiency improves to meet EU targets and greater use of demand side actions are seen.
- Transport: The Government's aspiration to end sales of conventional petrol and diesel powered cars and vans by 2040 is met. EVs become the most popular personal mode of transport. Natural gas is used in heavy goods vehicles but, by 2050, hydrogen becomes the fuel of choice in this sector to aid the decarbonisation target.
- Heat: Homes become more thermally efficient, and heat pumps are the dominant technology. Green gas and increased use of district heating also have a role.

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- Electricity supply: Onshore wind and solar, co-located with storage, dominate the picture. This achieves the 2050 target without carbon capture utilisation and storage (CCUS). Flexibility is provided by small scale storage, small gas-fired plant, some interconnection, and hydrogen production by electrolysis.
- Gas supply: Gas from the UK Continental Shelf (UKCS), Norway and liquefied natural gas (LNG) remain important in the short and medium term. However, in this scenario, where the 2050 target is met without CCUS, there is significant development of green gas. In Community Renewables, hydrogen is only produced by electrolysis.
- Community Renewables builds on the consumer renewables sensitivity from FES 2017.

Within this section we have used selected scenario results to help explain the methodology taken in using the NG FES to produce scenarios for the SPT area. In many cases the scenario selected is Community Renewables, however it should be made clear that this is not due to Baringa or SPEN view this scenario as more likely to occur. Community Renewables has been used because it often has the largest change in demand and supply capacities of the four scenarios, and therefore shows the impact of methodologies more clearly.

The NG FES use three time periods per year to assess how supply and demand may change. These periods are based on the times of peak and minimum net demand seen on the GB transmission system, and include the effect of all distribution connected and behind the meter supply.

- **Winter Peak:** Period of peak net demand on the transmission system, assumed to be 17:00-18:00 on a winter (Nov-Feb) weekday
- **Summer Minimum (AM):** Period of very low net demand on the transmission system, assumed to be 5:00-6:00 on a summer (Jun-Aug) Sunday morning. This is the period of current minimum demand on the transmission system
- **Summer Minimum (PM):** Period of very net low demand on the transmission system, assumed to be 13:00-14:00 on a summer (Jun-Aug) Sunday after. For regions with significant volumes of solar PV capacity, their high expected output in the middle of the day could result in net transmission demand being at a minimum at this time.

In the SPT region the difference in net transmission demand in Summer Minimum (AM) and Summer Minimum (PM) periods is sufficiently high (AM is lower than PM), and the potential for additional PV capacity sufficiently low, that in all scenarios the Summer Minimum (AM) periods remains as the period of minimum net transmission demand. For this reason the analysis in this report focuses on Winter Peak and Summer Minimum (AM) only.

2.1.2 Macro Assumptions

The NG FES include several macro assumptions that influence the scenarios. In the main these have been left unchanged when developing scenarios for the SPT area. The key assumptions in terms of driving changes supply and demand that have been inherited from the NG FES are:

- **Population Growth:** In the FES a population growth from 64.3 million in 2017 to 70.6 million in 2040 is assumed across all scenarios.

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- **Energy efficiency:** The FES uses the EU's 2030 Climate and Energy Framework[8] as a benchmark the for the rate of decarbonisation, assuming that in the two high decarbonisation scenarios (CR and TD) there is a large improvement in energy efficiency at least equivalent to the EU 2030 target. For the two other scenarios there is limited progress. A similar split exists for the appliance efficiency.
- **Economic Outlook:** I&C demand in the FES is modelled assuming Gross Domestic Product (GDP) grows at a rate of 2.0% for the high growth scenarios (CR and TD) and 0.9% for the low growth scenarios (CE and SP).
- **EV population:** The EV uptake in the FES is influenced by the government's target for nearly all new cars and vans sold by 2040 to be zero emission[9]. Two of the FES scenarios (CR and TD) comply with this target and show strong EV uptake, for the other two scenarios uptake is lower, but EVs are still expected to become dominant after 2040.
- **Supply technology load factors:** The FES uses load factor assumptions for the expected output of supply and storage technologies at different times of the year. These assumptions are based on observed output from recent years, and are selected to reflect stress on the system at periods of peak and minimum net demand.

In developing the SP FES the following additional high level assumptions have been made:

- **Grid Supply Points:** The SP FES results are provided for all current GSPs, without assuming any splitting or new GSP sites. The changes in supply and demand at existing GSPs identified in the SP FES will be used by SPEN when planning investment, which may include the splitting of GSPs or other changes – but any changes will be a result of the analysis described in this report rather than being an input to it.
- **Network constraints not a barrier to change:** Changes in supply and demand technologies have been applied without consideration of current or future network constraints. SPEN are committed to providing a network that is not a barrier to changes in energy production and consumption, and will use the SP FES to ensure that appropriate investments are made to allow this at lowest cost.

2.1.3 Stakeholder engagement

Stakeholder feedback has been key in designing a robust approach to scenario development. We have worked with SPEN to identify a wide range of stakeholders, and develop a stakeholder engagement plan.

This has involved:

- Bilateral conversations with other network operators (including SSEN and NGTO) to discuss the proposed approach to scenario development
- Bilateral conversations with NG FES team and Scottish Government to discuss their assumptions

[8] https://ec.europa.eu/clima/policies/strategies/2030_en
[9] https://www.gov.uk/government/news/plan-for-roadside-no2-concentrations-published

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- Workshop with SPEN internal stakeholders (from both SPT and SPD) to get feedback on approach and draft 2017 FES results
- Workshop with SPT External Stakeholder group (including representation of academia, skills bodies, consumers, local government, Ofgem, and others) to get feedback on specific areas of uncertainty and assumptions, including briefing note on use of FES

A full log of the stakeholders contacted as part of this project is included in Appendix A.

A public summary document has been prepared in conjunction with this report that details the results using the 2018 FES data, and further meetings to discuss the results will be held with relevant stakeholders.

2.1.4 Technologies considered

In developing the scenarios we have considered a wide range of demand and supply technologies, at different grid levels. We have divided demand and supply into the following categories:

Figure 10 Technologies considered

Demand and behind the meter supply	Distribution connected supply	Transmission connected supply

• Domestic
• Industrial and Commercial (I&C)
• Heat Pumps (Domestic)
• District Heating (large scale heat pumps)
• Electric Vehicles
• Vehicle-to-grid
• Behind the meter PV
• Home battery storage
	• Wind
	• PV
	• Hydro
	• CHP
	  - Renewable
	  - Non-Renewable
	• Controllable
	  - Renewable
	  - Non-Renewable
	• Storage
		• All likely technologies considered

For each technology the key metric is the supply/demand on the system at specific points in time, specifically at Winter Peak and at Summer Minimum (AM). We have developed capacity projections for each technology and also an understanding of how each technology may operate, to allow the net supply/demand from each technology to be calculated.

2.2 Overview of SPT's licence area and GSPs

The SPT licence area covers Central and Southern Scotland, as shown in Figure 11. This area lies between two key Transmission boundaries; B4, shared with Scottish Hydro-Electric Transmission, to the north, and B6, shared with National Grid Electricity Transmission, to the south.

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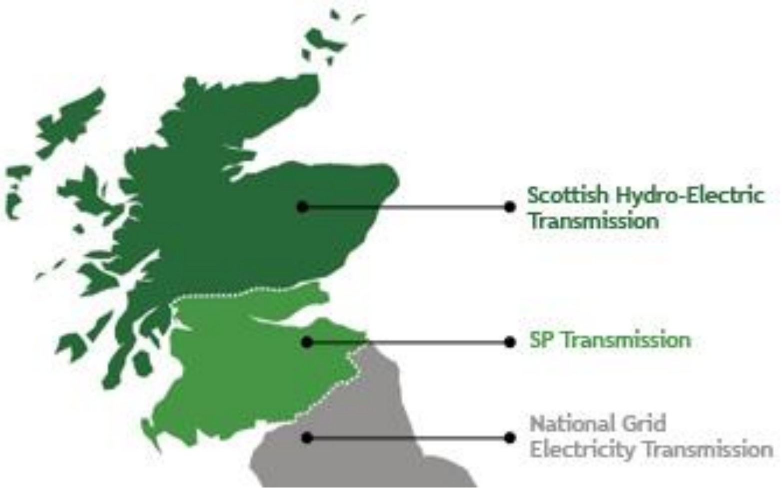
Figure 11 SPT Area with neighbouring Transmission Operators



The SPT network supplies the SPD distribution network below it, through a series of Grid Supply Points (GSPs). There are 90 GSPs in the SPT area, heavily clustered around the urban centres of Edinburgh and Glasgow, as shown in Figure 12.

We have supplied results for distribution connected demand and supply technologies at a GSP level, to allow SPT to understand the potential loads on its system over the RIIO-T2 period.

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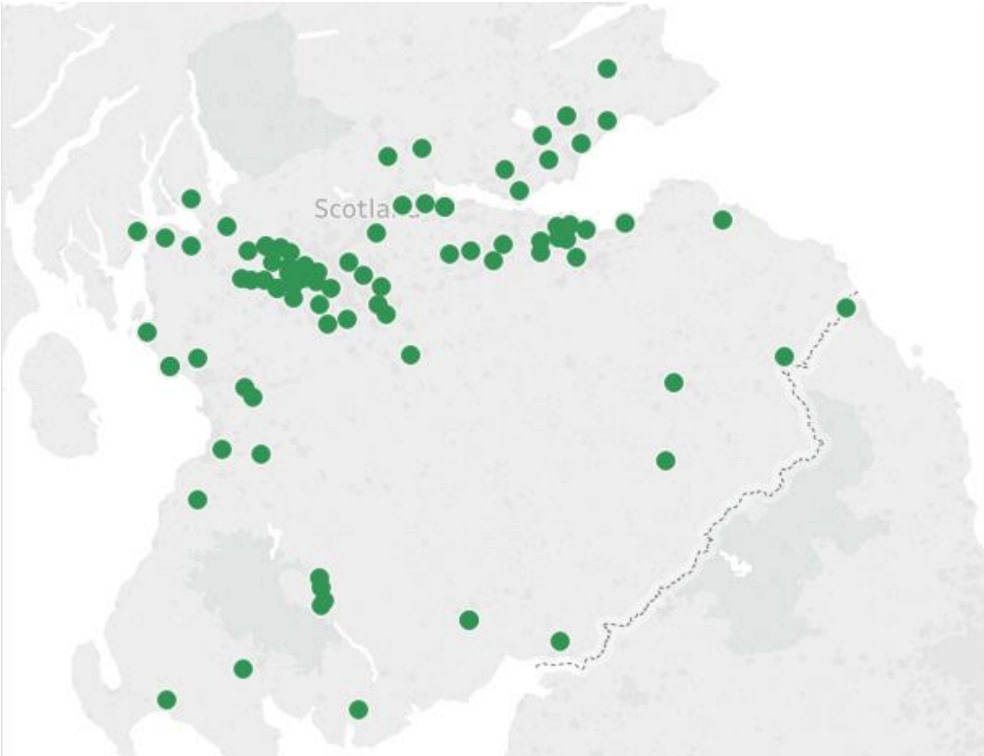
Figure 12 SPT Area with location of all GSPs



2.3 Demand and behind the meter supply

2.3.1 Introduction

In this report the following definitions of demand are used:

- **Underlying Demand:** All primary consumption of electricity. This includes domestic demand from lighting, appliances, cooking, non-domestic demand, and new sources of demand from electric vehicles and heat pumps.
- **Metered Demand:** All demand as metered from the distribution network. This includes all underlying demand but is altered by behind the meter supply and storage technologies (ie output from domestic level solar PV will reduce metered demand).
- **Net Demand:** The net demand/supply seen by the transmission network. This includes all metered demand and distribution connected supply and storage technologies (ie output from distribution connected wind generation will reduce net demand).

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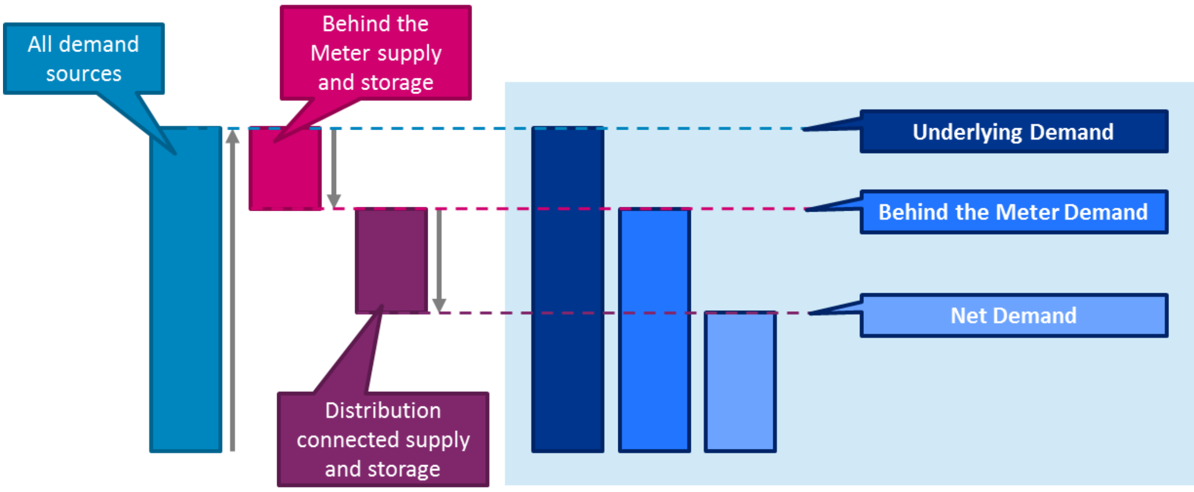
Figure 13 Demand definitions used in this report



In order to have a clear view of the underlying demand and behind the meter supply on the network, the uptake of the following components has been modelled separately:

- Domestic Demand
- I&C Demand
- Heat Pumps (HPs)
- District Heating (DH)
- Electric Vehicles (EVs)
- Vehicle-to-grid (V2G)
- Behind the meter Photovoltaics (PVs)
- Home Battery Storage

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Each of these components is modelled at GSP level and then combined to determine the metered demand per GSP at the Winter Peak and Summer Minimum (AM) demand periods. This metered demand is combined with distribution connected supply to determine the net demand/supply balance at GSP level.

The following subsections describe the methodologies used for each of the components and discuss how the FES data has been combined with other sources to ensure the projections for each component are appropriate for the SPT area.

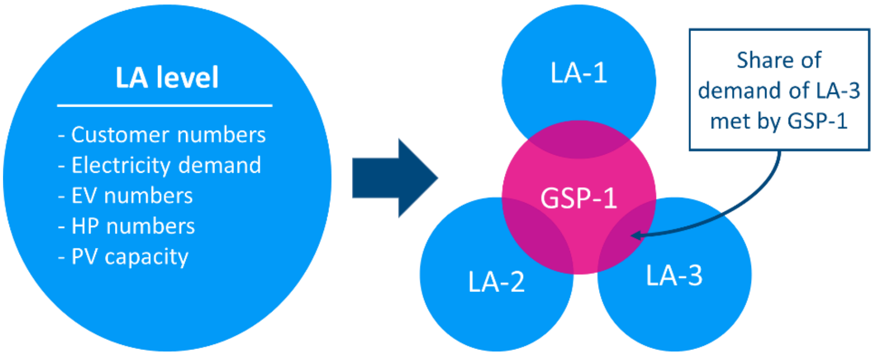
2.3.2 FES data availability

In the 2018 FES, demand data for all components were provided at GSP level by National Grid. Some of these data could be used directly by the model, but in most cases extra analysis was performed to improve the spatial allocation based on a more in-depth understanding of the SPT area. This analysis requires mapping of certain datasets from local authority (LA) level to grid supply point (GSP) level, a many-to-many mapping.

The mapping tool created for this analysis uses postcode data per GSP provided by SPEN[10], postcode data per LA from the ONS[11], and postcode level domestic electricity consumption from the BEIS "Sub-national electricity sales and numbers of customers (2005-2016)"[12]. Combining these datasets allows the fraction of the electricity demand in each LA that is connected to each GSP to be calculated, as shown in Figure 14. It should be noted here that even though the spatial mapping is based on the electricity demand, the assumption has been made that the same mapping can also be applied to domestic customer numbers, EVs, HPs and PVs. This assumption is necessary because the supporting data on customer numbers, EVs, HPs, and PVs is not available at the spatial resolution required for accurate mapping to the GSP. This is a simplifying assumption as in practice the distributions will not be uniform, but as a first approximation it seems reasonable to allocate these primarily domestic technologies based on domestic consumption.

[10] LVBusbar Postcode Data – CK updated 28022018
[11] Office for National Statistics – through https://www.doogal.co.uk/PostcodeDownloads.php
[12] https://www.ov.uk/government/collections/sub-national-electricity-consumption-data

Figure 14 Schematic of LA to GSP mapping

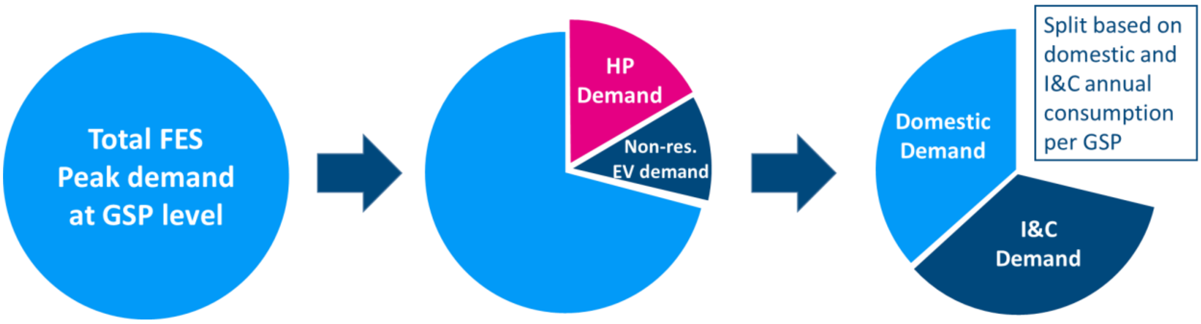


2.3.3 Domestic demand

The underlying domestic demand at GSP level provided directly by National Grid in the FES data has been used without significant alteration. However, in some cases the FES allocated domestic demand to GSPs without domestic customers, or gave unexpected outliers for a few GSPs. For this reason, a few alterations have been made, to provide domestic demand that is more representative of the SPT area, as described below.

To determine the domestic demand, the model uses the total demand at GSP level according to the FES - i.e. the sum of HP, domestic, industrial and commercial demand (non-residential EV demand is included in the FES I&C demand, residential EV demand is treated separately). The behind the meter HP demand is separately provided by the FES and subtracted from the total demand. The non-residential EV demand is calculated as described in Section 2.3.7 and subtracted also. The demand that remains is split into domestic and I&C demand based on the share of annual demand[12] of each component. This share is found by mapping the domestic and I&C annual demand[12] from LA to GSP level according to the mapping approach as described above. A schematic representation of the process is shown in Figure 15.

Figure 15 Schematic domestic and I&C peak underlying demand methodology



Rather than implementing a fixed split of Domestic and I&C peak demand per GSP over the period to 2040, the model reflects the expectation that demand will develop differently in these sectors over

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time – based on varying assumptions on changes in efficiencies and DSR – and therefore adjusts the split accordingly.

2.3.4 I&C demand

The I&C underlying demand follows directly from the procedure shown in Figure 15. However, when determining the share of I&C demand per GSP, the model accounts for the fact that the mapping based on domestic consumption is not directly applicable to I&C demand, by application of a correction factor.

As well as estimating the I&C demand per GSP based on domestic demand share, the mapping tool also provides the number of I&C customers (based on the sub-national customer data[12]), which allows for a comparison with the actual number of I&C customers at GSP level as provided by SPT[13]. The mismatch found between the customer numbers per GSP has been used to correct the I&C annual demand per GSP.

It should be noted here that in the model the split between domestic and I&C demand per GSP is assumed to be the same at Winter Peak as at Summer Minimum (AM) – i.e. based on the share of annual demand. This may not be exactly representative of the actual split at Summer Minimum (AM) in particular, but the difference is expected to be limited and as the sum of domestic and I&C demand per GSP remains the same, the impact on the network will be small.

2.3.5 Heat Pumps

The behind the meter HP demand at both Winter Peak and Summer Minimum (AM) is provided by the FES at GSP level, allocated based on the share of domestic demand per GSP. However, in order to make the HP demand more representative within the SPT area, two 'suitability factors' have been chosen to spatially re-allocate the HP demand:

- Off-gas Fraction
- New Build Rate

According to DECC[14] HPs are most likely to be installed in rural areas where homes are less clustered, starting with buildings off the gas grid, which are most likely to have space and be using expensive fuels. Off-gas postcode data from Xoserve[15] has been used to determine the fraction of off-gas grid homes per GSP, which has been used as the first suitability factor. The second suitability factor is based on the fact that HPs perform best in well-insulated buildings, and are therefore much more

[13] Load Type and Customer Numbers
[14] The Future of Heating: Meeting the Challenge. DECC [2013]
[15] Xoserve off-gas postcodes: http://www.xoserve.com/wp-content/uploads/Off-Gas-Postcodes.xlsx

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likely to be installed in new builds. Statistics on the new builds per local authority[16] have been mapped to GSP level to come up with the growth percentage per GSP.

The two suitability factors have been normalised to ensure they are accounted for with the same weighting and multiplied to derive the relative suitability score for each GSP. This score is then combined with the percentage of domestic consumption per GSP, which accounts for the size of the GSPs, in order to determine the fraction of the total HP demand that will be assigned to each GSP.

The uptake of the HP peak demand to 2040 is included in the FES data and is left unchanged for the SPT area. Uptake of HPs is strongest in the high decarbonisation scenarios, partly enabled by the increase in energy efficiency as a result of government policies assumed in the FES (see Section 2.1.2). However, as the penetration level of households with HPs remains fairly limited in all scenarios until 2040 (i.e. between 5% and 28%), it has been assumed that the suitability factors could be applied equally for all years in the model. This assumption has been checked by comparing the number of HPs in 2040 - for the scenario with the strongest HP uptake (Community Renewables in the 2018 FES) - with the amount of suitable dwellings (off-gas and new builds). It shows that even in this high uptake scenario only slightly more HPs than suitable dwellings are expected to be installed by 2040, and therefore the assumption to equally apply the suitability factor until 2040 is reasonable.

We envisage that the same methodology will be applied when the SPT scenarios are refreshed with 2019 FES data next year. However, if it is the case that the 2019 FES data has significantly stronger HP uptake, there may be a justification for distributing the HP demand based only on the share of domestic demand per GSP from a certain year onwards, similar to the cluster growth approach used for EVs and PVs (Sections 2.3.7 and 2.3.8).

The approach taken in this analysis ensures that the total demand in the SPT area stays in line with the FES but improves the spatial allocation at GSP level to make the data more representative of the SPT region. The development of the building level peak demand based on the components described above is shown in Figure 16.

[16] https://www.nrscotland.gov.uk/files//statistics/household-projections/2014-based/tab/2014-house-proj-table6.xlsx

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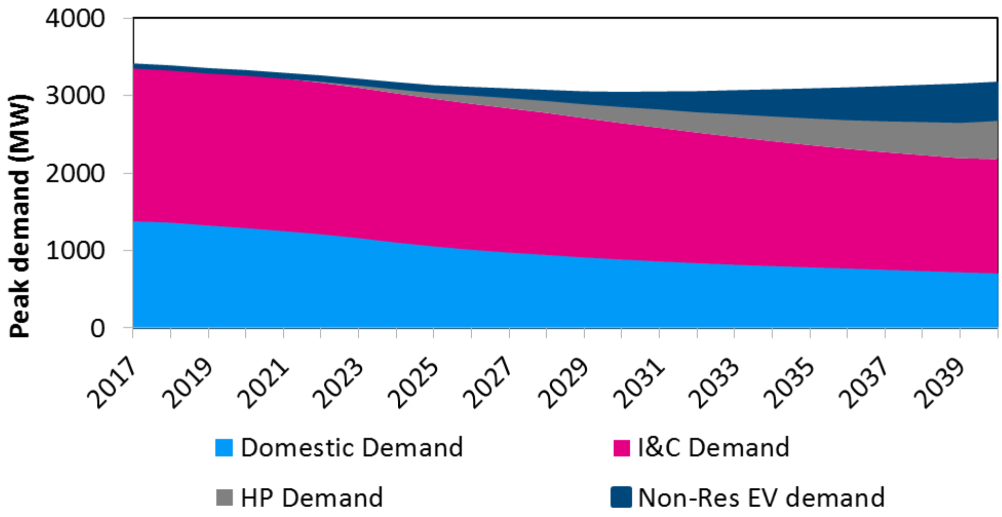
Figure 16 Building level underlying demand for SPT area, Winter Peak, Community Renewables



2.3.6 District Heating

The electricity demand of District Heating (DH) at peak and Summer Minimum (AM) is provided at GSP level in the 2018 FES data, allocated to each GSP by the FES based on their share of domestic demand. To improve the spatial allocation, the DH demand has been re-allocated based on the domestic heating demand density[17] per GSP instead, and a minimum scale of 50 kW has been observed to avoid allocating unrealistically small DH systems to the GSPs. This low threshold has been assumed such that the model includes the potential deployment of small scale communal heating systems, where a heat pump provides the baseload heating.

2.3.7 Electric Vehicles

In the 2018 FES multiple EV types are taken into account. However, privately owned cars are still the only vehicles which are expected to have an impact on the network at peak time. National Grid assumes that heavy goods vehicles and buses will have managed overnight depot charging, hence actively avoid peak periods, and that light delivery vehicles, vans and other fleet vehicles, will be charging overnight and will be operating at peak time. For the private cars, the FES assumes that 67.4% of the EVs charge at home (Residential), and the remainder will charge at forecourts or at public charge points (Non-residential).

The 2018 FES data contains the residential EV demand per GSP as well as information on the demand per EV, which enabled the calculation of the number of EVs per GSP. These values were compared to the number of plug-in vehicles per LA[18] according to the Department for Transport (DfT), mapped to GSP level, which shows that both approaches gave comparable results. However, as the FES EV data

[17] http://heatmap.scotland.gov.uk/
[18] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/689647/veh0131.ods

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is based on the DVLA[19] dataset, which has a better spatial resolution, the FES values are expected to be more accurate and have therefore been used as the starting point for the EV numbers.

The current EV numbers are compared to the current number of cars per LA[20] mapped to GSP level to determine which GSPs have high levels of early EV uptake, i.e. “clusters”. The FES assume that the current clusters of EVs will start spreading out until an equal penetration of EVs is achieved by the time that the total number of EVs in GB reaches 5 million. The approach used in the model is similar, but it assumes that current clusters will remain until an EV penetration level of 16% (which is comparable to 5 million EVs in GB) is reached before they start spreading out towards an equal distribution at 50% penetration. These percentages are based on the assumption that EV uptake follows the ‘Innovation adoption lifecycle’.

The adoption lifecycle is a sociological model which describes the adoption or acceptance of a new product or innovation. It illustrates the adoption of a technology over time as a ‘bell curve’ (Figure 17), indicating that a new product will initially be accepted by innovators and early adopters, before it will be taken up by the majority of consumers. For the uptake of EVs in the SPT area we assume that EV clusters remain until the end of the early adopter phase, after which they will start to spread towards equal distribution at the end of the early majority phase. The years for which these phase transitions occur differ for each scenario. As an example, the EV uptake in two GSPs is shown for the Community Renewables scenario in Figure 18.

To further improve the spatial allocation of EVs, we considered using a high average income per GSP as a proxy for strong expected EV uptake. However, preliminary analysis showed that the clusters found based on the DVLA approach largely matched the GSPs with high income, and it was therefore deemed unnecessary to enhance the clustering approach.

[19] DVLA. Vehicle registration by postcode and body type and propulsion in 2015.

[20] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/623742/veh0105.ods

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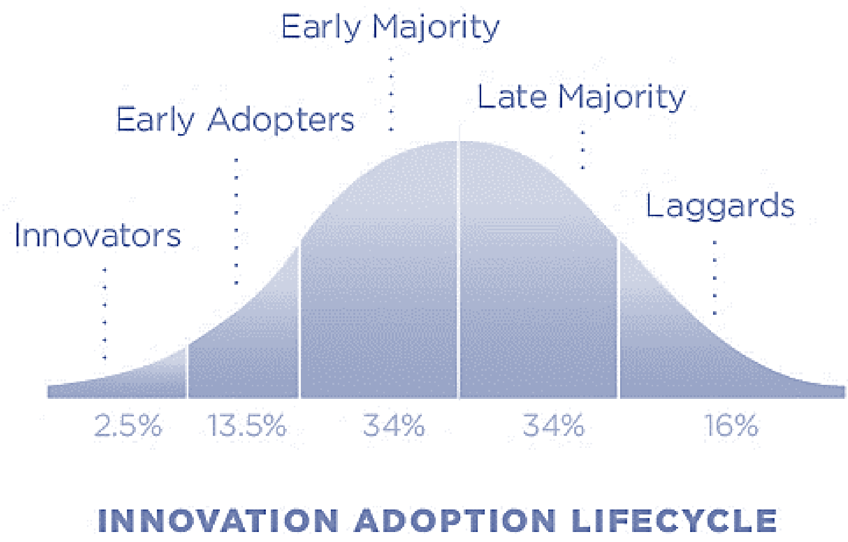
Figure 17 Bell curve illustrating the Innovation adoption lifecycle[21]



The Winter Peak and Summer Minimum (AM) demand per EV have been derived directly from the FES for both residential and non-residential charging. The FES data also accounts for the change in efficiency of cars over time. The number of EVs per GSP that charge at home can simply be multiplied by the demand per EV to calculate the total residential EV demand at the time of peak and Summer Minimum (AM). The demand due to non-residential charging[22] is derived in the same way. A portion of this charging demand is assumed to be "flexible" and can be shifted away from peak demand periods[23], as discussed in Section 2.3.11.

[21] CC BY 2.5, https://en.wikipedia.org/w/index.php?curid=11484459

[22] Note that in the FES this non-residential EV demand is included in the I&C demand and is therefore subtracted from the total FES demand (Section 2.3.2) to calculate the domestic and I&C demand.

[23] Flexible charging may be enabled by smart meters and time of use tariffs, DUoS reform etc. The FES do not make explicit assumptions about these underlying factors, but gives a wide range in flexibility volumes, reflecting the uncertainty around this area of technology and policy.

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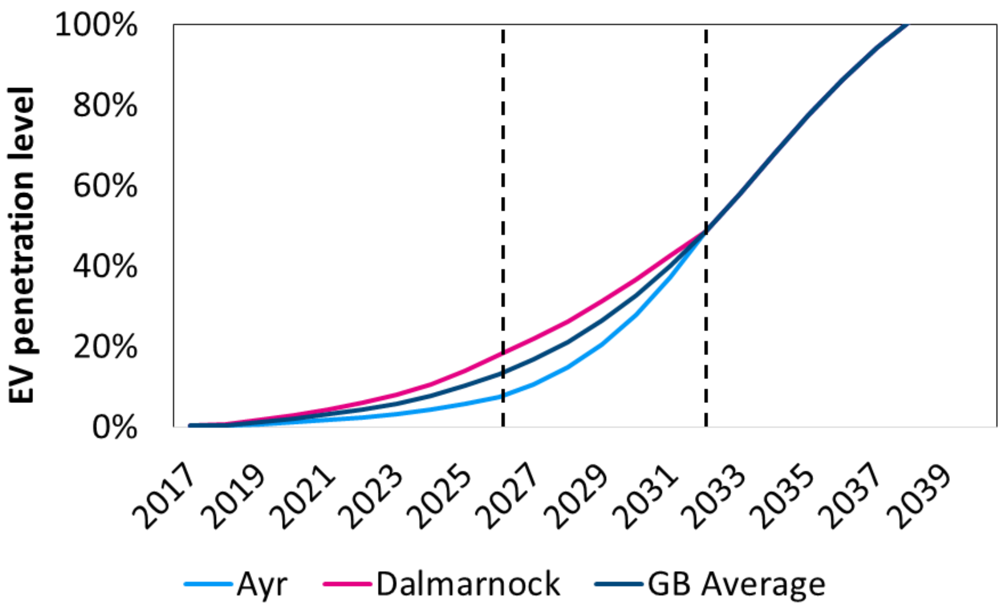
Figure 18 EV uptake in two SPT GSPs as compared to the GB average (based on the 2017 total car population), Community Renewables scenario



2.3.8 Vehicle-to-grid

In the 2018 FES data the vehicle-to-grid (V2G) capacity is included for the whole of GB. The capacity is calculated by the FES by assuming a certain percentage of consumers will make use of V2G, ranging from 2% for all scenarios in 2030 to 10-13% in 2050. Our model allocates this V2G capacity to each GSP based on its share of EVs (i.e. with respect to the total amount of EVs in GB).

As there is much uncertainty around how much of the V2G capacity will actually end up being used, the model does not assume a 'usage' factor, but simply presents V2G as available capacity. This way the model provides data that can assist in the decision-making process, without forcing the network operator to assume a certain amount of V2G in its network planning.

2.3.9 Behind the Meter PV

The FES data provides the PV capacity at GSP level based on the Feed-in Tariff[24] (FiT) data, which is directly used in the model. For the uptake of PV the FES simply assumes the distribution per GSP will remain unchanged. However, similar to the case of EVs, it is expected that once behind the meter PVs become more common, they will become more equally distributed (in this case according to the domestic demand). Therefore, the model assumes that after the early adopters phase the distribution of PV grows towards an equal spread in the year that PV penetration has reached the end of the early majority phase. The year in which this occurs will depend on the scenario, and it should be noted that because of the slow PV uptake in Scotland the technology only reaches the early majority phase in the Community Renewables scenario.

[24] https://www.gov.uk/government/collections/feed-in-tariff-statistics

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To further improve the allocation of PV we considered whether more behind the meter PV should be assigned to GSPs with a high percentage of rural area which have more space to install PV systems. However, preliminary analysis again indicated that this preference for rural is already present in the FiT data and therefore the PV has not been spatially re-allocated any further.

It should be noted that the load factors for PV are extremely low at Winter Peak time (0%) and Summer Minimum (AM)[25] (4%). As a result of this, the impact of PV on the network at GSP level is expected to be small.

2.3.10 Home battery storage

The FES battery data is split into three sets (i.e. domestic, distribution connected and transmission connected) and can therefore be used directly. For the spatial allocation of storage the FES assumes it will be deployed in similar locations as renewables, and we therefore ensure that the uptake of home storage will follow the adapted uptake of domestic PV as described above.

Assumptions on the (dis)charging behaviour of the batteries is included in the FES data. Batteries will only discharge at Winter Peak time, with a load factor of 87% and will charge at Summer Minimum (AM) with a load factor of 60%[26].

2.3.11 Flexibility

2.3.11.1 Introduction

The values determined by the model represent the 'inflexible demand' as many assumptions on DSR and smart charging are already taken into account in the FES. In order to get a better understanding of the impact of flexible demand, information on the assumed flexibility has been provided by National Grid that enables us to also model 'total underlying demand' – i.e. the sum of the inflexible and flexible demand. Figure 19 shows the breakdown of all underlying demand into the flexible and inflexible components, for the Community Renewables scenario at Winter Peak.

It should be noted that there is assumed to be no load reduction at Summer Minimum (AM), consistent with the FES. In reality there is the potential for demand turn up, but this is expected to be low in magnitude and is not explored in this analysis.

There is significant uncertainty around what the level of future demand flexibility will be. Ofgem's ongoing review of network access and forward looking charges[27] could change the incentives on

---

[25] The time of summer minimum is based on the time of minimum metered demand on the GB transmission system according to National Grid and is therefore affected by the PV penetration level. However, due to the fairly limited amount of PV on the SPT network in all scenarios, the time of summer minimum is expected to remain unchanged, occurring in the very early morning.

[26] NGET FES – Distribution and Micro Load Factors

[27] https://www.ofgem.gov.uk/system/files/docs/2017/11/reform_of_electricity_network_access_and_forward-looking_charges_-_a_working_paper.pdf

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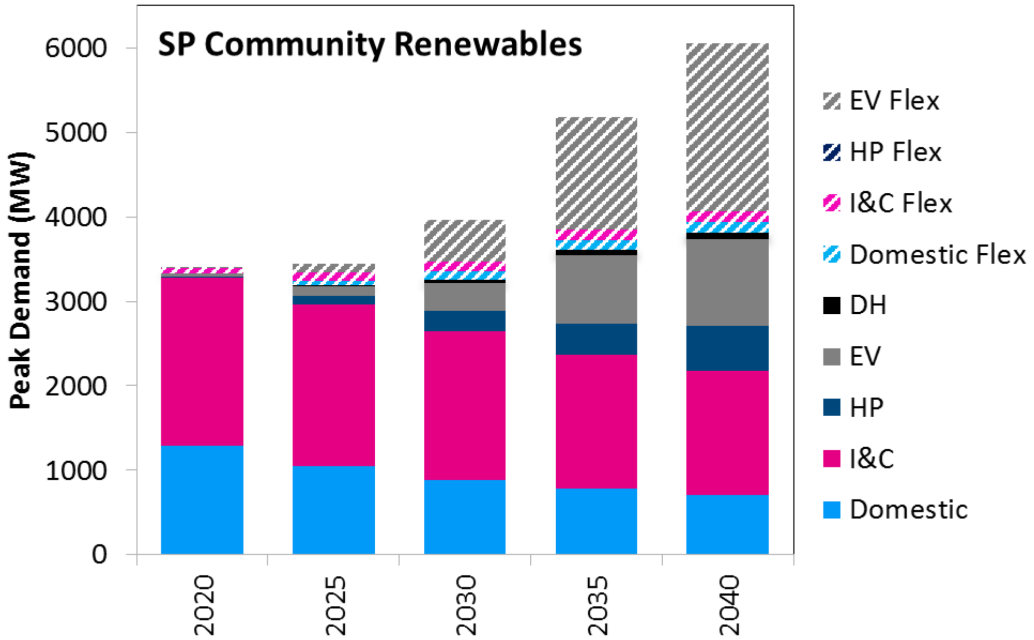
consumers to provide flexibility. For example, sharper, more granular DUoS (Distribution Use of System) price signals to residential customers could encourage those customers to shift usage away from peak times. However, the nature of such incentives, and the behaviour of consumers in response to such incentives, are very uncertain. The FES are not explicit around the underlying assumptions that result in the levels of flexible demand shown in Figure 19, but have a wide range across the 4 scenarios, reflecting the current uncertainty.

Figure 19 Inflexible and flexible underlying demand in the SPT area, Community Renewables



2.3.11.2 Domestic

In the case of domestic demand flexibility, National Grid's assessment of the impact of smart appliances, time of use tariffs and consumer behaviour has been used directly. The FES show a wide range in flexibility, as shown in Figure 20 for Winter Peak periods (shown as a percentage reduction of total load).

An important enabler for domestic demand side response is the smart meter, which is currently being rolled out to all households in GB. The FES recognises that the rollout programme faces some substantial challenges if the 2020 targets are to be met, but assumes that in the Two Degrees and the Community Renewables scenarios the rollout is achieved according to the original programme. In the other scenarios rollout is expected to be slower and the rollout profiles have therefore been extrapolated so that they meet the 2020 target two years later.

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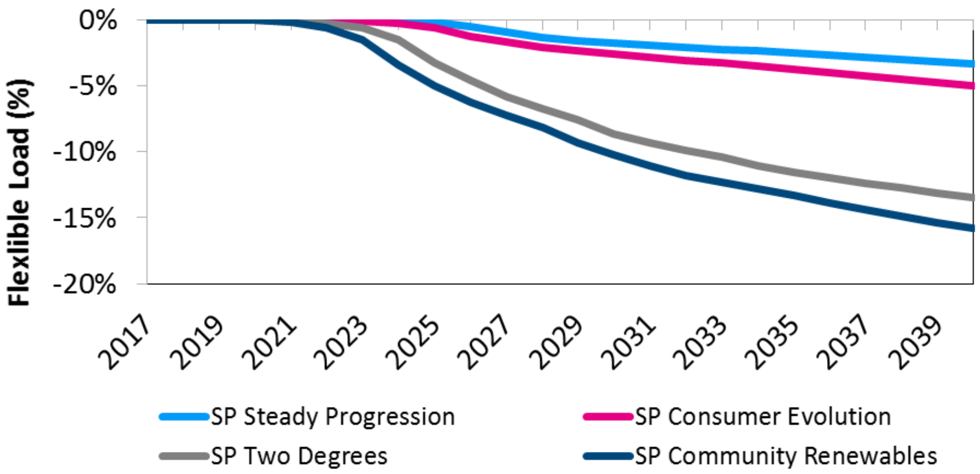
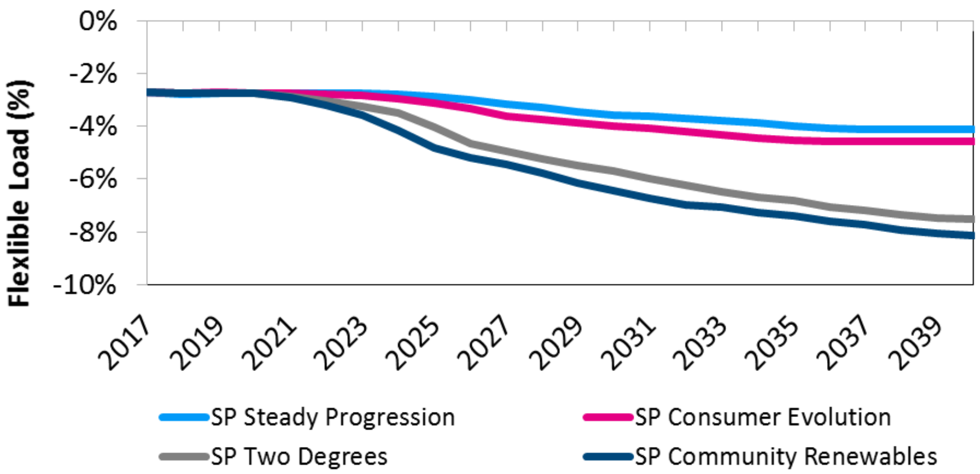
Figure 20 Flexibility of domestic demand



2.3.11.3 I&C

The 2018 FES provide the total GW that will become available through I&C DSR in GB as a whole, and this has been used to calculate the percentage of DSR based on the total I&C peak demand. The current levels of flexibility of I&C demand are already significant and larger than the flexibility of the domestic demand. The main reasons for this are that larger I&C customers are easier to engage with and their electricity consumption is already half-hourly metered, which is required to determine the actual amount of demand reduced and hence the payment. For the two strongest scenarios it is assumed that the percentage of flexible load will increase significantly towards 2040, whilst for the other two scenarios little change is expected.

Figure 21 Flexibility of I&C demand



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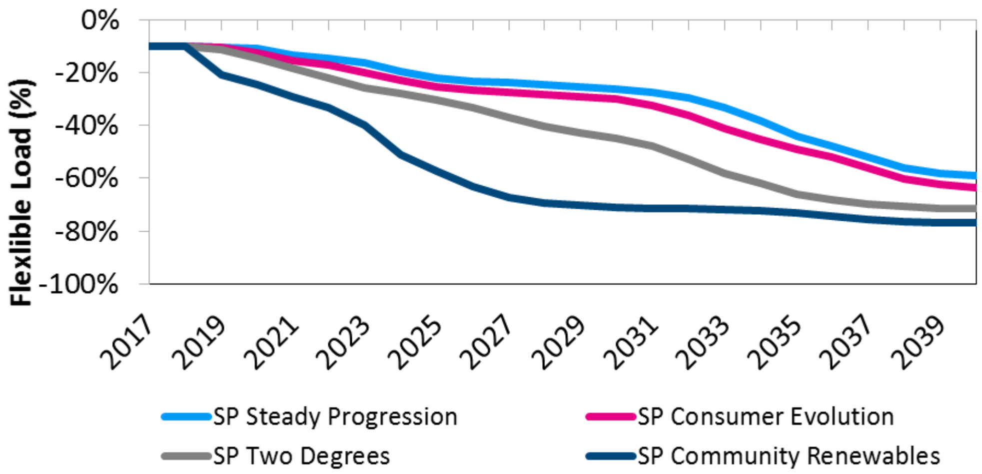
2.3.11.4 *Electric Vehicles*

National Grid has provided SPEN with flexibility assumption for EV charging, consistent with the 2018 FES data, which has been used directly in the SP FES. For residential EV charging, engagement with smart charging is expected to be high for all scenarios (Figure 22), which will result in a large amount of flexible EV load available to the network. For non-residential (i.e. destination and forecourt) charging the flexibility of the non-residential EV demand is assumed to be 0% for all scenarios.

Figure 22 Flexibility of EV demand



2.3.11.5 *Heat Pumps*

HP demand is assumed to be entirely inflexible in the 2018 FES because consumers are expected to be not engaged with reducing their heating demand at peak times. One of the reasons for this is that few consumers have dedicated thermal storage and therefore cannot shift their heating demand without reducing their comfort levels, which they are unlikely to do. The impact on the network of this assumption is fairly small because of the limited expected HP uptake in the SPT region.

2.3.12 Summary

The underlying demand and behind-the-meter supply has been modelled in close alignment with the FES. Wherever possible both the current values as well as the growth rates have been directly taken from the FES, but in some cases separate data sources were required to either disaggregate the data into separate components of the underlying demand, or to improve the spatial allocation.

Based on the information provided by National Grid on the flexibility assumptions in the 2018 FES data, the model is now able to accurately provide the share of demand that is flexible, giving a clear picture of the difference between the inflexible and the total (i.e. inflexible + flexible) underlying demand on the network.

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2.4 Distribution connected supply/storage

2.4.1 Introduction

Supply and storage technologies that connect directly to the distribution level network contribute to the net supply/demand seen at on the SPT network through Grid Supply Points (GSPs). Estimating the quantities and locations of these technologies is critical to planning load on the SPT network.

We have separated distribution (DX) connected technologies into the following types:

- Wind
- PV
- Hydro
- CHP
  - Renewable
  - Non-Renewable
- Controllable
  - Renewable
  - Non-Renewable
- Storage

In the following subsections we discuss the overall approach taken when applying the FES assumptions for DX technologies to the SPT area, and the specific methodologies used for each of the technology types above.

2.4.2 Overall approach

The FES provide a good estimate of where distribution (DX) connected technologies are *currently* connected to. The current capacity of each technology type for each GSP has been developed by NG in close collaboration with the Distribution Network Operator (DNO) for the South of Scotland, SPD. The 2017 year-end values used in the 2018 FES can be thought of as the best view of SPD at the time of agreeing these assumptions in early 2018.

The FES grows the capacity of DX connected technologies using a single growth rate for each technology for the whole of GB, which scales the capacity of technologies by the same amount for a given scenario and year, regardless of location. This growth rate seeks to capture the average growth across GB, but does not capture how growth may differ by region and for individual GSPs.

2.4.3 Current Capacity

Our approach for most technologies has been to use the FES capacities by GSP for 2017 directly, without alteration, as these represent SPD's internal view of current capacity (as of early 2018). Total capacity for the SPT Area is calculated as the sum of all SPT GSPs.

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CHP and Controllable generation technologies are combined into an "Other" category in the FES SPT data. For these technologies we have not used the capacities in the FES, and have instead used SPD primary data, in this case its live (as of 4th June 2018) database of embedded generation[28], published as part of the SPD Long Term Development Statement (LTDS). This database includes all connected embedded generation projects, with a description of their connection GSP and generation/storage type. Using this information, it has been possible to calculate the capacity of Controllable and CHP distributed generation currently connected to each GSP.

2.4.4 Near Term Capacity

For the period 2018-2020 we do not use FES assumptions, but rather use SPEN's view of potential distribution connected projects. SPD has information of specific projects that are seeking connection on its network, which is not available to NG when developing the FES. This project information improves upon the GB average growth rates in the FES, and is at a GSP level.

Though SPD have a good view of potential projects that may connect to the SPD network, there is still significant uncertainty in identifying exactly which projects will be built, for two key reasons:

1. SPD only know about projects that have submitted a connection application, but some projects can be built within a couple of years of submitting an application
   - It is likely that there will be some applications received within 2018 that will be built within 2019-2021, which are currently not visible to SPD
2. Many project developers apply speculatively for connection agreements, as a way of de-risking part of a project, without having fully tested other areas of the project business case
   - The number of applications SPD receives is far above the number of projects that are finally built

To reduce the impact of the first point we have limited the horizon for using SPD projection information to 2 years, 2018-2019. This reduces the risk of missing out some "known-unknown" projects, that are not currently visible to SPD but will in reality be built within the period covered.

To reduce the impact of the second point, a High/Medium/Low ranking has been applied to all projects seeking a connection agreement, using connection status, planning status, and other local market information. "High" ranked projects are assumed likely to go ahead, typically having gained a connection agreement, planning consent, and have started construction. Taking the sum of unique "high" ranked projects with assumed energisation 2018-2019, an annual increase in embedded generation/storage capacity of 167MW/year is projected. This matches well with the historical growth rates seen 2015-2017, 155MW/year, as shown in Table 2.

The methodology above gives the SPEN central view of which projects are likely to connect in the near term, but there is still uncertainty around the projection – some projects may be cancelled or delayed, or some well advanced "known unknown" projects may come to SPD seeking a connection agreement for imminent energisation.

[28] By "embedded generation" we mean any generation technologies connected directly to the distribution network.

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To reflect this uncertainty we have taken the range of annual growth seen 2015-2017 to give High/Medium/Low growth rates, and mapped these to the scenarios being studied, based on propensity to decarbonise and propensity to decentralise, as shown in Table 3. It can be seen that the SP assumptions have the same Low growth rate, but have much higher Medium and High growth rates. This reflects the local knowledge SPEN has of potential projects, and matches growth that has been seen historically in the SPT area.

In each of the SPT scenarios, the list of High probability projects is scaled in capacity so that a) capacity increases are shared evenly over 2018 and 2019, and b) the total capacity increase matches the High/Medium/Low values in Table 2. For Medium growth scenarios this means that capacity increases by the end of 2019 match well the central SPEN projection of high probability projects, capturing the expected growth per GSP. In the Low and High growth scenarios, capacity increases are scaled to match the relevant growth rates in Table 2. This ensures that the same GSPs are affected in each scenario, matching the SPEN central view of likely projects, but the total increase over the SPT area is varied to reflect the uncertainty of these projects, even over a relatively short 2 year horizon.

Table 2 Embedded generation/storage growth 2015-2017

	MW/year	Ranking
Actual capacity increase 2015-2016	259	High
Actual capacity increase 2016-2017	52	Low
Average capacity increase 2015-2017	155	Medium

Table 3 Assumed near term growth in embedded capacity, 2018-2019

Scenario	SP Growth Ranking	Rational	SP FES Assumption, MW/year	NG FES Assumption, MW/year
Community Renewables	High	High decarbonisation, High decentralisation	259	90
Two Degrees	Medium	High decarbonisation, Low decentralisation	155	54
Steady Progression	Low	Low decarbonisation, Low decentralisation	52	50
Consumer Evolution	Medium	Low decarbonisation, High decentralisation	155	62

2.4.5 Long Term Capacity

From 2020-2040 we assume capacity over the SPT area grows according to the annual growth rates as seen in the 2018 FES. These rates vary by year and by scenario, for each technology. These

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growth rates are derived by NG for GB as a whole, for a more granular definition of technologies than used in this report. For the SPT area the capacity weighted average growth rate is calculated, reflecting the current mix of (granular) technologies in the SPT area with GB growth rates applied thereafter.

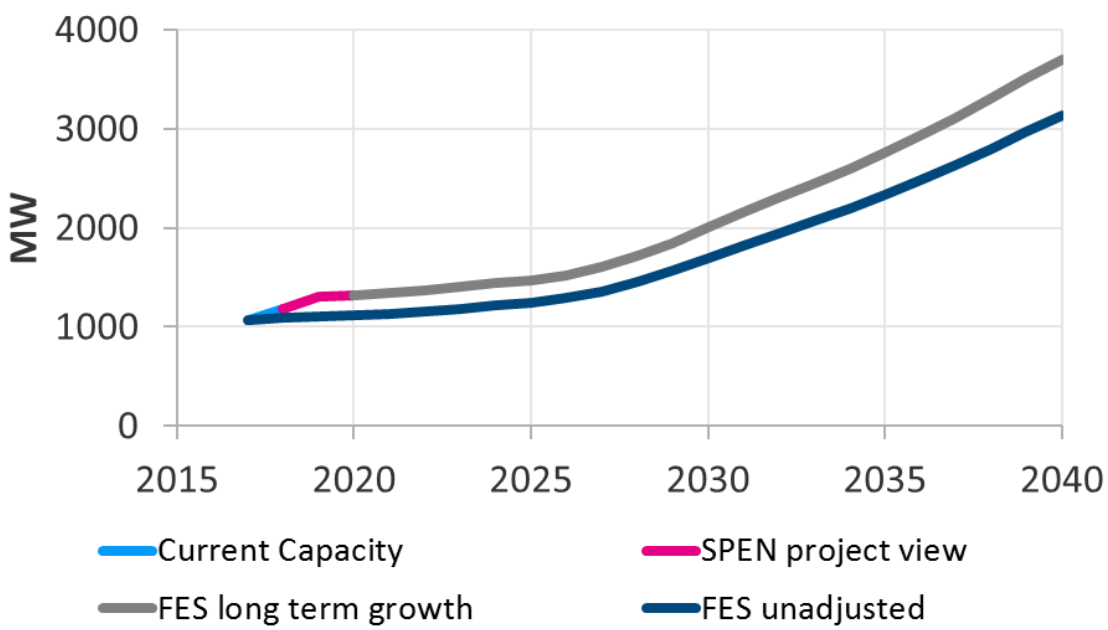
The GB growth rate does not reflect local conditions in the SPT area, though there is no strong evidence that the SPT area will see systematically different growth than the GB average. However, the growth rates across the FES provide a reasonable range with which to test the SPT network, and so have been used directly.

The growth rates used are calculated by using year on year growth in nameplate capacity (MW) in the FES SPT data.

2.4.6 Total SPT capacity over full horizon

Figure 23 shows the approach to calculating capacity for the SPT area over the full horizon (in this case applied to Wind DX in the Community Renewables scenario).

Figure 23 Approach for SPT area total DX capacities, Wind DX, Community Renewables



By matching the FES *growth rate* in the long term this means that the final capacities for the SPT area from the analysis presented in this report do not match the assumptions in the raw FES data directly.

An alternative approach is to match the absolute capacity (MW) in the FES in the long term. Our view is that the FES has a GB-wide growth assumption which encapsulates the average of many small projects over GB, and can be ignored when project specific data is available. Where we have good visibility of named projects we should use them (ie near term SPEN project view) before deferring to the GB-average growth rate thereafter. For some technologies and scenarios this approach will

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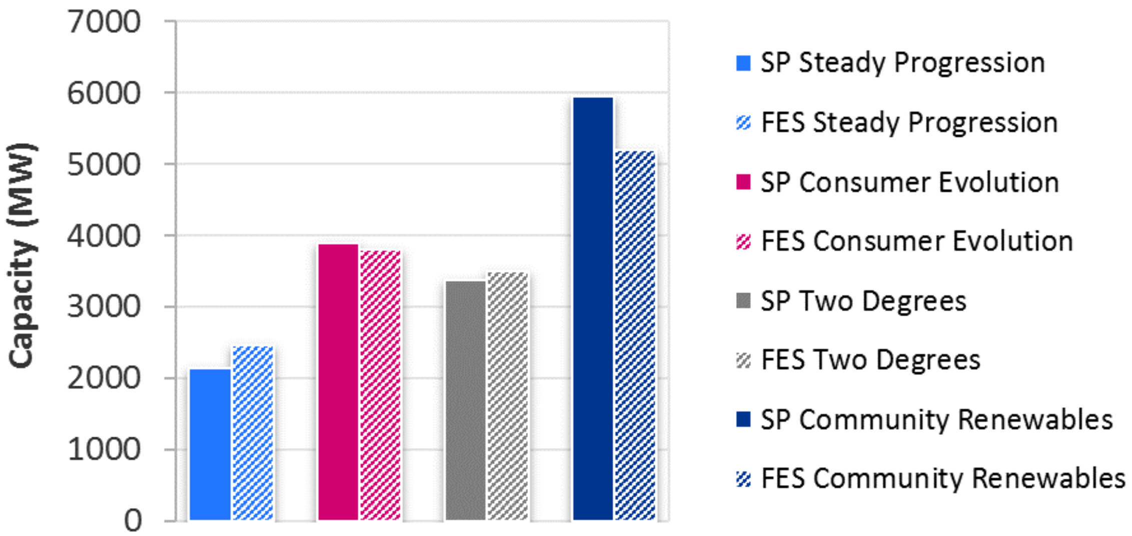
result in higher calculated capacities for the SPT area than in the raw FES data, for other technologies and scenarios it will be less. The sum of all distribution connected supply and storage technologies capacity in 2040 is shown in Figure 24. It can be seen that the SPT assumptions used in this report broadly match the raw FES assumptions, and cover a slightly larger range in capacities. Were all DNOs to apply the approach outlined here we would expect similar (but opposite) differences to be seen for the other DNO areas, such that the total capacity calculated broadly matches the raw FES GB capacity assumptions.

Figure 24 Total DX supply and storage capacity in SPT area, 2040, SPT vs FES assumptions



2.4.7 Capacity Siting

All distribution supply and storage capacity must be assigned to a GSP, to allow the net demand/supply at each GSP to be calculated for Winter Peak and Summer Minimum (AM) and be used by SPT in its load planning.

The approach to siting the SPT area capacities to individual GSPs varies depending on the stage in the horizon:

- Current
  - For Wind, Hydro, PV and Storage use SPT FES data available at GSP level, which matches SPEN view
  - For Controllable and CHP (both Renewable and Non-renewable variants) FES data amalgamates these into an "other" category – so instead use the SPEN live view of connections that feeds into the LTDS publication
- Near term
  - SPEN project data described above is at GSP level

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- Long term
  - Various technology specific methodologies are used, described in subsequent subsections

2.4.7.1 Wind

Wind capacity is assigned to GSPs in the long term by applying the SPT area growth rate (%) for each year to the wind capacity at each GSP in the previous year. This results in linear growth at each GSP from 2020 onwards. This approach assumes that GSPs with high wind capacity are likely to see the bulk of future any growth, due to having favourable wind conditions and works access. While there is a risk that some of these sites may in reality become "full" due to the capacity increases assumed to 2040, it is SPEN's view that this is unlikely, and that they are seeing strong growth in areas of already high penetration.

Where year-on-year reductions are seen, this reduction in capacity is shared over GSPs, based on their share of capacity in 2017 – ie capacity built after 2017 is assumed to stay online while older capacity is retired.

2.4.7.2 PV

Large scale PV capacity is assumed to only be sited in rural areas (typically these types of projects are built in existing agricultural fields).

To classify GSPs as "Rural" or "Urban" we have used Office of National Statistics postcode data to understand the classification (eg rural, urban etc) of individual postcodes, then mapped postcodes to GSP using SPEN mapping tables. We calculate the total area covered by any postcode of a "rural" type, to give the total rural area per GSP.

PV capacity is assigned to GSPs in the long term by distributing the total SPT area increase in capacity in relation to the relative share of "rural" area for each GSP.

The same retirement methodology is used – if year-on-year reductions are observed these are shared over the 2017 capacities, keeping all capacity built after 2017.

2.4.7.3 Hydro

Hydro capacity is assigned to GSPs in the long term by applying the SPT area growth rate (%) for each year to the hydro capacity at each GSP in the previous year, in the same manner as Wind. This results in linear growth at each GSP from 2020 onwards.

Hydro capacity in the SPT area is confined to a handful of GSPs currently. The "linear growth" approach assumes that no new sites will be developed, and that capacity increase will come from expanding existing projects. Using the Scottish Hydropower Resource Study[29] we estimate that there

[29] Scottish Hydropower Resource Study, 2008
http://www.gov.scot/Resource/Doc/917/0064958.pdf

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is limited potential for hydro capacity growth in the SPT area, compared to Scotland more broadly, and so although the FES show a range of growth scenarios it is likely that SPEN will select a no or low growth scenario in its SPT load planning. For no or low growth scenarios the linear growth assumption above is reasonable.

The same retirement methodology is used – if year-on-year reductions are observed these are shared over the 2017 capacities, keeping all capacity built after 2017.

2.4.7.4 CHP

CHP capacity is assigned to GSPs in the long term according to different types of expected heat demand. CHP is split into renewable (ie biomass) and non-renewable (ie gas) variants, with a slightly different approach for each.

Renewable CHP

We assume that due to air quality restrictions renewable CHP (likely biomass or biogas fired) will be sited away from residential areas, and will instead be sited near industrial centres to cover industrial heat demand. As a proxy for industrial heat requirement, which is not spatially disaggregated in the FES data, we have used the I&C peak electricity load for each GSP, calculated as described in Section 2.3.4.

Increases in Renewable CHP capacity at the SPT area level are distributed to individual GSPs based on the relative share of I&C demand at each GSP.

The same retirement methodology is used – if year-on-year reductions are observed these are shared over the 2017 capacities, keeping all capacity built after 2017.

Non-Renewable CHP

Non-renewable CHP is assumed to be built primarily for district heating, which we assume is likely to be located in areas of high heat density (GWh/km^2). To estimate heat density we first calculate annual heat demand (GWh) per GSP, using the Scottish Government Heat Map[30]. Using this annual heat demand and the area (km^2) of postcodes covered by each GSP we can calculate the heat density (GWh/km^2) of each GSP.

Increases in Non-Renewable CHP capacity at the SPT area level are distributed to individual GSPs based on the relative heat density of each GSP, ie with more capacity being built in areas of high heat density.

The same retirement methodology is used – if year-on-year reductions are observed these are shared over the 2017 capacities, keeping all capacity built after 2017.

[30] http://heatmap.scotland.gov.uk/

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2.4.7.5 *Controllable*

Controllable generating capacity (and battery storage) can be classed as "flexible", in that the output can be increased or decreased quickly in response to price signals and/or system need.

Our approach sites all inflexible generation (ie renewable and CHP), then sites flexible plant to GSPs according to the calculated thermal constraints of each GSP and need for flexible plant to provide reserve services. Controllable plant is split into renewable (ie biomass) and non-renewable (ie gas) variants, with a slightly different approach for each.

Where flexible technologies are sited is dependent on the system need / opportunity they are being built for. Currently, much of the new flexible capacity on the distribution system is built to either supply power at the system peak load, or be used for system services (ie primary and secondary response etc). As a result there is an incentive to be sited in areas of low distribution network constraint, to ensure that there is full access to wholesale power and balancing markets.

As the "Distribution System Operator" (DSO) model evolves, there will likely be incentives for flexible assets to site in areas of high constraint, as DSOs seek to manage local balancing issues, reducing the need for investment in the distribution network itself.

In the analysis presented here, we have assumed that initially capacity is sited in GSPs of low constraint (matching what is seen currently) but that after a user-defined year SPD will be able to provide the necessary incentives to encourage capacity to site in areas of high constraint.

There is a high degree of uncertainty around if and when SPD will be able to offer such incentives under a future DSO model. We have reflected this uncertainty through varying the assumed year implementation of local balancing for each scenario. The SPEN DSO Vision document[31] from 2016 states an ambition to have a full DSO model (ie including local balancing) implemented within 7 years, which implies 2023. This aligns with the start of price control period RIIO-ED2, and it is likely that local balancing mechanisms would be linked to incentives coming from new price control periods.

Table 4 shows the assumptions and rationale for the local balancing implementation date used for each scenario.

[31] https://www.spenergynetworks.co.uk/pages/dso_vision_consultation.aspx

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Table 4 Assumed SPD local balancing implementation year

Scenario	Year of local balancing implementation	Rationale
SP Community Renewables	2023	▸ High Decentralisation scenario. ▸ 2023 aligned with start of RIIO-ED2 and SPEN ambition from DSO Vision
SP Two Degrees	2028	▸ Low Decentralisation but High Decarbonisation scenario ▸ 2028 aligned with start of RIIO-ED3 price control period.
SP Steady Progression	2033	▸ Low Decentralisation and Low Decarbonisation scenario ▸ 2033 aligned with start of RIIO-ED4 price control period.
SP Consumer Evolution	2023	▸ High Decentralisation scenario. ▸ 2023 aligned with start of RIIO-ED2 and SPEN ambition from DSO Vision

Using the dates above, the high level methodology for siting controllable (and storage) capacity is as follows (shown schematically in Figure 25):

1. Calculate the headroom of each GSP in each year
    a. Take **thermal capacity** of each GSP, using SPEN supplied data, assume this stays constant over the horizon (ie no reinforcement)
    b. Take calculated metered **demand** for each GSP in each year (as described in Section 2.2), for Winter Peak and Summer Minimum (AM) periods
    c. Take calculated DX **supply** for Wind, PV, Hydro and CHP technologies, using load factors at peak and Summer Minimum (AM) consistent with FES assumptions, to calculate the total supply at each GSP
    d. Calculate the thermal **headroom** for both Winter Peak and Summer Minimum (AM) at each GSP as
        i. *Thermal headroom = Thermal capacity + distribution supply – metered demand*
    e. Find the constraining headroom by taking the lowest of the peak and Summer Minimum (AM) values (this is nearly always at Winter Peak when demand is high)
2. For years prior to the local balancing model implementation, share new capacity over the 10 GSPs with the highest thermal headroom
3. For year after the local balancing model implantation, share new capacity over the 10 GSPs with the lowest thermal headroom

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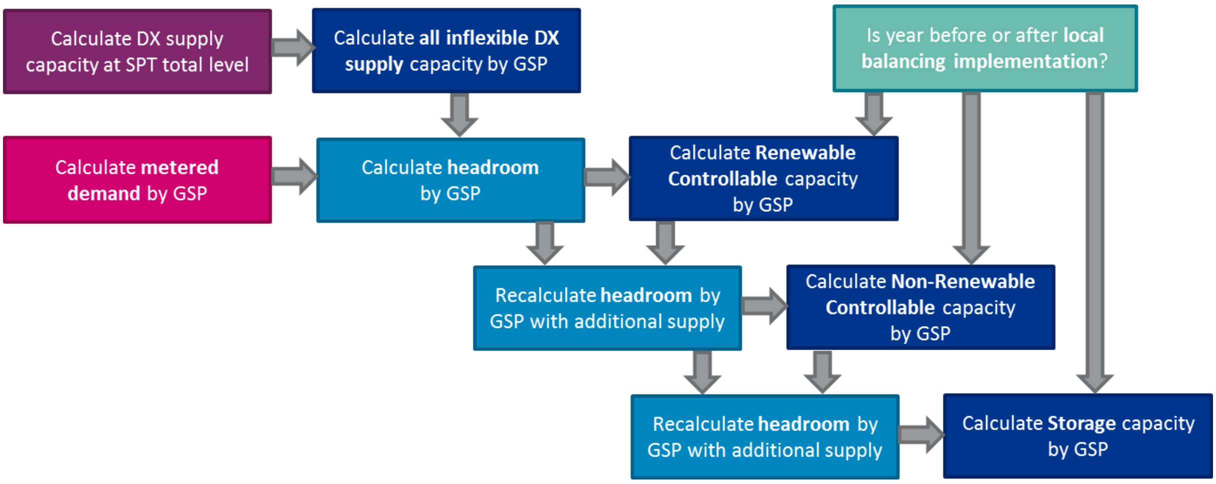
This process is performed for renewable controllable, non-renewable controllable and storage technologies in succession, with the headroom recalculated after each technology is sited. Annual changes in capacity are spread over 10 GSPs for 2 reasons:

1. If capacity is sited in a single GSP there is a risk that the annual increase is not of a credible size for a single project
2. In the early years, where capacity is sited at the GSP of highest headroom, the ranking of GSPs does not change due to additional controllable technology, and so annual increases in capacity are sited at the same site(s) for many years, spreading this over 10 GSPs reduces this effect whilst providing a credible strategy for how projects may be sited

Figure 25 Process for siting inflexible and flexible distribution technologies



Renewable Controllable

As with CHP, we assume that new Renewable Controllable plant (ie Biomass or Biogas) is only sited in industrial areas, for air quality reasons.

Where there is an increase in capacity, the GSPs are filtered to include only those with high I&C load, and then the annual capacity increase is assigned to GSPs with highest or lowest headroom, as described above.

The same retirement methodology as for other technologies is used – if year-on-year reductions are observed these are shared over the 2017 capacities, keeping all capacity built after 2017.

Non-Renewable Controllable

For Non-Renewable Controllable plant (ie gas engines) we follow a similar approach as for Renewable Controllable plant, but without the constraint that new capacity must be sited in industrial areas only and including any Renewable Controllable plant on the supply side when calculating the GSP headroom.

Where there is an increase in capacity, annual capacity increase is assigned to GSPs with highest or lowest headroom, as described above.

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The same retirement methodology as for other technologies is used – if year-on-year reductions are observed these are shared over the 2017 capacities, keeping all capacity built after 2017.

2.4.7.6 Storage

By "Storage" we mean battery storage, there being limited potential for pumped storage within the SPT area. Storage is a flexible technology and is treated in the same way as Controllable plant when siting capacity changes, but including any Controllable plant (Renewable and Non-renewable) on the supply side when calculating the GSP headroom.

Where there is an increase in capacity, annual capacity increase is assigned to GSPs with highest or lowest headroom, as described above.

The same retirement methodology as for other technologies is used – if year-on-year reductions are observed these are shared over the 2017 capacities, keeping all capacity built after 2017.

2.4.8 Load factors

To understand how technologies contribute to supply, we use "load factors" assumptions to scale nameplate capacity into expected output, taking into account diversification effects, intermittency, and outages.

Load factor assumptions for all technologies are taking directly from the FES GB-wide assumptions. These vary by technology and year (though many technologies do not change by year), and are given for Winter Peak and Summer Minimum (AM) periods.

Where multiple FES technologies have been aggregated into the categories used in this study, we have taken the capacity weighted load factor across all grouped technologies for each year, to ensure the same energy output as assumed in the FES.

A summary of load factors is given in Appendix C.

2.4.9 GSP net demand and supply

Using technology load factor and capacity assumptions, the total expected supply output for each GSP can be calculated for Winter Peak and Summer Minimum (AM) periods. By subtracting the total supply from the metered demand at each GSP, the net demand (or supply) from each GSP to the SPT network can be calculated.

2.4.10 Summary

The FES provide a reasonable range of possible capacity evolutions for supply and storage technologies in the SPT area. Our approach has been to:

- Where possible (Wind, Hydro, PV, Storage) use the FES data verbatim for current capacities, at a GSP level
- For CHP and Controllable generation capacities use the live LTDS data to give SPEN's view of currently connected capacities

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- Use local project status knowledge for named projects (assigned to GSPs) for the period 2018-2019
- Assume the same growth at a total SPD level as seen in the FES for the period 2020-2040, but use bespoke methodologies for siting capacity to GSPs based on local knowledge
- Use the FES verbatim for load factors of all technologies

2.5 Transmission connected supply/storage

Large supply and storage plant connect directly to the SP Transmission network. These are large in size and are relatively few in number, and so it is feasible to give projections for named projects rather than simply aggregated capacities (as for distributed generation). The FES provides capacity assumptions for named projects at the transmission level, including opening and closure dates and capacity changes.

The NG FES team has worked closely with SPEN in coming up with the assumptions for transmission connected plant. Our understanding is that the starting point and early years of the FES assumptions represent SPEN's view, whereas the longer term capacity evolution is developed by NG to match the narrative of its scenarios, while ensuring there is enough supply to meet demand on a GB wide basis. SPEN is given early visibility of the longer term assumptions before publication, to allow SPEN to check that these assumptions are realistic, within the FES framework.

2.5.1 Approach for named sites

The approach taken for this analysis has been to take the FES assumptions directly, without alteration. We believe the FES incorporates the best currently available assumptions for large plant, and provides a reasonably large range where uncertainties exist. We validate the capacity assumptions against other data sources in Section 3.

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3 Scenario results

3.1 Introduction

In this section we present the SPT results using the 2018 FES input assumptions, other data sources, and methodology as outlined in Section 2. Where we refer to scenarios we use the following scenario names:

- SP Steady Progression
- SP Consumer Evolution
- SP Two Degrees
- SP Community Renewables

These scenarios are based heavily on the 2018 FES, but have been refined as described previously.

The analysis covers the period 2017-2040, however it is the ***pace of change through the RIIO-T2 period (expected 2021-2026)*** that is of most importance to SPEN when planning investment for their RIIO-T2 submission.

We have included results at the SPT total level (i.e. the sum over all GSPs), though the underlying data is all at GSP level for use by SPEN. In some cases we present maps which show the spatial allocation of the data by GSP.

Where available, we have compared the results with other data sources. The primary alternate sources are:

1. Scottish Government Climate Change Plan 2018[32]
2. Feedback from SPT Stakeholder group workshop

The data available from the Scottish Government Climate Change Plan 2018 is not in a format that allows for direct comparison with the scenario results presented here, and some transformations were needed, as described in the relevant sections below.

Stakeholder feedback was gathered at a workshop led by Baringa. A summary of the SPT methodology and results were presented to attendees, then small group discussions held on key topics. A snap-shot of projections was shown for 2030, with a multiple choice poll used to capture stakeholder views on which projection was most likely. 2030 was used as it matches the data points in some of the alternate data sources, and is reasonably close to the end of the RIIO-T2 period. In the charts below we highlight the most popular projection selected by stakeholders using a yellow star: ★

[32] CLIMATE CHANGE PLAN: The Third Report on Proposals and Policies 2018-2032, Feb 2018 http://www.gov.scot/Topics/Environment/climatechange/climate-change-plan

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It should be noted that the stakeholder sessions were held before the FES 2018 data were available. The FES 2017 data were shown to stakeholders for their feedback, but in the results here we include the SPT projections based on FES 2018, and only include the FES 2017 projection where this was selected by stakeholders as the most likely capacity of each technology. In all cases, the capacity projection selected as most likely by stakeholders was within the range of the SPT FES 2018.

3.2 Demand and behind the meter supply

This section outlines the results for demand and behind the meter supply, derived using the 2018 FES assumptions and the methodology outlined in Section 2.3.

3.2.1 Domestic demand

3.2.1.1 SPT Results

As shown in Figure 26 there is a clear distinction between the domestic peak demand projection (excluding demand associated with heat pumps and EVs) in the two scenarios with high decarbonisation (SP Two Degrees and SP Community Renewables) and the two scenarios with lower decarbonisation (SP Steady Progression and SP Consumer Evolution). In the high decarbonisation scenarios a significant reduction in domestic peak demand is expected as a result of consumers that have the willingness and the financial means to invest in more efficient appliances, and in the efficiency of their homes. Furthermore, this consumer engagement also results in the high levels of domestic demand-side response expected for these scenarios (14% and 16% of domestic peak demand in 2040 for respectively TD and CR). For the other scenarios, there will be fewer investments and flexibility (less than 5% of domestic peak demand DSR), which combined with the growing population results in a nearly constant peak demand over the pathway to 2040.

Figure 26 Total SPT underlying domestic demand (excluding HPs and EVs), Winter Peak (MW)

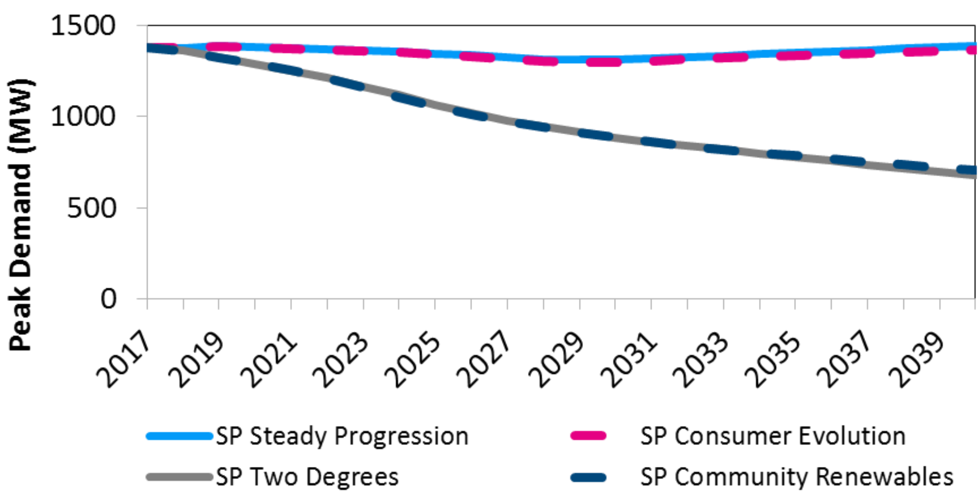

Figure 27 shows that the methodology for spatially allocating the domestic demand (described in Section 2.3.3) results in most of the domestic demand being sited in urban areas. It should be noted

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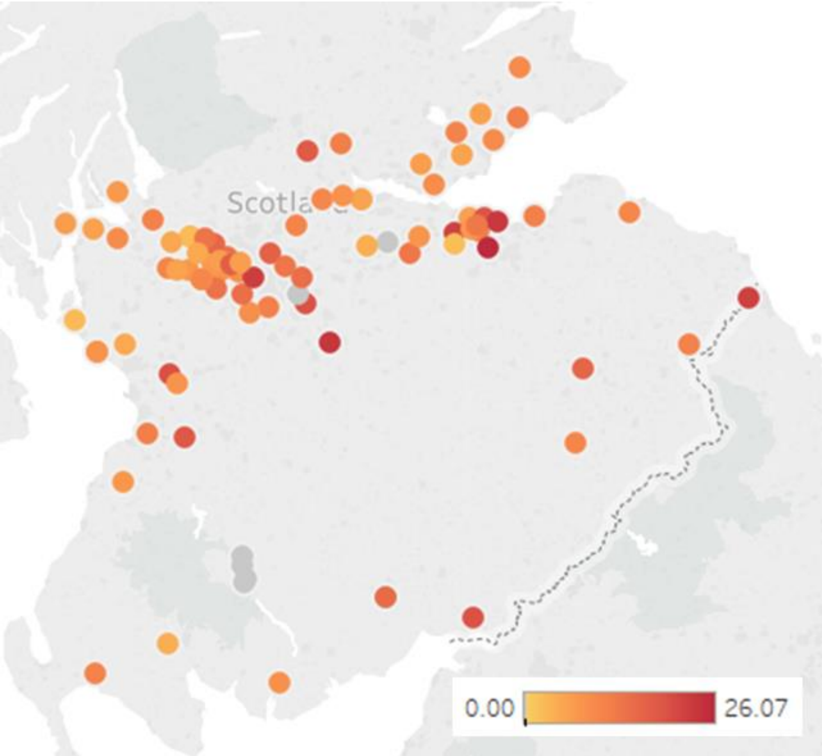
that the total domestic demand at SPT level changes over time but the spatial distribution over the GSPs is left unchanged over the years.

Figure 27 GSP SPT underlying domestic demand, Winter Peak, 2030, Community Renewables

(the chart shows absolute demand in MW)



3.2.2 I&C demand

3.2.2.1 SPT Results

As shown in Figure 28, even though there is growth in the I&C sector for all scenarios there is a slight decrease in peak demand. This is partially caused by the increasing levels of DSR, but is also a result of efficiency gains.

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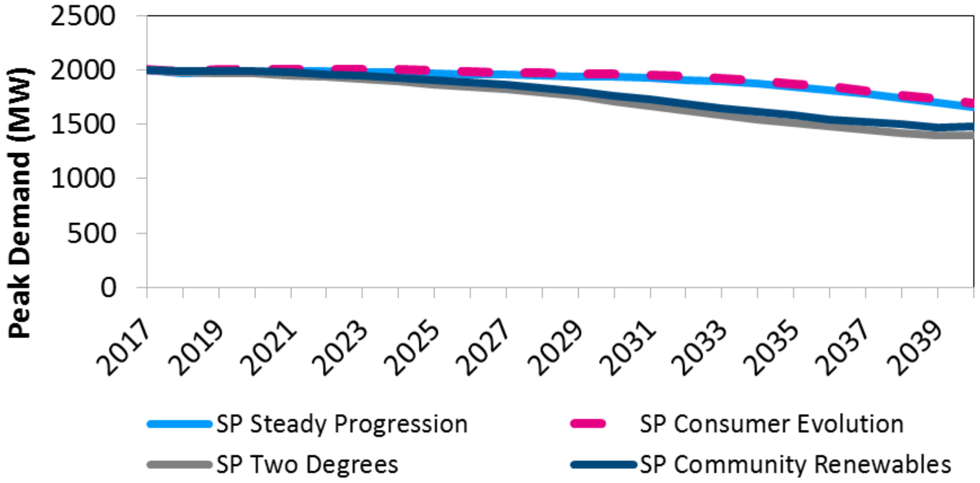
Figure 28 Total SPT underlying I&C demand, Winter Peak (MW)



3.2.3 Heat pumps

3.2.3.1 SPT Results

HP uptake in terms of the level of penetration in the housing stock is presented in Figure 29. We have also included penetration levels of hybrid HPs in the SPT area, based on the assumption that the uptake of hybrids in the SPT area is equivalent to GB wide uptake rate according to the FES. The solid lines represent the households that have a HP as their only heating system and the dashed lines also include the households that use hybrid systems.

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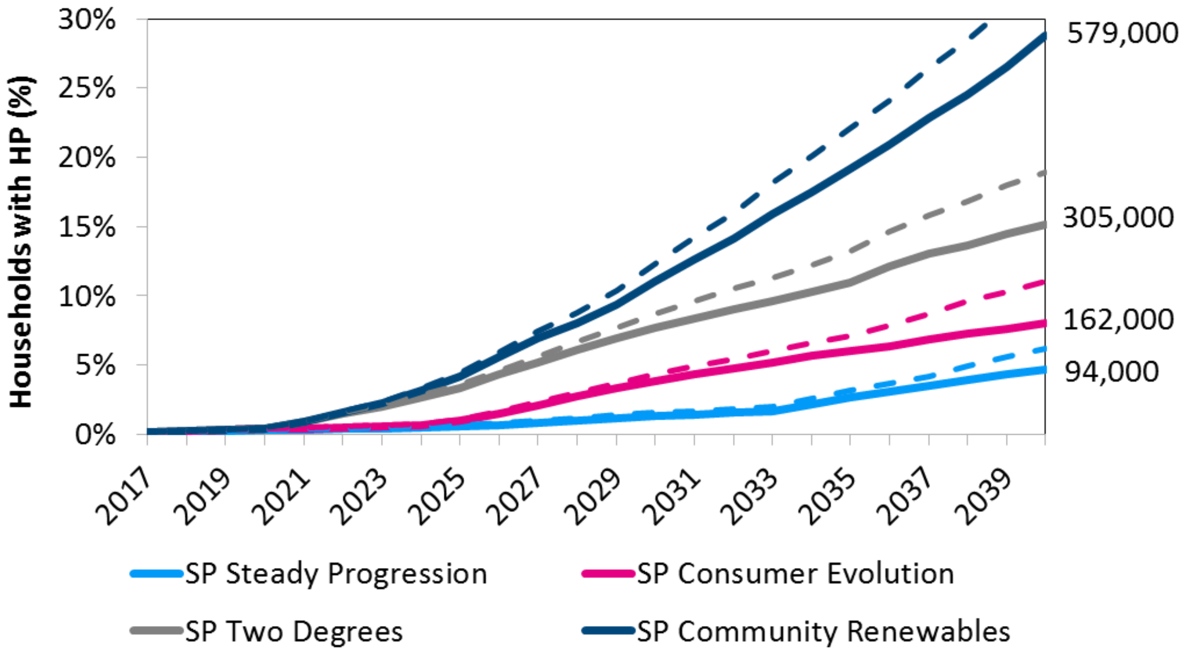
Figure 29 SPT uptake of Heat Pumps (% of domestic properties) and number of HPs in 2040

Dashed lines include households with hybrid systems, solid lines exclude hybrid systems.



The total HP peak demand in the SPT area is shown in Figure 30, noting that hybrid heat pumps are assumed to be running on gas at times of peak demand. There is a significant spread in HP uptake, with the strongest uptake in the high decarbonisation scenarios for which homes are becoming more thermally efficient and hence more suitable for HPs. The main reason for the slower HP uptake in the Two Degrees scenario compared to the Community Renewables scenario is the increased use of hydrogen for heating in this scenario.

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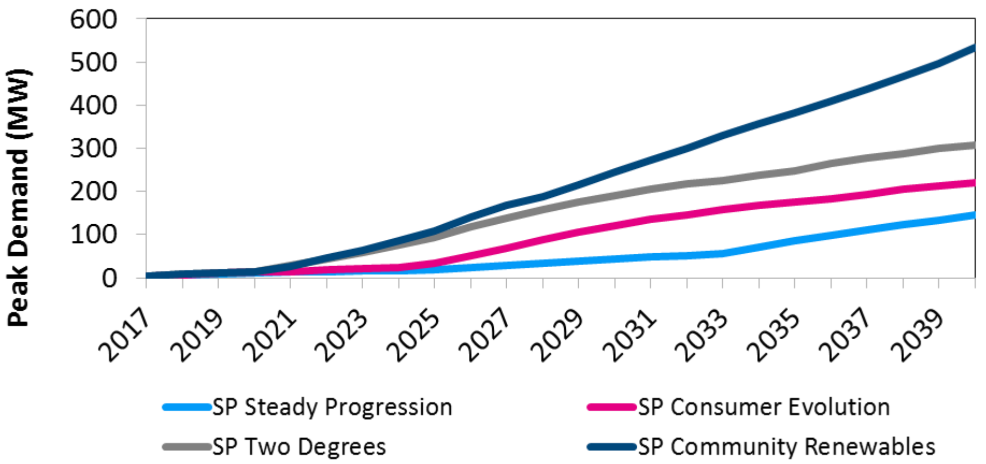
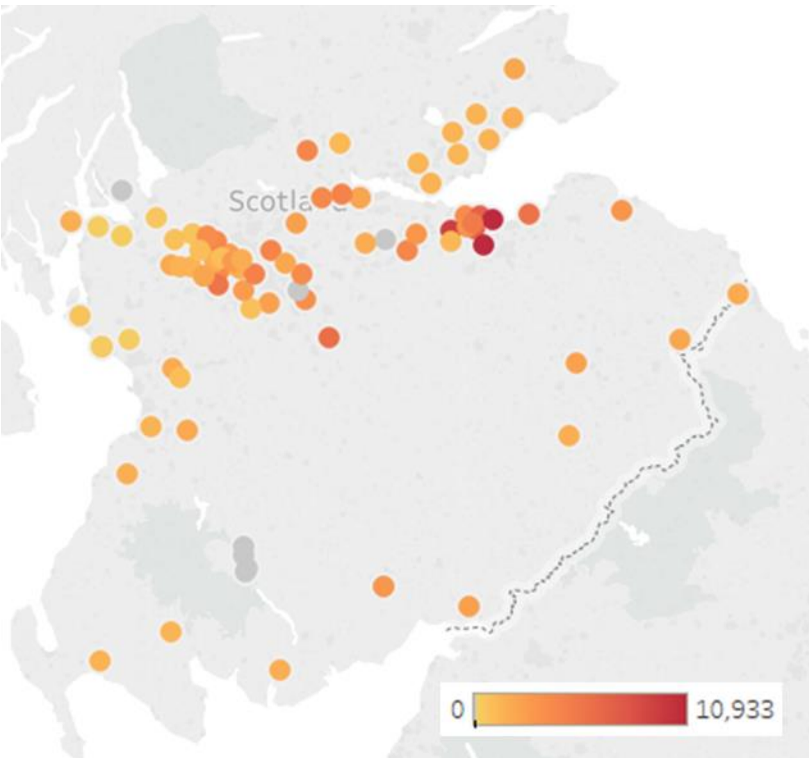
Figure 30 Total SPT Heat Pump underlying demand, Winter Peak (MW)



As discussed in Section 2.3.5 the HPs have been spatially re-allocated. In Figure 31 this results in a large number of HPs being installed in some urban GSPs which have a high rate of new builds, as well as an increase in the amount of HPs in off-gas areas, although this is less visible due to the smaller number of customers in these areas.

Figure 31 GSP SPT Heat Pumps 2030, Community Renewables (absolute number of heat pumps per GSP)



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3.2.3.2 *Comparison with other data sources*

In order to assess the appropriateness of the FES scenarios for the SPT area they have been compared to other Scotland specific data sources wherever possible, as is shown in Figure 32. For HPs, the metrics used vary quite strongly; the Scottish Government[33] and DECC[34] include all low carbon heating technologies (including resistive heating based on low carbon electricity) and the CCC[35] accounts for all types of HPs (i.e. including hybrids). For the best comparison for the SPT area we will therefore also use the share of households with any type of HP (represented by the dashed lines in Figure 29). The comparison is shown in Figure 32.

The metrics may not all be directly comparable, but in general the other data sources suggest a significantly stronger HP uptake than presented by the 2018 FES scenarios. However, the Scotland specific data sources - alongside the uptake levels according to the 2017 FES scenarios - were also presented to the group of stakeholders, who unanimously expected a much slower HP uptake, as described by the 2017 FES Slow Progression scenario. The uptake for this scenario is also included in Figure 32 and is within the range of HP uptake presented by the FES 2018 scenarios. Note that the views of stakeholders, which were at the lower end of the 2017 FES are better reflected by the 2018 scenarios, which have been revised downwards.

The stakeholders thought it was unlikely that strong heat pump uptake would occur in on-gas areas because of the current low gas prices, and there was a feeling that even though heat pumps could replace oil heating in off-gas areas, this was not expected to occur soon due to lack of consumer engagement. Only if government policies were introduced to require new builds to have heat pumps did the stakeholders expect that uptake would be significantly stronger. Examples given by the stakeholders of significant differences between the SPT area and the GB average concerning heat pump uptake were the colder climate, the larger share of flats, and the high proportion of poorly insulated solid wall buildings in rural areas, which all mean there are likely to be fewer suitable properties.

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33 Scottish Government, Climate Change Plan, The Third Report on Proposals and Policies 2018-2032: http://www.gov.scot/Resource/0053/00532096.pdf

34 DECC, The Future of Heating: Meeting the challenge (2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf Note that the DECC scenarios may be somewhat outdated, as they were created in 2013, prior to DECC being superseded by BEIS.

35 Committee on Climate Change Scottish emissions targets 2028-2032: https://www.theccc.org.uk/wp-content/uploads/2016/03/Scottish-Emissions-Targets-2028-2032.pdf

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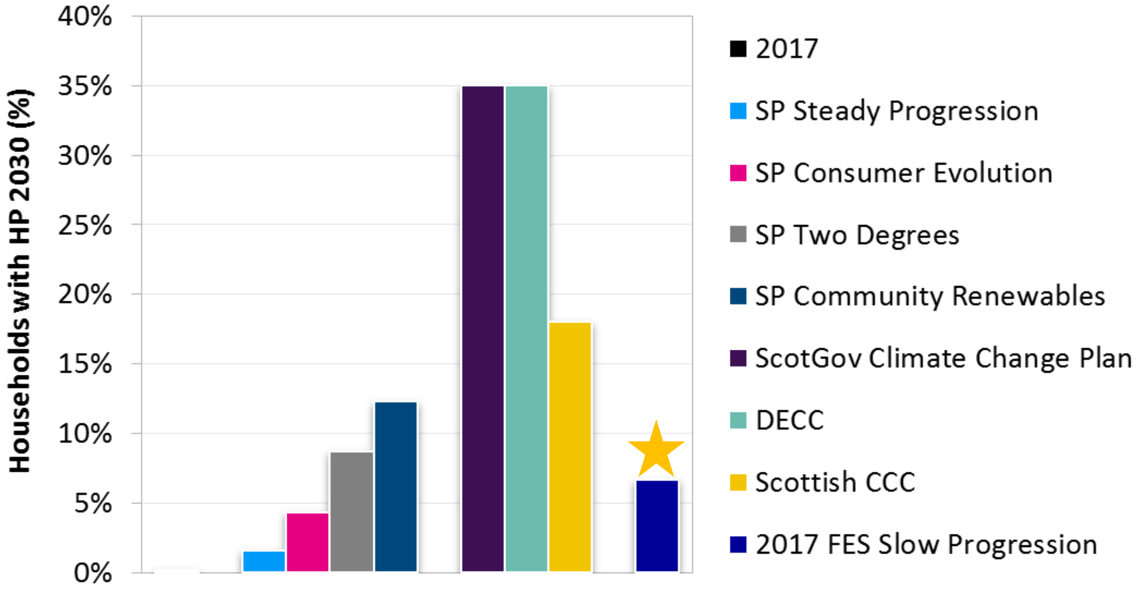
Figure 32 Total SPT Heat pumps, alternate data sources (% properties) and stakeholder view (star)



3.2.4 District Heating

Figure 33 shows that uptake of DH is significant for the high decarbonisation scenarios, with the strongest uptake in the Two Degrees scenario because there are expected to be more large scale coordinated actions to develop alternative heating technologies. In the low decarbonisation scenarios there is very limited DH uptake, which is related to the fact that most customers wish to retain their gas boilers.

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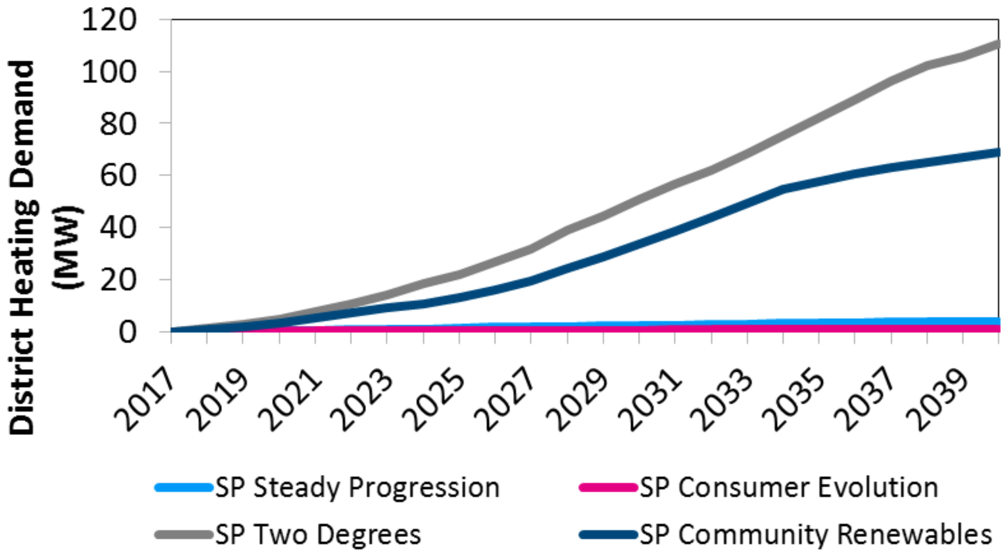
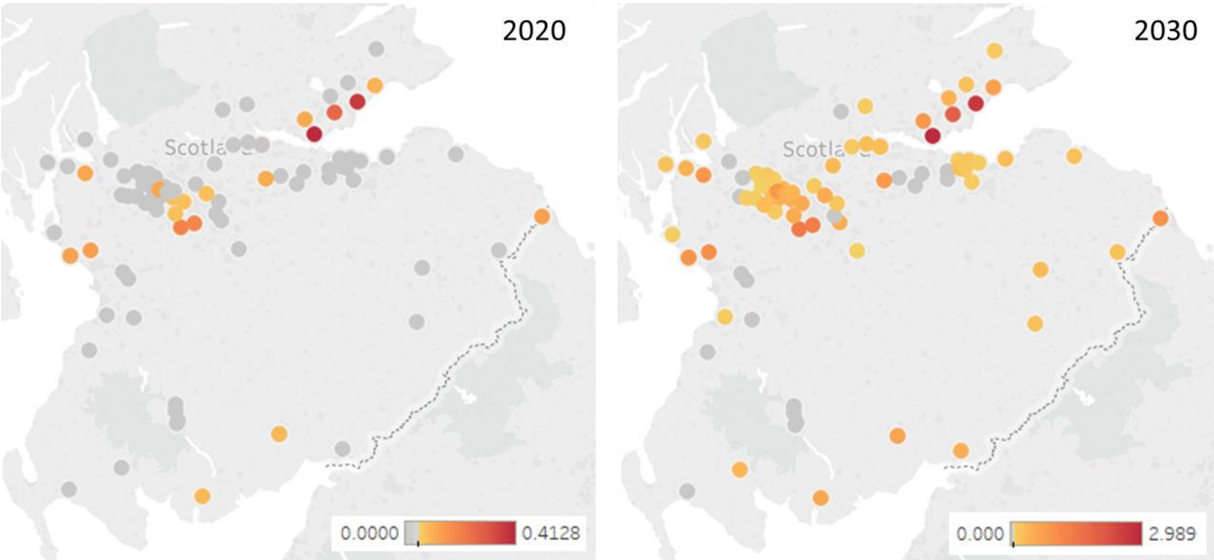
Figure 33 Total SPT District Heating underlying demand, Winter Peak (MW)



As was discussed in Section 2.3.6, the DH demand has been re-allocated based on the domestic heating demand density per GSP, observing a minimum peak demand of 50 kW per system. The resulting DH demand per GSP is shown in Figure 34.

Figure 34 GSP SPT District Heating demand, Winter Peak, 2020 and 2030, Community Renewables

(the charts show absolute demand in MW)



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3.2.5 Electric Vehicles

3.2.5.1 SPT Results

The EV penetration level in the total car population is shown in Figure 35. For clarity, the total number of EVs in 2040 is also provided. In the two high decarbonisation scenarios EV uptake is stronger given increasing emphasis on EVs by the vehicle manufacturers in the run up to the UK government's ban on the sale of all diesel and petrol cars from 2040. For the other two scenarios EV uptake is slower given an expectation that the ban will be shifted further back. However, EVs will still become the dominant choice for personal transport from 2040 onwards.

Figure 35 Total SPT Electric Vehicles (% of total car population within year[36]) and the number of EVs in 2040

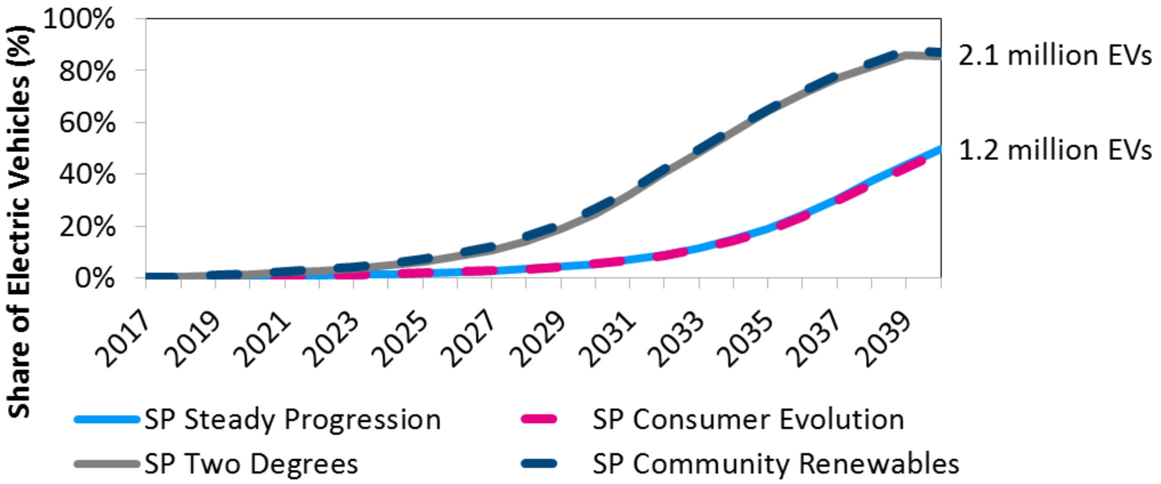

Figure 36 shows the growth of EV peak demand (of both residential and non-residential charging) in the SPT area until 2040. It can be seen that the total peak demand is less in the SP Community Renewables scenario than for the SP Two Degrees scenario. While the uptake of the number of EVs is nearly the same for these scenarios, it is assumed that in the Community Renewables scenario consumers are more engaged with smart charging and the total impact of residential charging on the network is therefore smaller.

[36] The total car population per year has been based on assumptions made in the ECCo model – which is described in Section 3.2.5.2.

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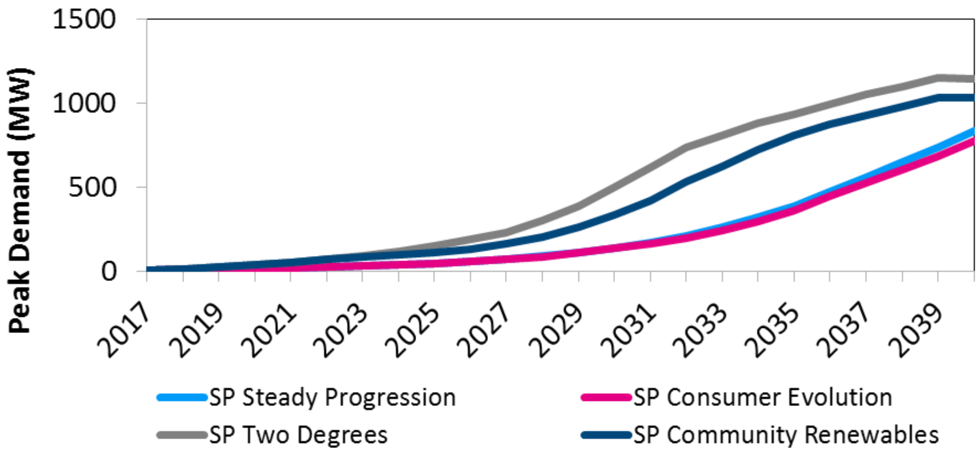
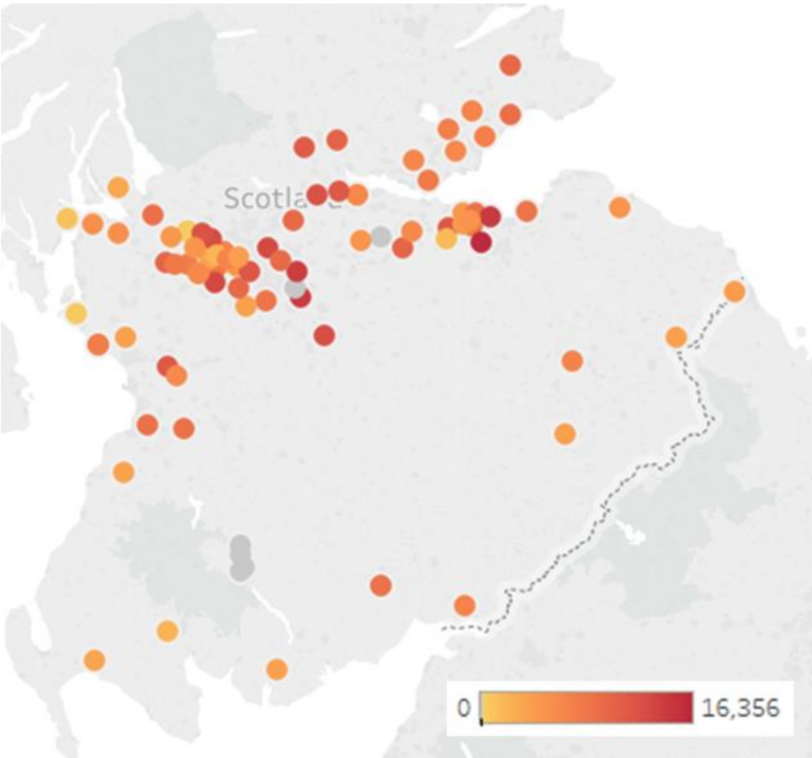
Figure 36 Total SPT Electric Vehicles underlying demand, Winter Peak (MW)



For the spatial allocation of EVs a clustering approach has been used, as was discussed in Section 2.3.7. As a result, the share of EVs per GSP differs in the early years but becomes more equally distributed as more consumers start purchasing EVs. In some GSPs no EV uptake is expected at all, as these GSPs have very few domestic customers connected to them. The number of vehicles per GSP in 2030 for the Community Renewables scenario is shown in Figure 37.

Figure 37 GSP SPT Electric Vehicles 2030, Community Renewables (the chart shows absolute number of EVs)



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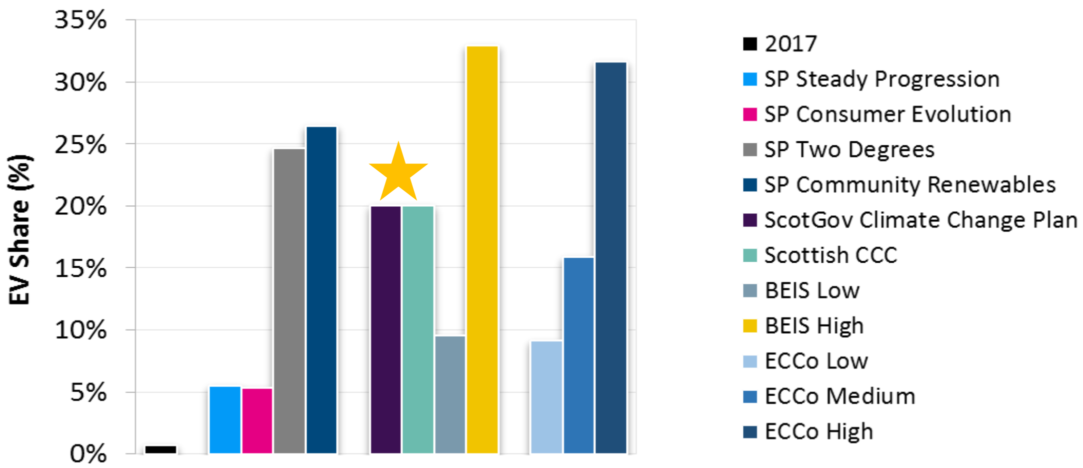
3.2.5.2 *Comparison with other data sources*

For EVs we have also compared the FES scenarios for the SPT area with other data sources to verify their suitability, as is shown in Figure 38. The strong uptake considered by the Scottish Government[37] is closely aligned with the upper bound forecasts described by the 2018 FES CR and TD scenarios (which meet the Scottish Government targets of 100% of new vehicles sales being EVs by 2032) but still slightly lower than the BEIS[38] High and ECCo model[39] High scenarios, for which there is an expected share of about 30% in 2030. However, in order to achieve such a high penetration level, the ECCo model assumes that plug-in car grants are continued until 2020, 100% access to home charging is achieved for home-based consumers and stricter CO_2 targets for cars are set, pushing up the price or restricting the availability of conventional petrol and diesel vehicles.

The stakeholders agreed that the strong uptake according to the Scottish Government seems feasible. They did not think there was a big difference between the EV uptake in the SPT and the GB average, although range anxiety for rural areas, and the frequent bad weather in Scotland could be a deterrent. They also pointed out the importance of public and rapid charging stations in urban areas in the SPT area, as there is a high percentage of flats which means many drivers will have no access to home charging.

Figure 38 Total SPT EVs, alternate data sources (% of total car population 2030) and stakeholder view (star)



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[37] Scottish Government, Climate Change Plan, The Third Report on Proposals and Policies 2018-2032: http://www.gov.scot/Resource/0053/00532096.pdf

[38] DECC Smart Grid Forum WS1 EV Uptake Scenarios as presented in SPD EV Uptake Forecasts (2017): https://www.spenergynetworks.co.uk/userfiles/file/Electric_Vehicle_Uptake_Forecasts.pdf

[39] The ECCo model is Element Energy's consumer choice model used to predict uptake of various powertrains and its impact on the GB automotive stock. It is based on the latest evidence on vehicle cost and performance trends, and uses parametrisation of consumer behaviour based on primary research on 2,000 new car buyers identifying how GB car buyers weigh up capital and running costs and other attributes. In its medium scenario only currently announced policy is considered. The low scenario is similar, but assumes less favourable fuel and battery costs. In the high scenario the model aims to achieve 60% ultra low emissions vehicle (ULEV) sales in 2030, as per the CCC's 5th Carbon Budget target.

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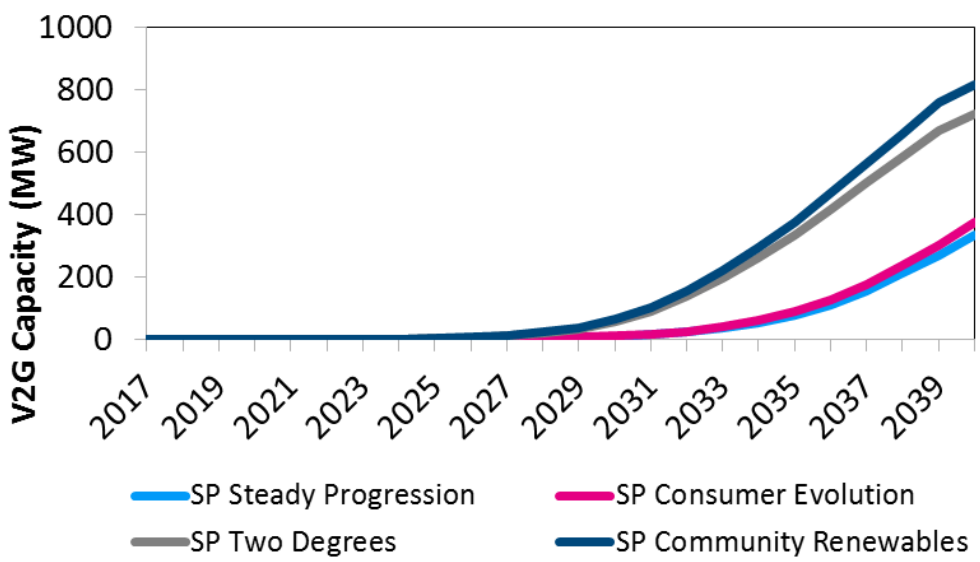
3.2.6 Vehicle-to-Grid

The uptake of the V2G capacity in the SPT region is shown in Figure 39 and is the result of a combination of an increased percentage of consumers that engage with V2G and the growing amount of EVs in the SPT area. It was discussed in Section 2.3.8 that there is a lot of uncertainty around V2G but it has the potential to have a huge impact on the network.

In the model the V2G supply has not been subtracted when calculating the metered demand but is provided separately to provide insight into available capacity for constrained GSPs. It should however be noted that the FES assumes that a large share of the available V2G capacity will actually be used, strongly reducing the impact EVs have on the peak demand.

Figure 39 Total SPT V2G capacity (MW)



The spatial allocation of V2G is based on the amount of EVs per GSP and therefore the distribution is similar to that in Figure 37.

3.2.7 Behind the meter PV

3.2.7.1 SPT Results

The behind the meter PV capacities that are forecast to be installed in the SPT area vary strongly across the different scenarios. In the decentralised scenarios (Community Renewables and Consumer Evolution) the focus is largely on local generation and the uptake of behind the meter PV is therefore much stronger than for the centralised scenarios, as can be seen in Figure 40. It is important to note that even with a large increase in PV capacity the impact on the network is only small because the PV generation is low at the times of Winter Peak and Summer Minimum (AM).

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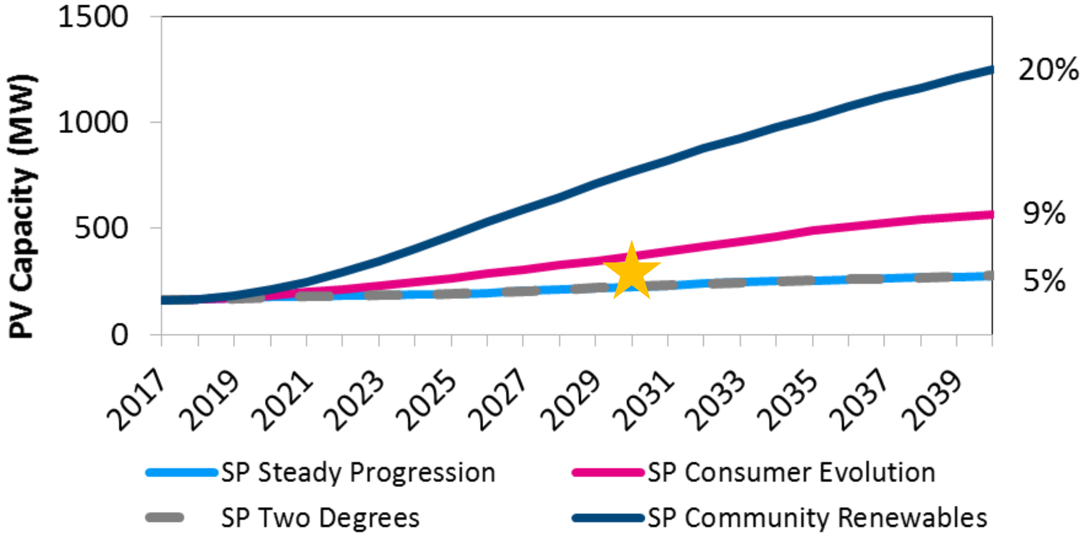
Figure 40 Total SPT behind the meter PV (MW) and stakeholder view (star). An estimate of the share of households with PV[40] is given for 2040.



As was discussed in Section 2.3.9, the distribution of the behind the meter PV capacity is based on the FiT data, and due to the limited PV uptake the model only re-allocates some of the capacity – based on the share of domestic demand – for the later years of the Community Renewables scenario. The distribution of the PV capacity in 2030 for the Community Renewables scenario is shown in Figure 41.

[40] The estimated share of households with PV in 2040 is based on an average PV system size of 3 kW and approximately 2 million households in the SPT area in 2040 based on the household projections as discussed in Section 2.3.5.

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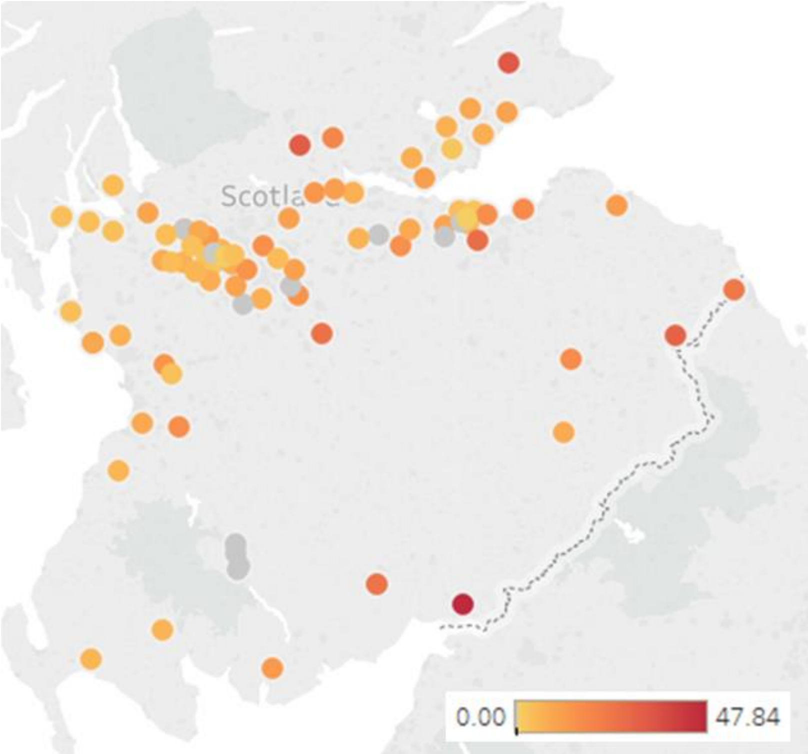
Figure 41 GSP SPT Behind the meter PV capacity 2030, Community Renewables (the chart shows absolute capacity in MW)



3.2.7.2 Comparison with other data sources

The behind the meter PV scenarios have not been compared to other data sources, however the 2017 FES-based results were presented and discussed by stakeholders at the consultation workshop. There was no clear, unanimous view among the stakeholders on the most likely outcome for behind the meter PV uptake, but the group leaned toward the more optimistic 2017 FES Consumer Power scenario (231 MW in 2030 – as indicated by the star in Figure 40).

3.2.8 Domestic Battery Storage

3.2.8.1 SPT Results

There is currently very little domestic battery storage capacity in the SPT area, but there is potential for strong growth in the decentralised scenarios. However, the resulting capacities are likely to remain relatively small in absolute terms in the T2 period, as can be seen in Figure 42. Domestic batteries are expected to be most commonly sited alongside behind the meter PV, where they are most economic, and their distribution will therefore be similar to the distribution as shown in Figure 41.

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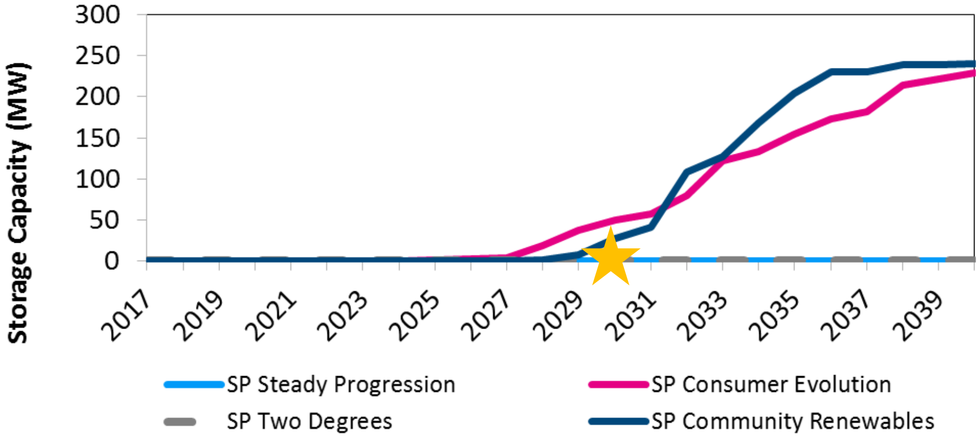
Figure 42 Total SPT Domestic Battery Storage (MW) and stakeholder view (star)



3.2.8.2 Comparison with other data sources

The impact of domestic storage on SPT's network is expected to be limited and hence the comparison of FES scenarios with alternative data sources has not been a focus. However, the potential of storage was discussed during the stakeholder meeting, and the stakeholders agreed (75% of respondents) that the 2017 FES Slow Progression scenario (2.6 MW in 2030 – as indicated by the star in Figure 42) was most likely for the SPT area. It should be noted that the uptake of domestic storage in the 2018 FES decentralised scenarios is much stronger than in the 2017 FES scenarios.

In the stakeholder discussion there was a lot of uncertainty around what the rate of uptake is likely to be, and participants disagreed over which type of storage would take off, domestic or grid level storage. Some thought that domestic storage would have the strongest uptake because there was consumer interest, as part of being self-reliant with behind the meter PV, whilst others thought the costs of domestic storage were too high and that the amount of grid level storage would increase as industrial users are becoming more exposed to peak pricing and thus have more incentive to self-balance.

The stakeholders agreed that the uptake of storage is heavily reliant on government policy decisions, and that the increasing amount of installed wind and solar capacity could be a significant driver of increased deployment of storage.

3.2.9 Flexibility

3.2.9.1 Domestic

The spread in flexible domestic demand in Figure 43 reflects the strong variation in customer engagement across the scenarios as discussed in Section 2.3.11.2. Note that as a result of the increasing efficiencies in the high decarbonisation scenarios, there will be less domestic demand that can be managed, which brings the absolute flexible load of all scenarios somewhat closer together.

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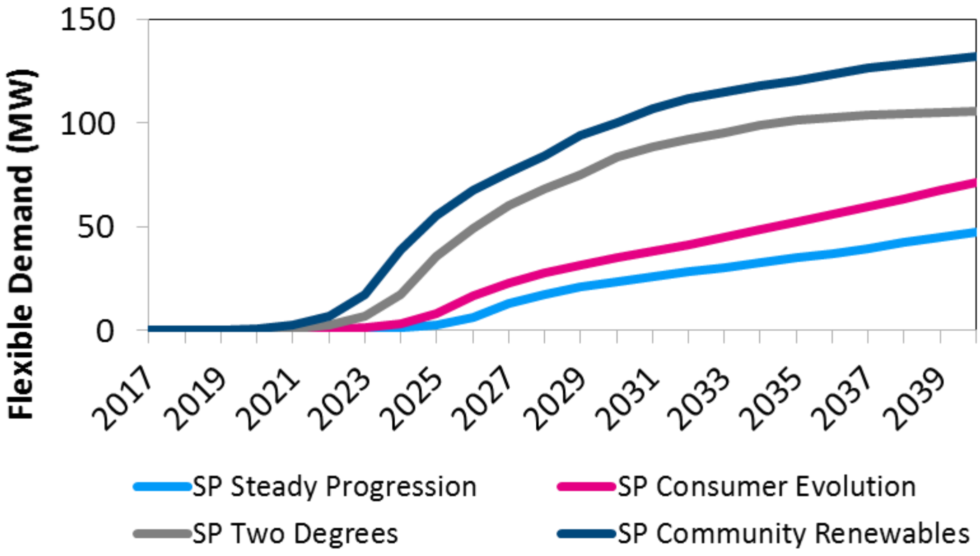
Figure 43 Flexibility of the domestic demand (MW)



3.2.9.2 I&C

Figure 44 shows an increase in flexible I&C demand for all scenarios as a result of the increasing amount of DSR – with the strongest increase for the high decarbonisation scenarios. SPEN do not have any visibility of how much I&C load is operating as DSR, and the existing 55 MW of flexible I&C demand for SPT in Figure 44 has been extrapolated from the current level of flexible I&C demand in GB as a whole from the 2018 FES.

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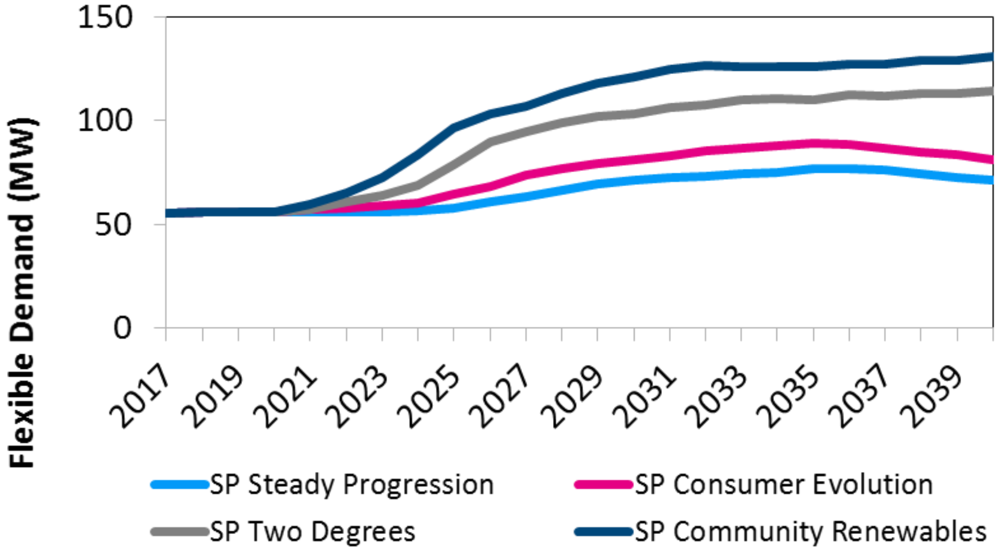
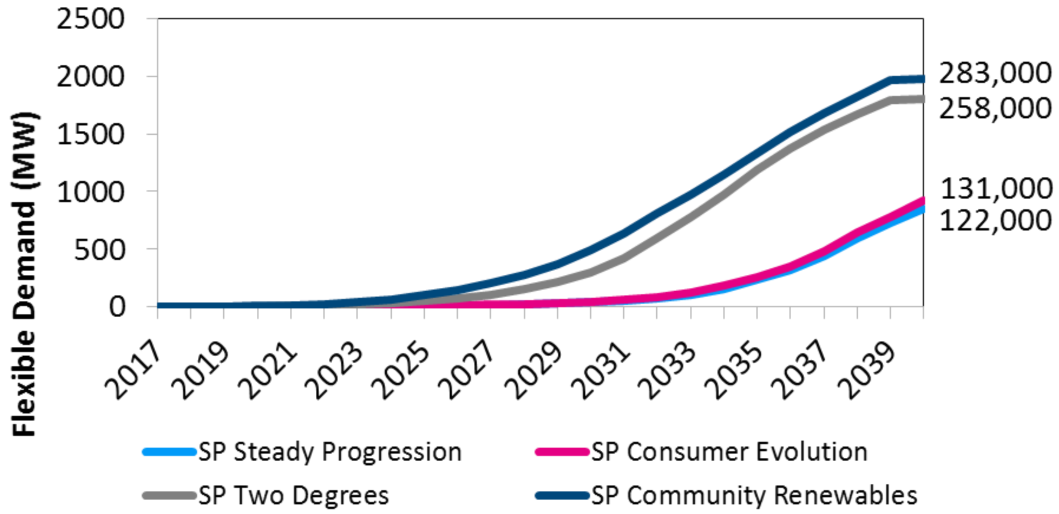
Figure 44 Flexibility of the I&C demand (MW)



3.2.9.3 Electric Vehicles

As discussed in Section 2.3.7 the uptake of EVs will have a significant impact on the network, and managing the charging through customer engagement is expected to play a vital role in keeping the network balanced. This is clearly shown in Figure 45, by 2040 the peak demand could be up to 2000 MW higher in the SPT region if no smart charging management is undertaken.

Figure 45 Flexibility of the EV peak demand (MW) and the estimated number of EVs[41] this equates to in 2040



[41] The estimated number of EVS that provide the flexible load at peak time is determined by dividing the total flexible demand by the average domestic charger size of 7kW as assumed by the FES.

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3.2.9.4 Heat Pumps

As is described in Section 2.3.11.5, in the 2018 FES customers are assumed to not be engaged with reducing their HP demand, and there is therefore no flexible HP demand.

3.2.9.5 Total

Combining all flexible demand and adding it to the inflexible demand allows us to determine what would be the total demand on the network if no flexibility were assumed, as is shown in Figure 46 for all scenarios. In the high decarbonisation scenarios there is a significant increase in total demand, but due to the large increase in flexibility over time, the actual peak load on the network does not change much. In contrast, the low decarbonisation scenarios see a smaller uptake in total demand, but does not have the same level of consumer engagement and therefore the impact on the network is larger.

Figure 46 clearly shows the importance of accounting for the flexibility of peak demand at the distribution network level whilst planning network upgrades.

Figure 46 Total SPT inflexible and flexible underlying demand (MW)

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3.2.10 Metered Demand

After calculating the total underlying demand, the model subtracts the load provided by the batteries and the PV generation (based on the FES assumptions for PV load factor and battery operation) to determine the metered demand, which is shown in Figure 47 for peak time and in Figure 48 for the time of Summer Minimum (AM).

Because of the low expected output of the behind the meter PV generation and the limited capacity of home storage, the difference between the underlying demand and the metered demand (after subtracting behind the meter supply) is small.

Figure 47 SPT Metered Demand, Winter Peak (MW)

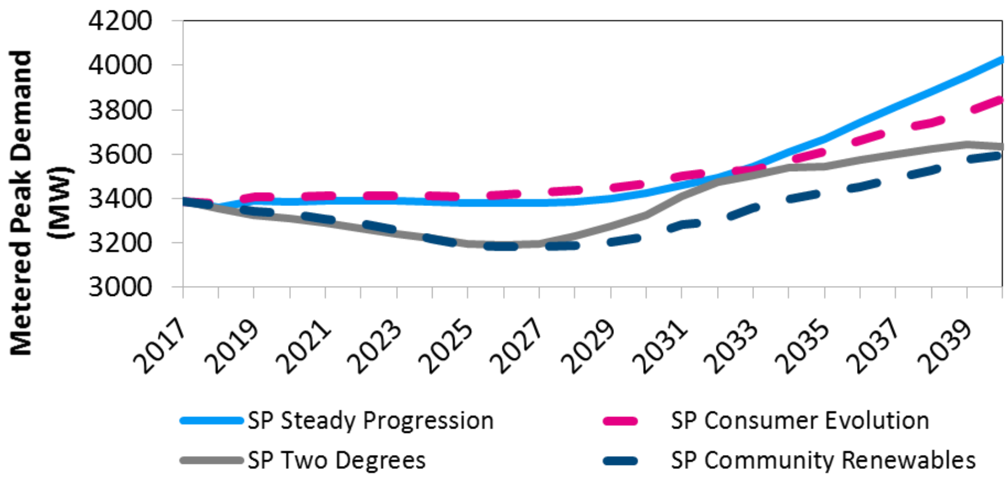
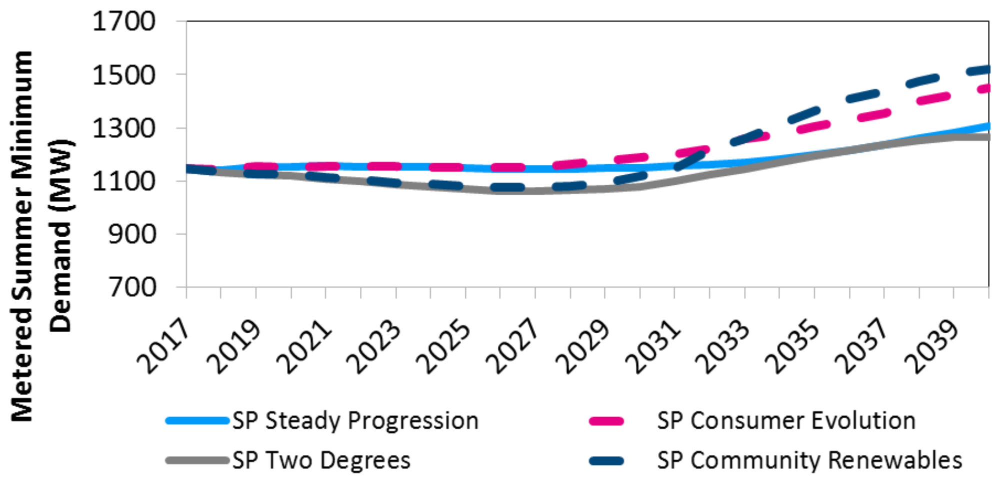


Figure 48 SPT Metered Demand, Summer Minimum (MW)



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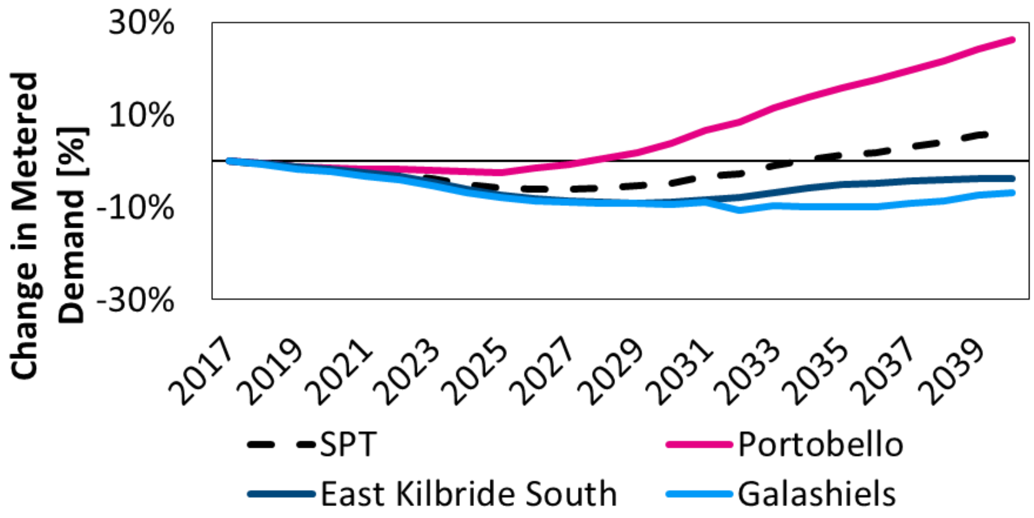
It is worth noting here that even though the increase of the total SPT metered peak demand is limited, at GSP level there is a greater scale of variability due to the distribution of the underlying components.

Figure 49 shows that although there is only a 6% increase in metered peak demand for the Community Renewables scenario at SPT level, at GSP level there is much more variety, potentially causing the need for network upgrades for certain GSPs. The total effect of changes in demand and supply at a GSP level is discussed in more detail in Section 3.4.2.

Figure 49 Change in metered demand at SPT and selected GSPs, Winter Peak, Community Renewables (%)



3.2.11 Summary

It can be concluded from this section that the increase of underlying peak demand is strongly dependent on the level of customer engagement. Careful consideration should therefore be taken when planning network upgrades to ensure sensible levels of flexibility are assumed. The impact of behind the meter generation on the network is expected to be smaller, particularly because the expected levels of installed capacity are limited.

Note that so far the results have mostly focussed on the SPT area as a whole, showing that the increase in peak demand is expected to be significant but can likely be offset by flexible load. However, it has been shown that at GSP level the uptake of technologies vary and hence so does the metered demand. The impact of this on the supply and demand balance of individual GSPs will be discussed further in Section 3.4.

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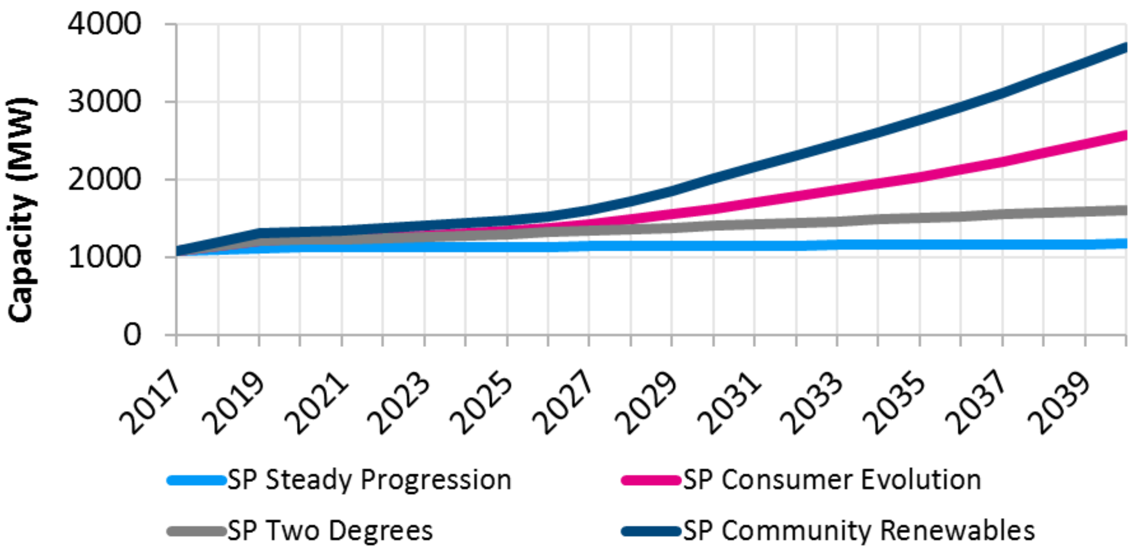
3.3 Distribution connected supply/storage

3.3.1 Wind

3.3.1.1 SPT Results

In recent years there has been steady growth in wind capacity on the SPD network. This is likely to continue over the next couple of years, based on planning and connection status. Capacity growth during the RIIO-T2 period is fairly limited in all scenarios, reflecting current uncertainty about future subsidies (i.e. no onshore wind - outside of Scottish Islands - is supported under the Contracts for Difference Scheme) and a number of good sites already being taken by wind farms supported under the previous Renewables Obligation. Capacity increases during this period ranging from 14MW (Steady Progression) to 179MW (Community Renewables). After the RIIO-T2 period growth accelerates strongly in some scenarios, creating a wider range in capacities as subsidy-free onshore wind increasingly competes with other sources of generation.

Figure 50 Total SPT Distribution Connected Wind capacity (MW)



The methodology for siting additional capacity results in wind capacity being spread around the rural areas of the SPT zone, as shown in Figure 51.

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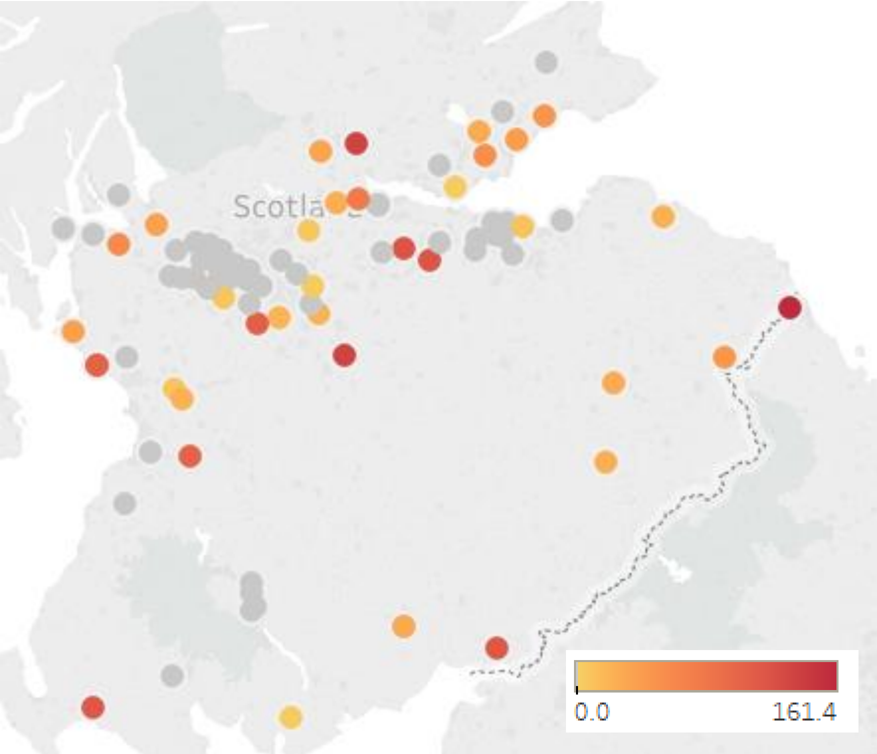
Figure 51 GSP SPT DX Connected Wind capacity 2030, Community Renewables (MW)



[Note that only distribution connected wind is shown here. There are significant volumes of transmission connected wind in the SPT area, particularly in the south west of Scotland]

3.3.1.2 Comparison with other data sources

We have not found any other sources of DX wind capacity projections explicitly. However, we have found projections for total wind capacity (DX and TX), and present these here. The sources used are the Scottish Government's Climate Change Plan, Baringa's GB Electricity Market Reference Case, and Stakeholder feedback.

The Scottish Government's Climate Change Plan suggests that renewable energy generation in Scotland could rise to 140% of Scottish electricity demand by 2030 (~68% in 2017). If we assume that demand stays constant (The Climate Change Plan and related Energy Strategy[42] present differing possible futures, where electricity demand may go up or down), this implies an increase in RES-E generation capacity of approximately 2.3x from 2017 to 2030. A 2.3x increase in SPT wind capacities by 2030 is broadly in line with the Two Degrees scenarios, and within the envelope of the SP FES as

[42] Scottish Energy Strategy: The future of energy in Scotland, Dec 2017
http://www.gov.scot/energystrategy

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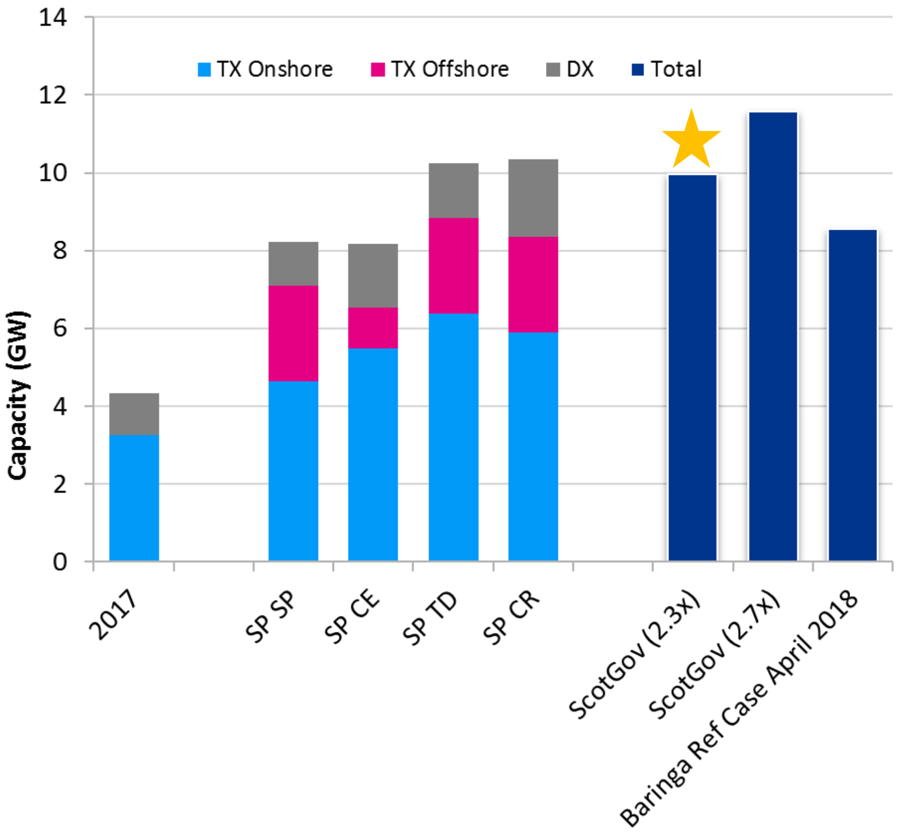
shown in Figure 52. Under the decentralised scenarios there is high growth in DX wind, though this is overshadowed in all scenarios by growth in TX wind, particularly offshore.

The 2.3x estimate assumes that all RES-E generation experiences the same growth rate. However, there is currently a large proportion of RES-E capacity in Scotland from hydro plant, which is unlikely to show much growth, at least within SPT's area. If we assume hydro capacities remain constant, this implies other RES-E generation needs to increase by 2.7x. This estimate is slightly outside the envelope of the SP scenarios but there is reason to believe it is an over estimate: there may be some growth in hydro capacities along with solar and other renewables. In addition, the 2.7x figure is for Scotland as a whole and it may be that more new capacity, particularly for onshore and offshore wind, is sited north of the SPT area.

Figure 52 Total SPT Wind capacity 2030, alternate data sources (MW) [stakeholder view, star]



The Baringa GB Electricity Market Reference Case is our in-house view of the evolution of the GB electricity system, updated regularly and used as a benchmark for a wide range of clients. The Baringa Reference Case includes projections of wind capacities at a regional level. We have mapped the capacities in the Baringa Reference Case to the SPT area and compared with the SPT FES results. The Baringa Reference Case broadly matches the Steady Progression scenario, at the lower end of the SP FES.

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As a final data source we asked SPT stakeholders for their views of likely 2030 capacities. 50% of respondents selected either the Scottish Government 2.3x or Slow Progression figure, at the upper end of the range presented in Figure 52. Only 8% of respondents believed that capacities would be outside the range of scenarios presented. In the stakeholder discussions there was broad agreement that there would be high growth in offshore wind, but some disagreement for potential growth of onshore wind.

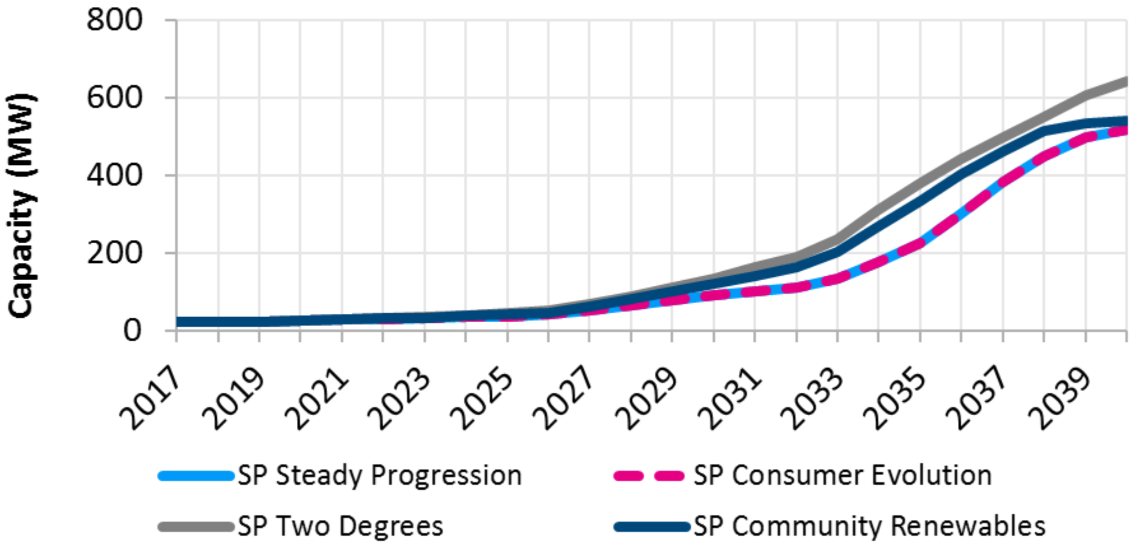
The alternate data sources for wind capacity projections are generally within the envelope of the FES derived SP scenarios, and suggest that these scenarios provide a suitable set for testing the impact on the SPT network. There is a reasonable range of capacities for all types of wind generation, which we believe adequately reflects the uncertainty that was apparent in the stakeholder discussions.

3.3.2 PV

3.3.2.1 SPT Results

The SP scenarios show strong growth in distribution connected PV capacity over the horizon studied, though with the bulk of the capacity change occurring after the RIIO-T2 period, as shown in Figure 53. The change in nameplate capacities over the RIIO-T2 period ranges from 13MW (Steady Progression and Consumer Evolution) to 22MW (Two Degrees). After the RIIO-T2 period capacities increase substantially, to 641MW by 2040 in the Two Degrees scenario. Though this is a significant increase in PV capacity, the impact on the SPT network is likely to be relatively low, due to the low expected output of PV at Winter Peak and Summer Minimum (AM) demand periods.

Figure 53 Total SPT Distribution Connected PV capacity (MW)



Using the "rural area" methodology for siting new capacity it can be seen that PV is distributed outside of the large urban centres (Figure 54).

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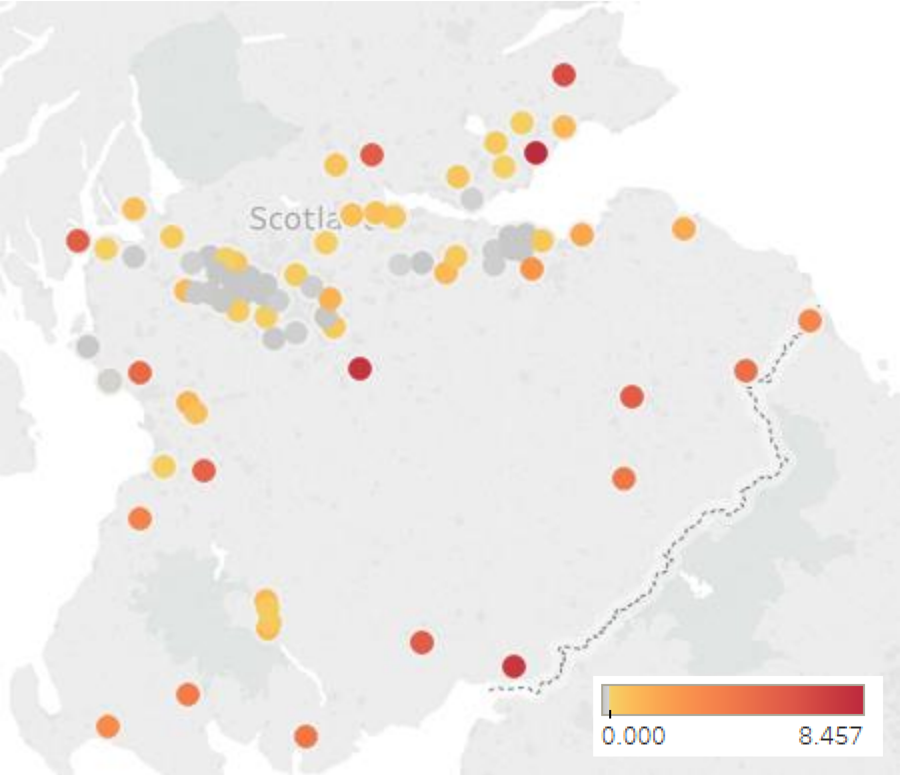
Figure 54 GSP level SPT DX Connected PV capacity, Community Renewables, 2030 (MW)



3.3.2.2 Comparison with other data sources

As for wind, we have not found explicit projections for solar capacity at the different grid levels. However, we have found projections for total PV capacity (Behind the meter, DX and TX), and present these here. The sources used are the Scottish Government's Climate Change Plan, Baringa GB Electricity Market Reference Case, and Stakeholder feedback.

Figure 55 shows capacity projections for 2030 for all sources. The SPT FES do not assume any transmission (TX) connected solar capacity, but other data sources may, and this has been combined with distribution connected (DX) capacity. Both calculations using the Scottish Government 140% RES-E figure give total capacities in the middle of the SPT FES range. Using the Baringa Reference Case grid scale solar growth assumptions gives a figure for solar capacity that close to the Steady Progression but is slightly outside of the SPT FES range.

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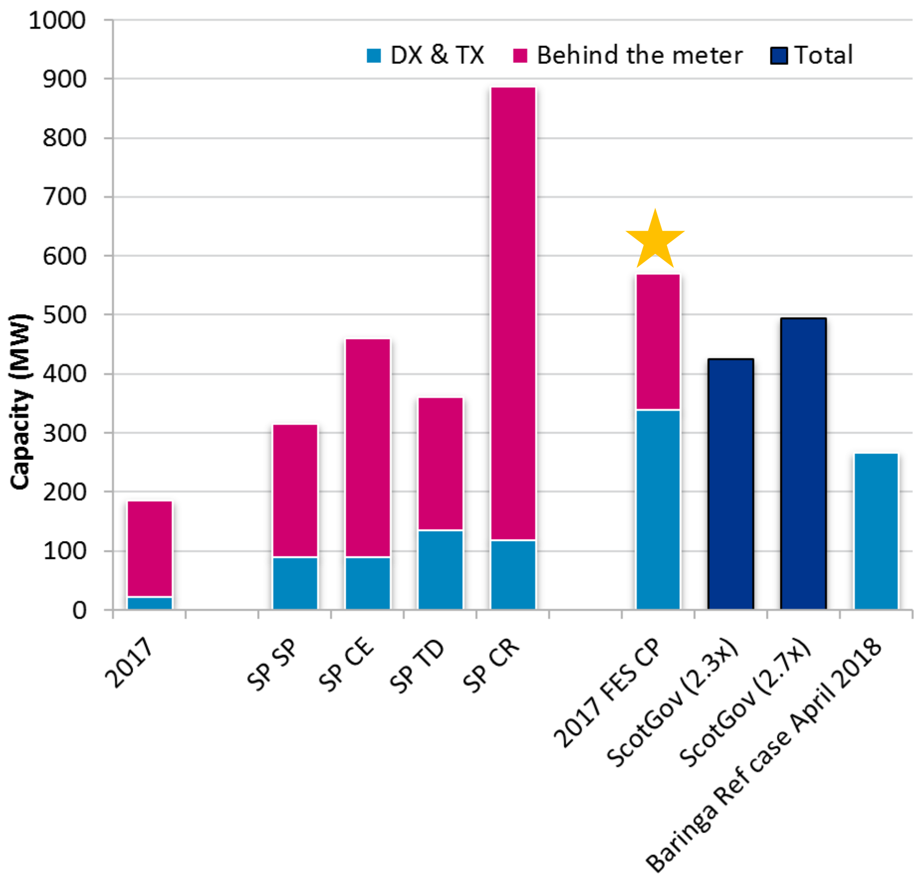
Figure 55 Total SPT PV capacity 2030, alternate data sources (MW) [stakeholder view as star]



While SPT stakeholders believed strong growth in PV capacity was possible, with 42% choosing 2017 Consumer Power as the most credible scenario in 2030, there were a range of views, with 25% choosing 2017 Steady State and 33% 2017 Slow Progression. There was less consensus on the expected outcome than for Heat Pumps, Electric Vehicles or Wind. No respondents believed that capacities would be outside the range of 2017 FES presented.

The range of PV capacity projections in the FES is relatively wide, matching the uncertainty from stakeholders, and broadly covers the other sources of projections we have used. We believe that it is a valid set of projections to use for SPT load planning.

3.3.3 Hydro

3.3.3.1 SPT Results

Hydro capacity shows modest growth over the period studied, as shown in Figure 56. Over the RIIO-T2 period the additional capacity ranges from 0MW (Steady Progression) to 12 MW (Community Renewables).

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The methodology used results in new hydro capacity being sited at GSPs with existing capacity, as shown in Figure 57 .

Figure 56 Total SPT Distribution Connected Hydro capacity (MW)

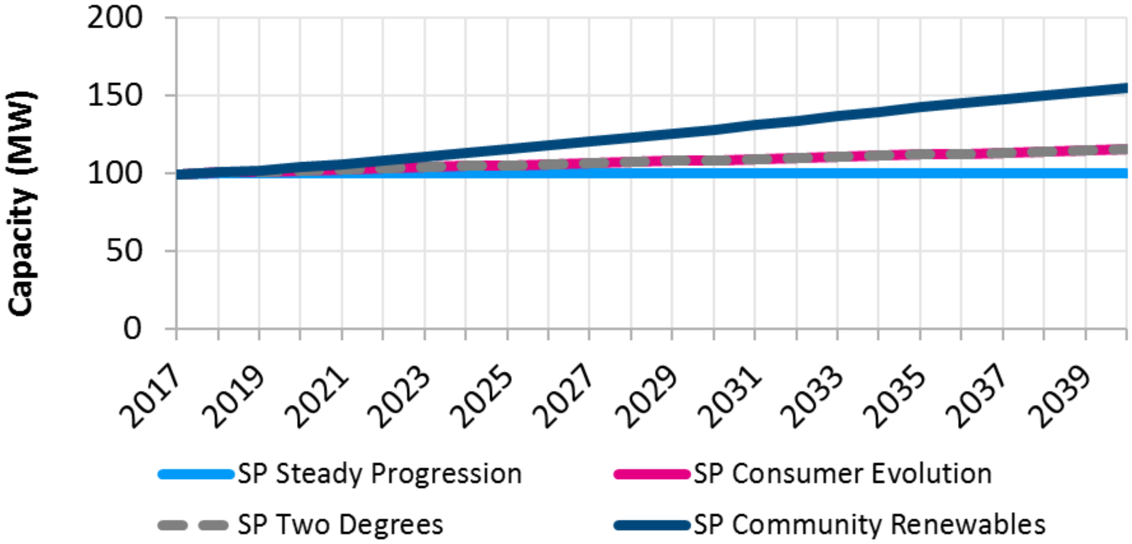

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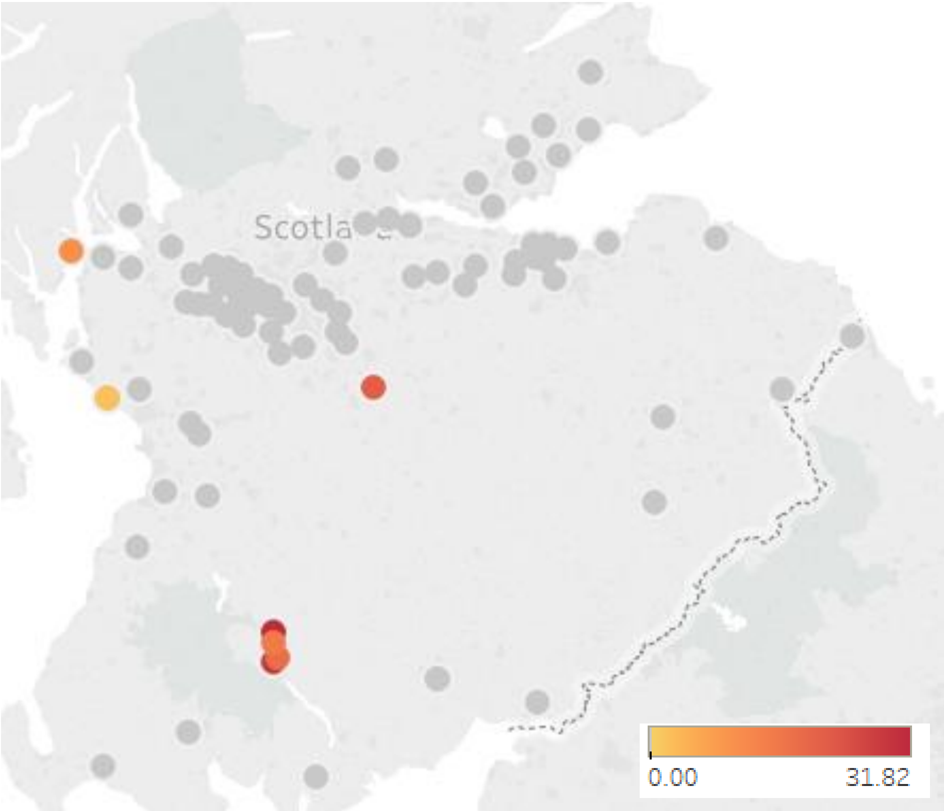
Figure 57 GSP level SPT DX Connected Hydro capacity, Community Renewables, 2030 (MW)



3.3.3.2 Comparison with other data sources

We have not found explicit projections for hydro capacity in the SPT area. However, we have used the Scottish Hydropower Resource Study (SHRS)[43] to map estimates of economically viable sites to the SPT area, and calculate that there is only 10.5MW of additional potential capacity for the area. This is within the range of the SPT FES, but is at the low end. By 2040 the Community Renewables scenario projects 55MW of additional capacity, implying use of sites beyond categorised by the SHRS, while in the Steady Progression scenario there is only 1MW.

We believe that the SPT FES cover a reasonable range in Hydro capacities for SPT load planning. However, we think the lower capacity growth scenarios are more likely, given limited resource opportunities.

[43] Scottish Hydropower Resource Study, 2008
http://www.gov.scot/Resource/Doc/917/0064958.pdf

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3.3.4 CHP

CHP capacities are expected to have fairly limited growth in absolute terms over the period modelled, and will have only a small impact on the change in overall supply/demand balance. We treat Renewable and Non-Renewable CHP separately, and describe the results from each below.

3.3.4.1 Renewable CHP

SPEN project planning data suggests fairly strong growth (in relative terms, the absolute capacities are small) in Renewable CHP capacity in 2018 and 2019. Thereafter, the SPT FES show slower growth, as shown in Figure 58.

Figure 58 Total SPT Distribution Connected Renewable CHP capacity (MW)

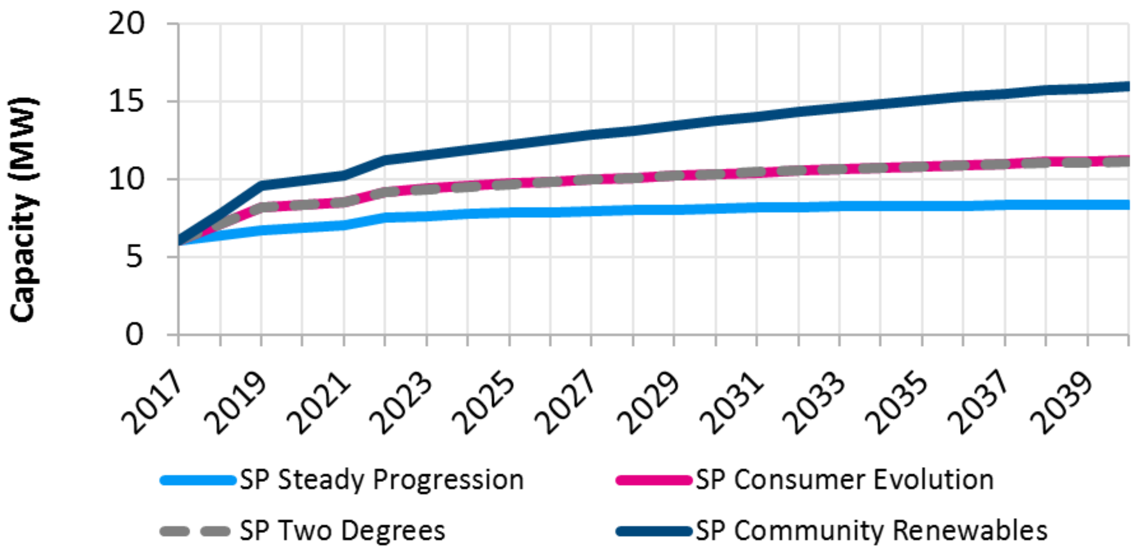

Figure 59 shows the spatial allocation of Renewable CHP capacity, sited at industrial sites outside of the main city centres.

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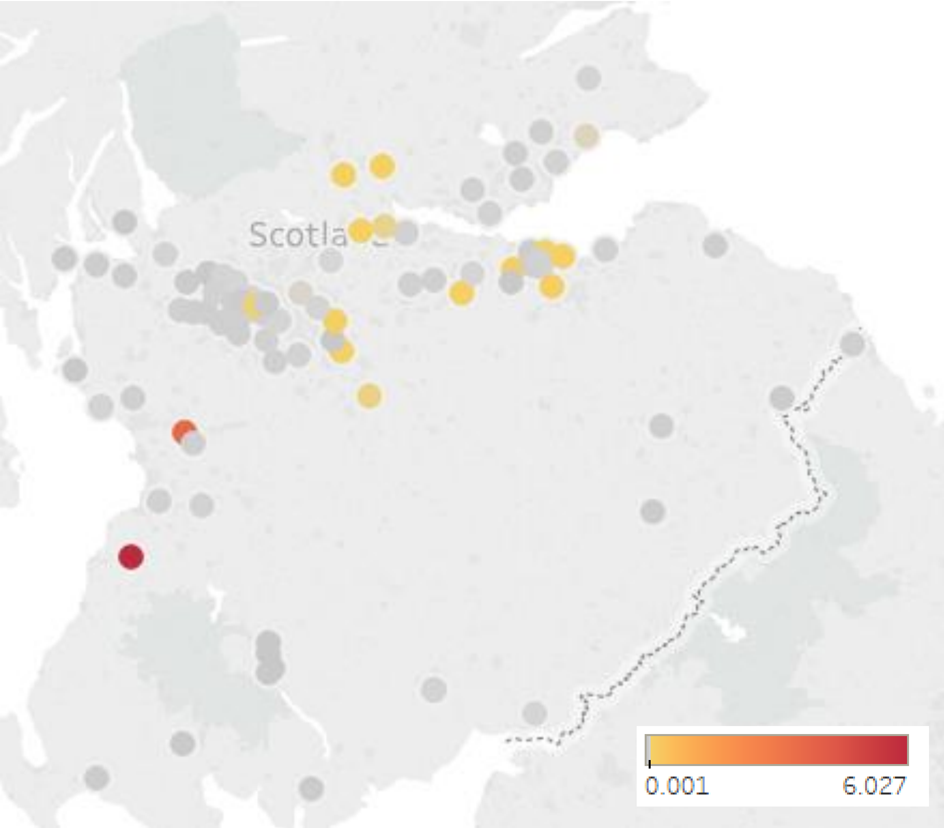
Figure 59 GSP SPT DX Connected Renewable CHP capacity, Community Renewables, 2030 (MW)



3.3.4.2 Non-Renewable CHP

Non-renewable CHP shows a range in potential growth in 2018 and 2019, then fairly flat growth thereafter, as shown in Figure 60. In the Two Degrees and Community Renewables scenarios capacity increases to 2032, then gradually decreases again, as high decarbonisation limits the use of carbon emitting technologies, even high efficiency CHP. Over the RIIO-T2 period there is little growth in any scenario, with a maximum of 2MW of additional capacity in this period (Community Renewables).

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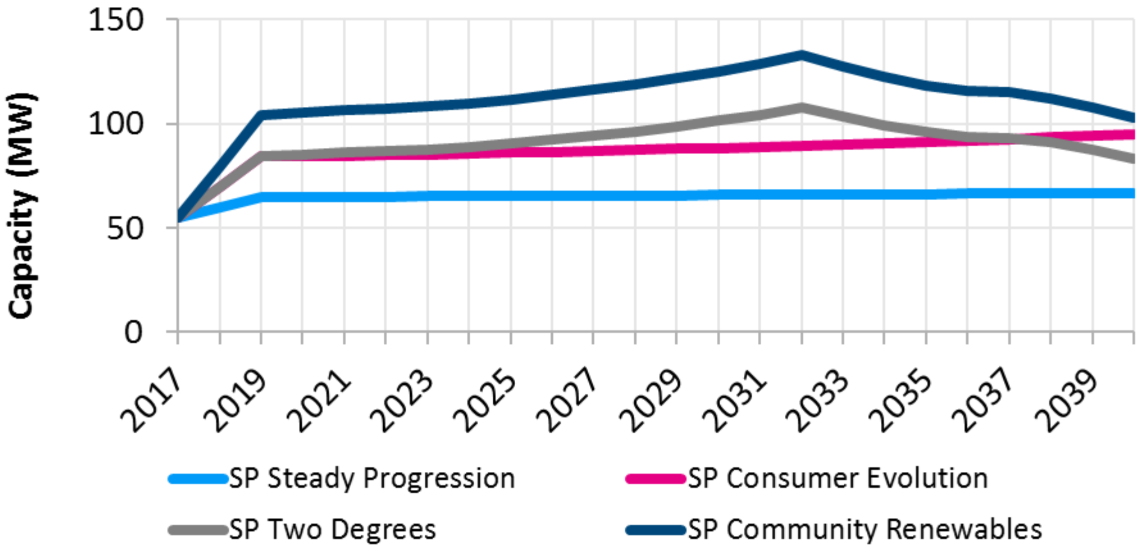
Figure 60 Total SPT Distribution Connected Non-Renewable CHP capacity (MW)



3.3.5 Controllable plant

Controllable plant capacities are not expected to show large change over the modelled period in absolute terms. However, the relative increase is high in some scenarios, and for individual GSPs the change in capacity can be large. We treat Renewable and Non-Renewable Controllable plant separately, and describe the results from each below.

3.3.5.1 Renewable Controllable

There is a central estimate of 44MW of additional capacity (mainly biomass) during 2018-19, with slower growth in all scenarios thereafter. During the RIIO-T2 period capacity increases range from 4MW (Steady Progression) to 38MW (Community Renewables). By 2040 the total installed capacity ranges from 189MW to 384MW.

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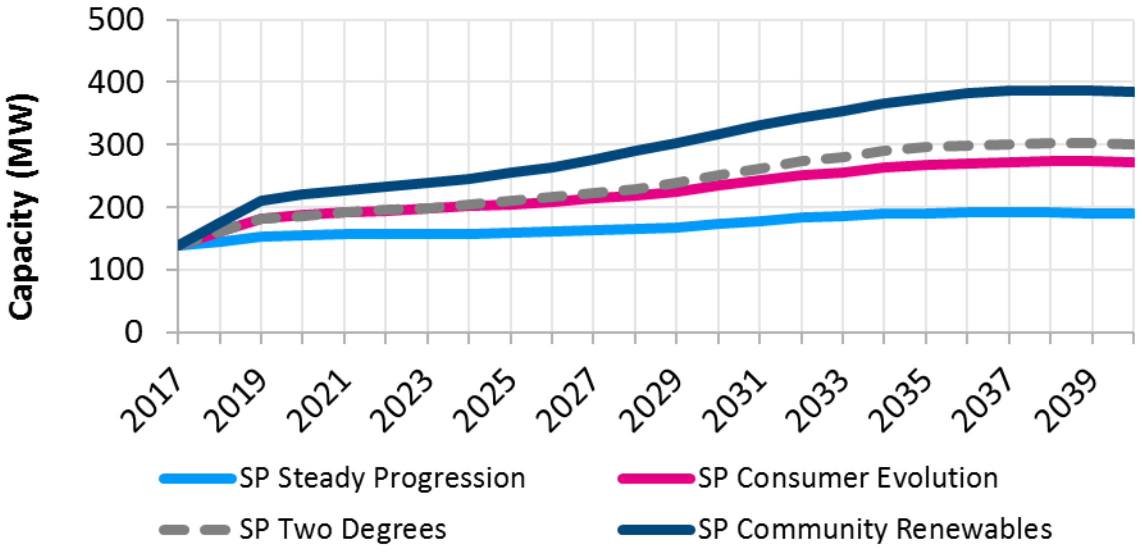
Figure 61   Total SPT Distribution Connected Renewable Controllable capacity (MW)



3.3.5.2 Non-Renewable Controllable

A number of large projects are expected to connect to the SPD network in 2018 and 2019, increasing capacity by 44MW in the Consumer Evolution and Two Degrees scenarios over this period. The FES assumes no growth thereafter, as shown in Figure 62. Given the strong growth rates expected in 2018 and 2019, assuming no growth in all scenarios may appear to be conservative. However, recent changes to the emissions limits for medium capacity plants[44] and the reduction in value of Embedded Benefits[45] are likely to make the business case for new projects much more challenging.

[44] Medium Combustion Plant Directive, http://ec.europa.eu/environment/industry/stationary/mcp.htm

[45] "Impact Assessment and Decision on industry proposals (CMP264 and CMP265) to change electricity transmission charging arrangements for Embedded Generators" – Ofgem, June 2017

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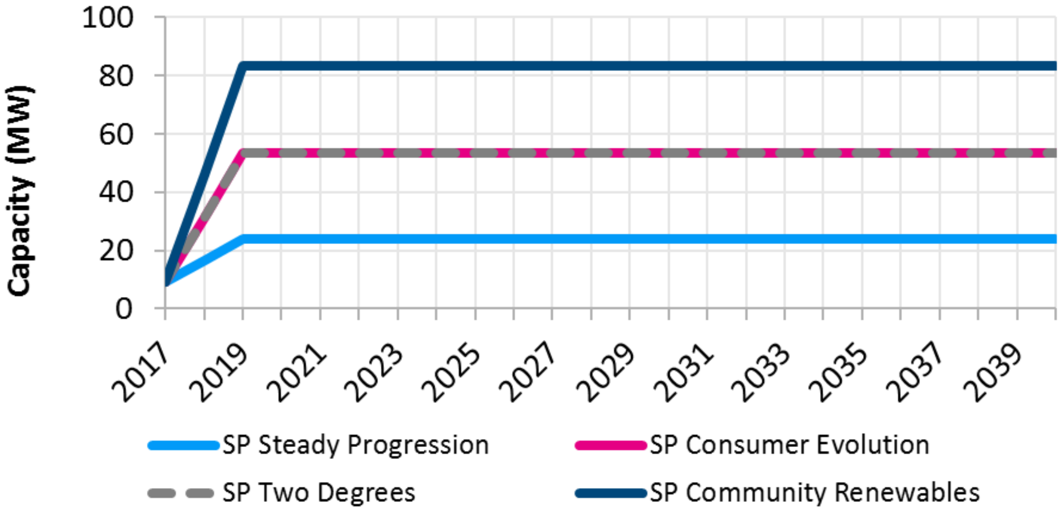
Figure 62 Total SPT Distribution Connected Non-Renewable Controllable capacity (MW)



3.3.6 Storage

3.3.6.1 SPT Results

The SPT FES show the potential for strong growth in distribution connected battery storage capacity, from close to 0MW in 2017 to nearly 1000MW in 2040 in the highest scenario, as shown in Figure 63. Over the RIIO-T2 period the range in additional capacity is fairly limited, from 10MW (Steady Progression) to 63MW (Community Renewables). Thereafter, growth rates diverge, leading to a wide range of installed capacities in 2040 of between 63MW (Steady Progression) and 967MW (Community Renewables).

The methodology for siting storage places new capacity initially into GSPs with high thermal headroom, then into GSPs with low thermal headroom. This can be seen in the spatial breakdown in Figure 64, with capacity sited at both Coatbridge (high headroom) Charlotte Street (low headroom).

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Figure 63 Total SPT Distribution Connected Storage capacity (MW)

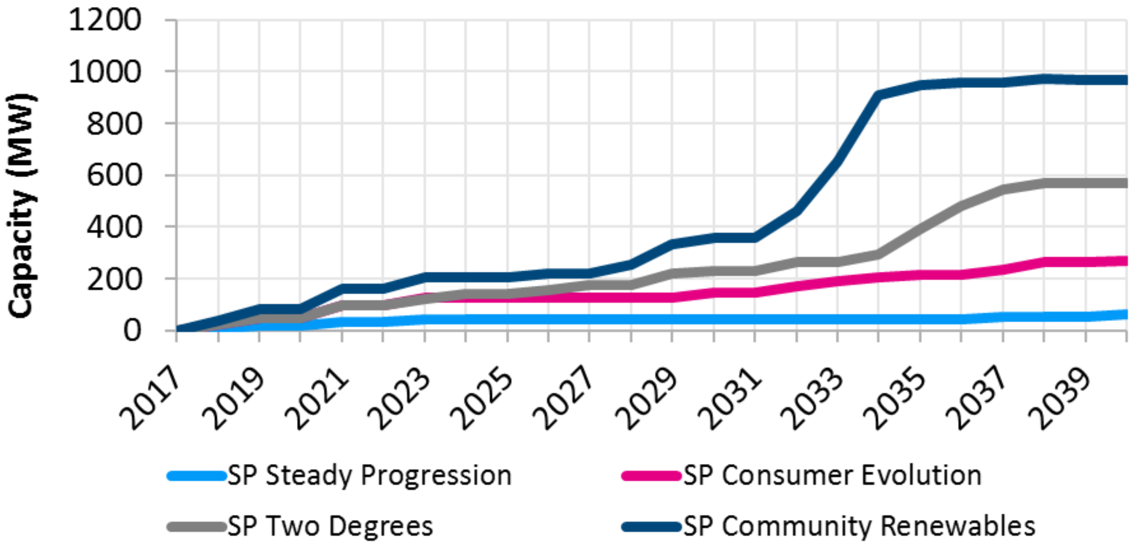
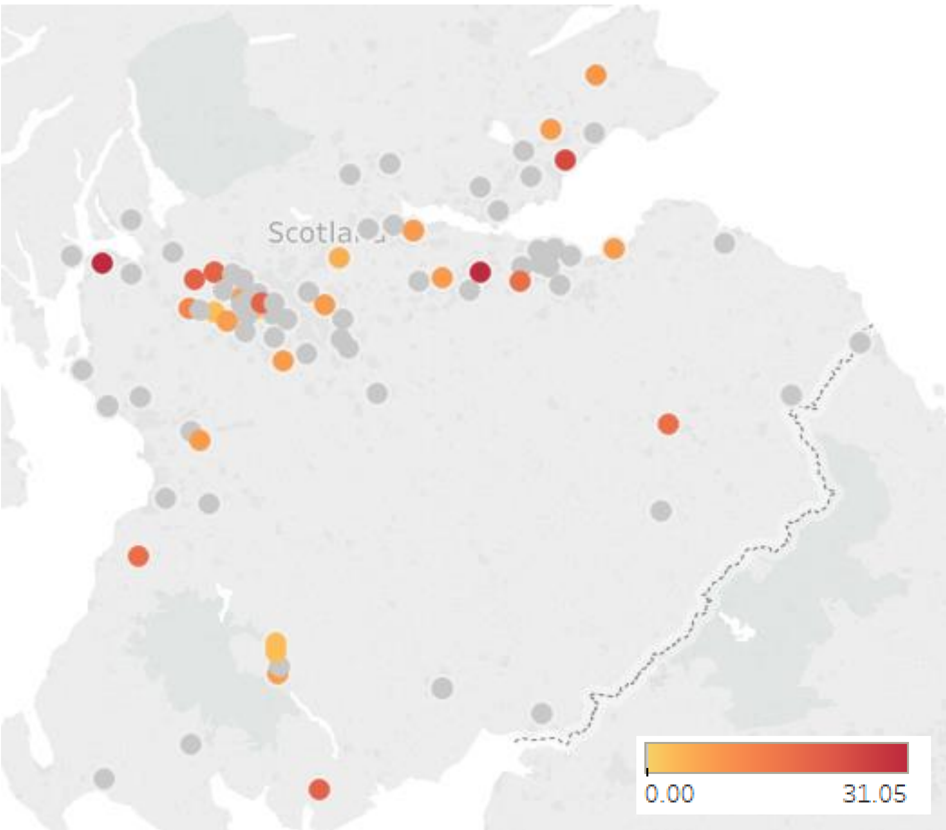


Figure 64 GSP SPT DX Connected Storage capacity, Community Renewables, 2030 (MW)



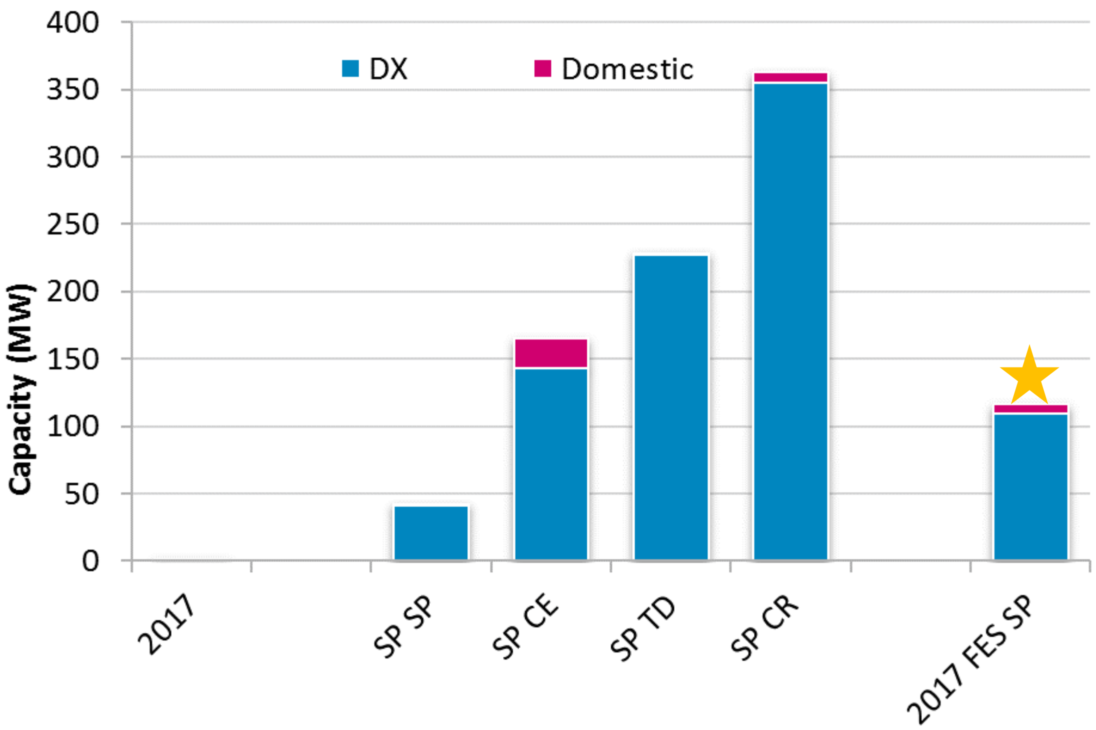
3.3.6.2 *Comparison with other data sources*

We asked stakeholders for their view on likely increases in battery storage capacity, taking both distribution connected and domestic storage into account. Stakeholders overwhelming selected the 2017 scenario “Slow Progress” (75% of respondents), in the middle of the 2017 FES range and within the 2018 SPT FES range, as shown in Figure 65. Only 16% of respondents believed that capacities would be outside of the FES range (8% higher and 8% lower). The 2017 Slow Progress scenario most closely maps to the 2018 Consumer Evolution and Steady Progression scenarios, at the lower end of the 2018 SPT FES range.

In stakeholder discussions there was disagreement as to the mix of distribution and domestic battery storage, and reference regularly made to the fact that future growth was highly uncertain and reliant on policy decisions.

We believe that the wide range of SPT FES projections adequately captures this uncertainty and can be used by SPT in their load planning.

Figure 65 Total SPT Battery Storage capacity 2030 (MW) [stakeholder view as star]



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3.3.7 Total Distribution connected supply

The total generation at peak for distribution connected supply technologies is shown in Figure 66 for the community renewables scenario. It can be seen that in the later years expected output at peak is dominated by wind and storage. There is no output from solar PV as it is assumed to be night-time during the Winter Peak.

Figure 66 Total SPT DX connected supply, expected output at peak, Community Renewables (MW)

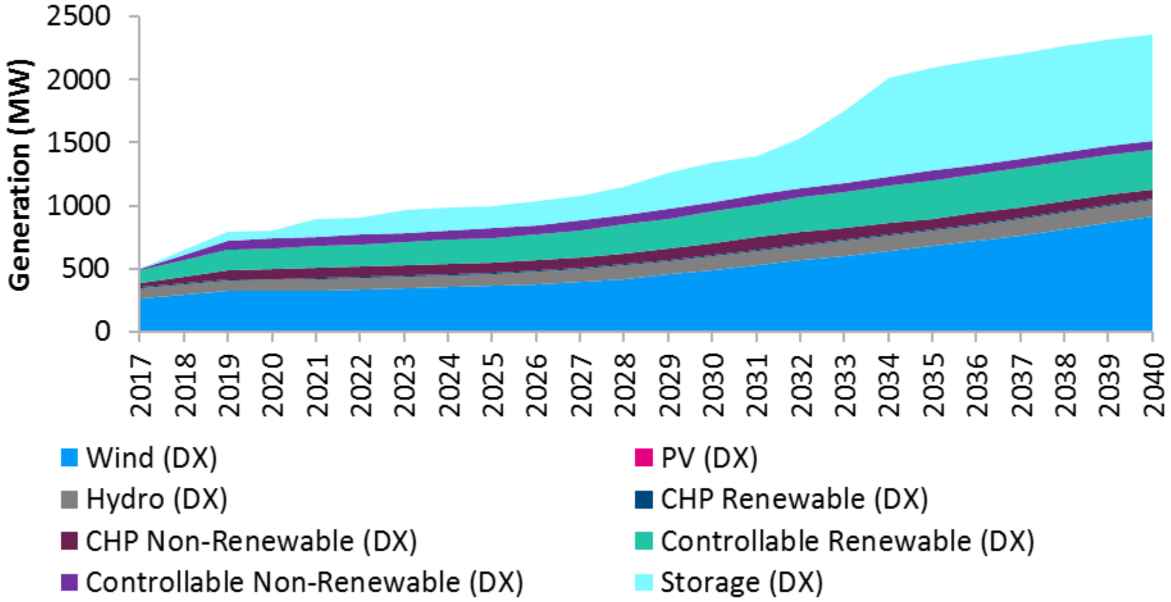

Figure 67 and Figure 68 show the total DX supply at peak and Summer Minimum (AM), across all scenarios. There is a large range in the total supply, particular in the period 2030 onwards, reflecting the uncertainty around the capacity of different technology types.

There is significant variation in growth rates of DX supply across different GSPs. Figure 69 shows the relative change in supply generation at peak for three selected GSPs, and for the SPT area as a whole, for the Community Renewables scenario. It can be seen that while there is limited growth at Portobello, Galashiels has growth of 400% by 2030 and 800% by 2040. East Kilbride already has significant DX supply capacity, and though the absolute increase in supply capacity is similar to Galashiels over the horizon modelled, the relative growth rate is much lower. Figure 69 Change in distribution generation at SPT and selected GSPs, Winter Peak, Community Renewables (%)

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Figure 67 Total SPT distribution connected supply, expected output at peak (MW)

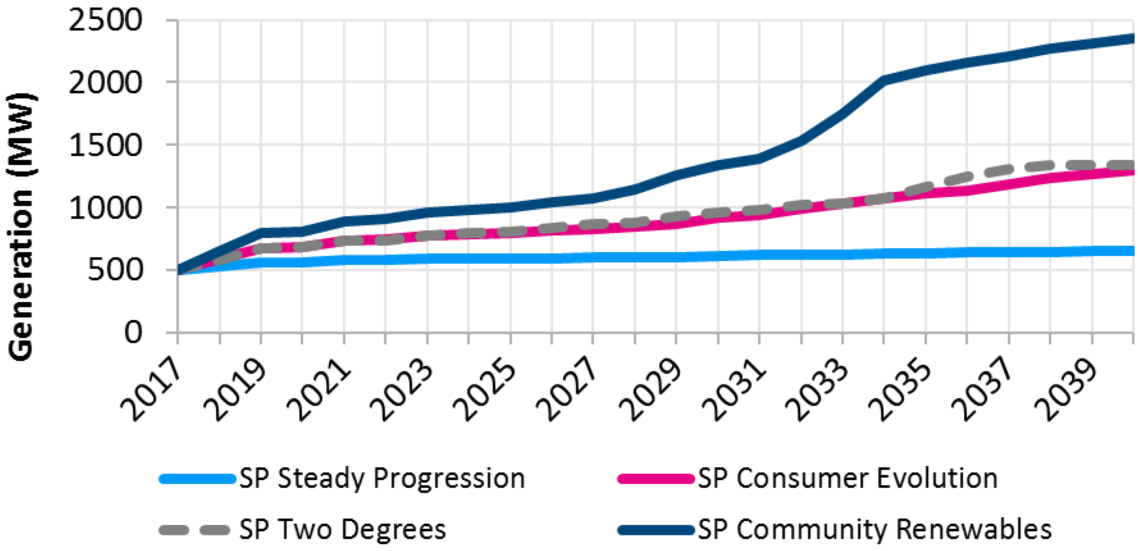

Figure 68 Total SPT distribution connected supply, expected output at Summer Minimum (AM) (MW)

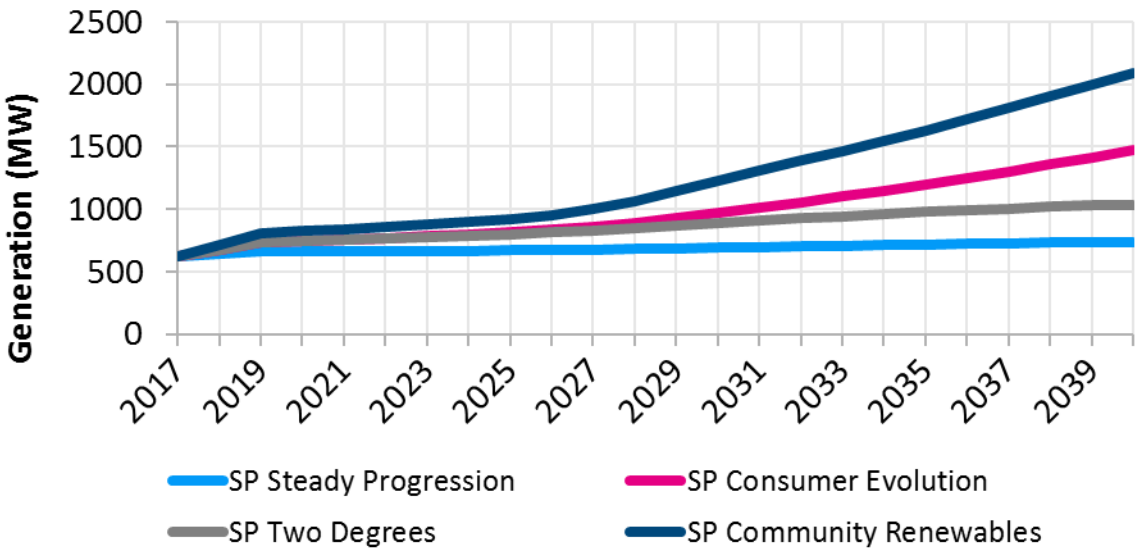

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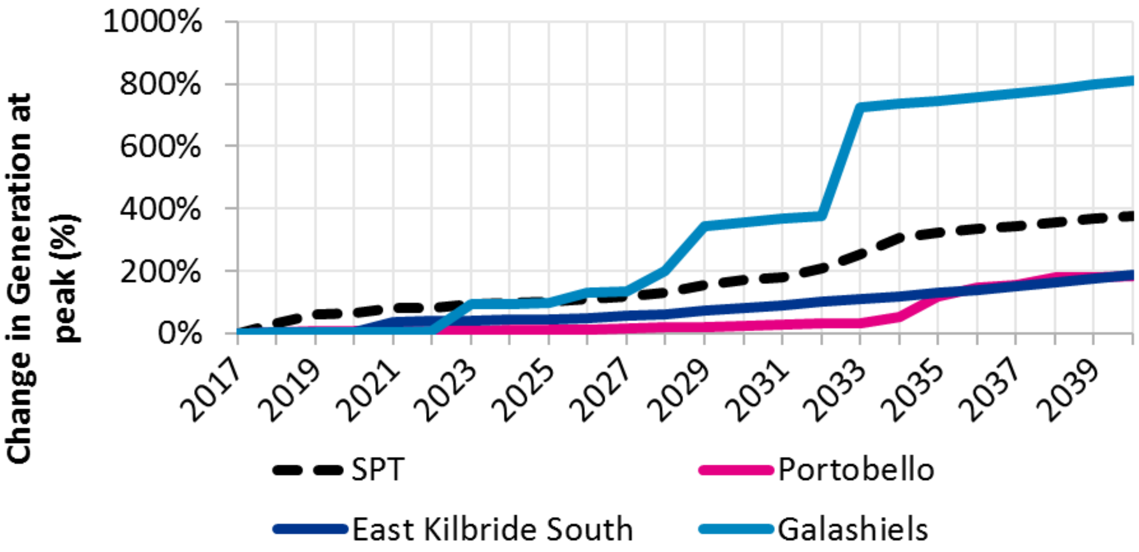
Figure 69 Change in distribution generation at SPT and selected GSPs, Winter Peak, Community Renewables (%)



3.4 GSP level net demand results

Net demand from supply and demand technologies on the distribution network is seen on the SPT network through GSPs. In this section we aggregate the net demand from all distribution technologies.

3.4.1 GSP net demand

The net demand at each GSP is found by summing all distribution connected demand and subtracting all expected output from distribution connected supply. This calculation is performed for each GSP, for Winter Peak and Summer Minimum (AM) periods, using appropriate demand levels and supply load factors for each period.

Figure 70 and Figure 71 show the net demand from GSPs for the whole SPT area, at Winter Peak and Summer Minimum (AM) respectively. It can be seen that for all scenarios there is a reduction of net demand in the near term, driven by increased supply, then relatively flat net demand over the RIIO-T2 period as supply increases are balanced by the early stages of electrified heat and transport. After the RIIO-T2 period there are range of pathways, depending on scenario and time period. There is notably strong growth in net demand at Peak in the Two Degrees and Community Renewables scenarios, primarily driven by electric vehicle uptake being faster than increased generation capacity.

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Figure 70 Total SPT net demand, Winter Peak (MW)

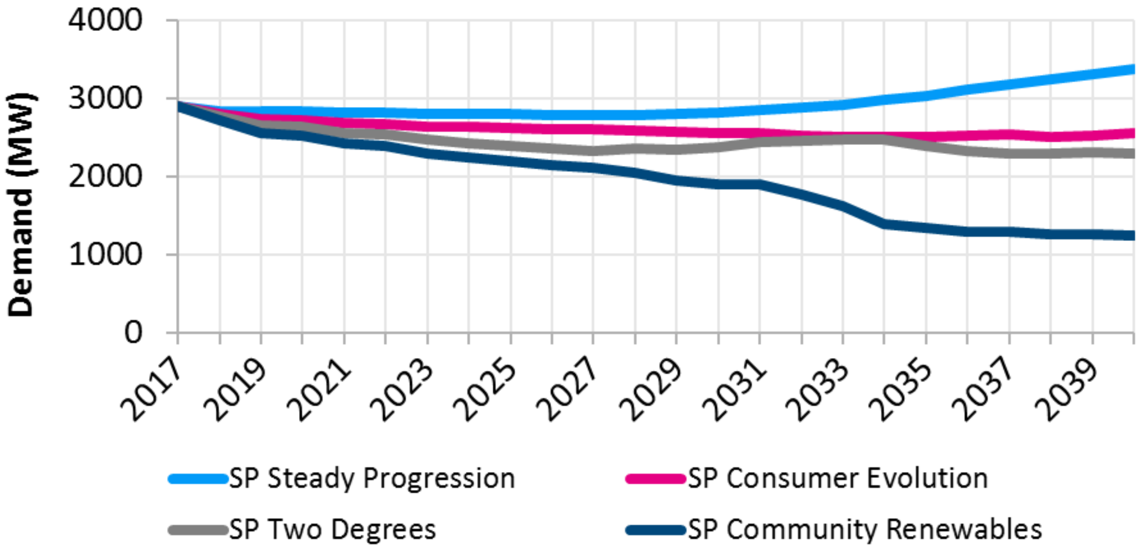
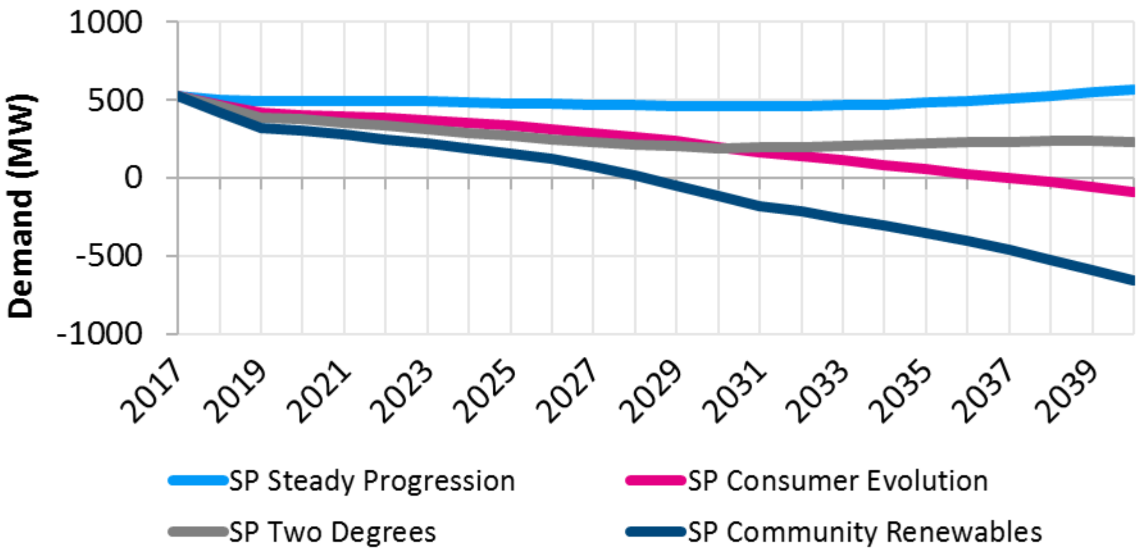


Figure 71 Total SPT net demand, Summer Minimum (AM) (MW)



3.4.2 Impact on individual GSPs

While net demand over the whole SPT area is fairly flat over the RIIO-T2 period, this does not show the impact on individual GSPs, some of which may experience more change in net demand and therefore result in investment on the SPT network.

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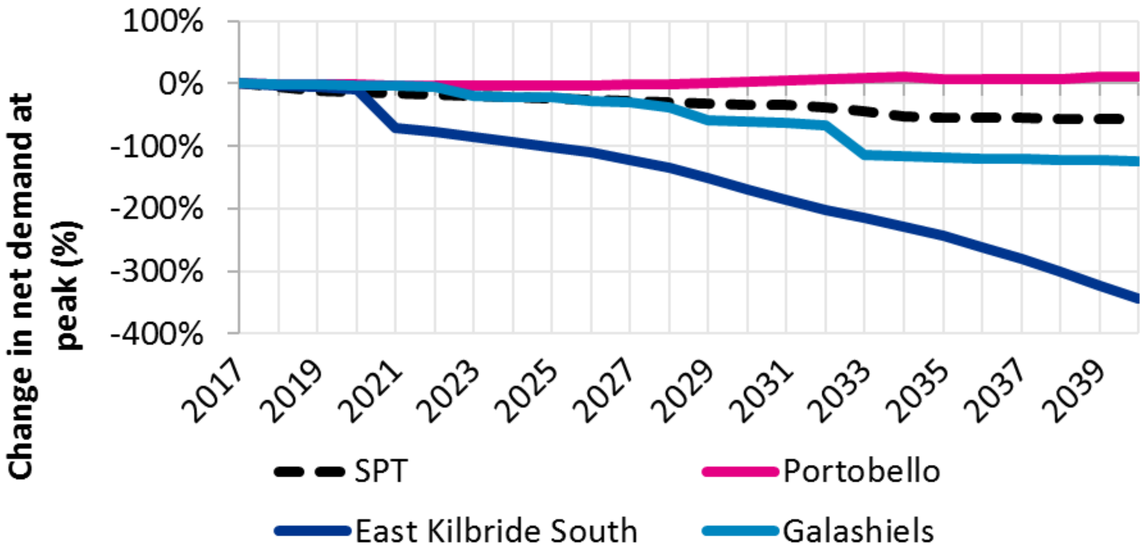
Figure 72 shows the relative change in peak net demand for three selected GSPs, in the Community Renewables scenario. It can be see that there is huge variation across different GSPs, with Portobello experiencing modest growth in demand while East Kilbride South has a significant reduction in net demand – becoming a net supply GSP at peak by 2026 in this scenario.

Figure 72 Change in net demand at SPT and selected GSPs, Winter Peak, Community Renewables (%)



To further investigate the impact on individual GSPs we have calculated the change in net demand from the 2017 starting point. While Summer Minimum (AM) net load is considered, the largest absolute changes from 2017 are usually at Winter Peak. Figure 73 shows the distribution of GSP net demand changes, by scenario and over the pathway. Steady Progression is the only scenario to show significant increases in net demand, and only towards the end of the horizon. All other scenarios show a general trend towards net supply for many GSPs

However, the figures assume some level of flexible demand is available that can be shifted away from peak periods. The assumptions in the FES on flexibility are quite bullish. We have performed a sensitivity where all flexible demand is assumed inflexible. Figure 74 shows how net demand changes by GSP if no flexible demand is available. There is a large increase in the number of GSPs seeing significant net demand growth, due to unmanaged electrified heat and transport.

This increase tends to happen from the late 2020s onwards, i.e. after the RIIO-T2 period, but is particularly rapid leading to significant upward swing in net demand. This has implications for network reinforcement through RIIO-T2 to accommodate a large expected increase in low carbon technologies shortly after this, given the lead times to undertake particular reinforcements.

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Figure 73 Change in net demand per GSP from 2017, all scenarios (MW)

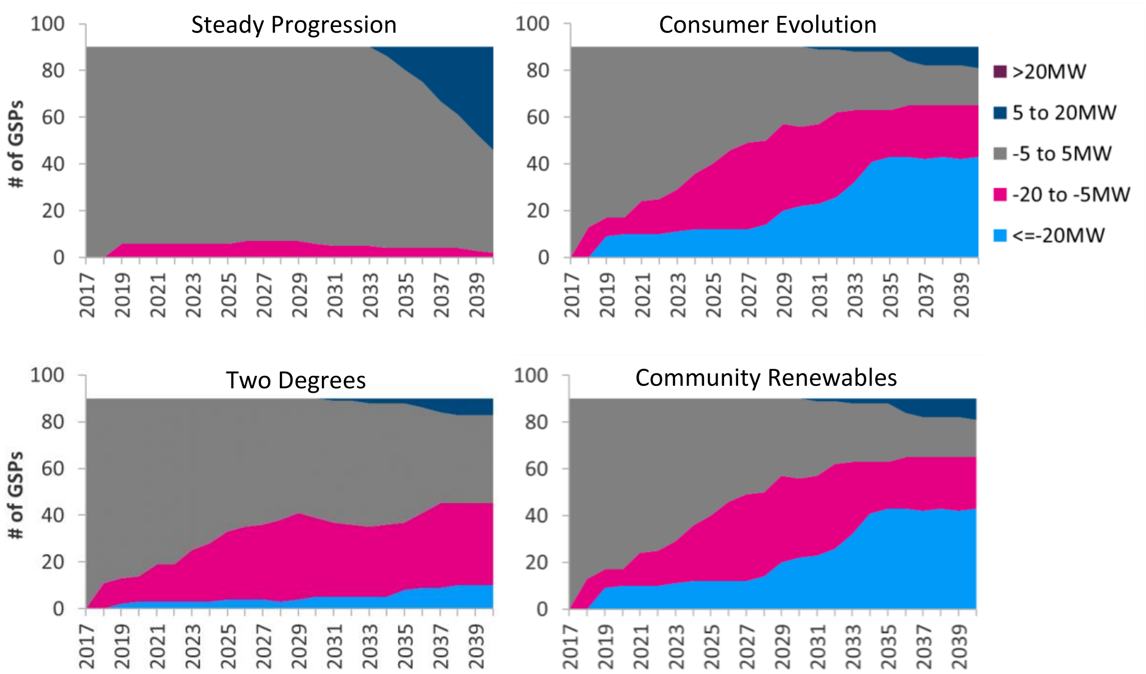
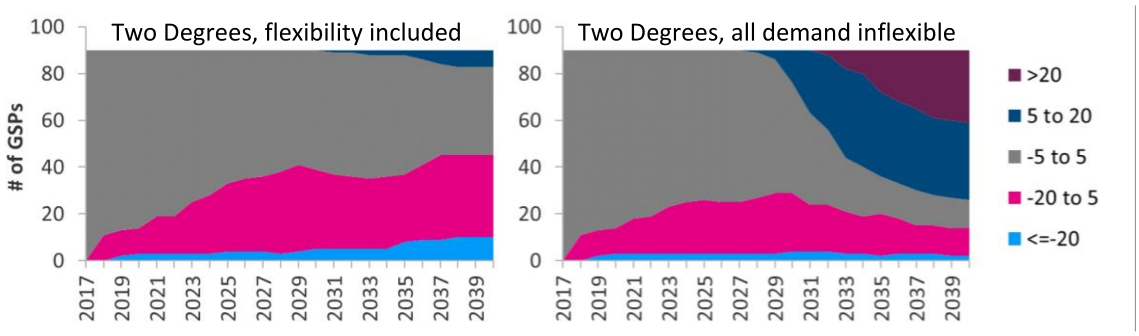


Figure 74 Change in net demand per GSP from 2017, Two Degrees – all demand inflexible (MW)



3.5 Transmission connected supply/storage

The capacity of generators and storage connected directly to the SPT network has been aggregated by plant type and is shown in Figure 75 – Figure 77. For the SPT Area we supply capacity results for named plant, but have been aggregated here for clarity.

There is relatively low uncertainty relating to thermal plant on the SPT network, with only two large plants (Hunterston and Torness, both nuclear) currently connected. These plants are widely expected to close in the early and late 2020s respectively, and there is no new thermal capacity expected at

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least till 2030. This low uncertainty is reflected in the similarities in capacity of thermal plant in all scenarios.

The bulk of recent capacity increases on the SPT network have come from wind projects, and this is set to continue. There is significant uncertainty around the rate of growth in wind capacity, particularly as projects are likely to remain reliant on government support mechanisms for some time to come. The FES capture this uncertainty through a large range in potential capacities, with a higher range in capacities for offshore wind projects, which are at an earlier stage of technological development.

As discussed in Section 3.3.1, having compared the range of wind capacities in these scenarios with other sources, we believe they provide a credible range for the purposes of planning investment on the SPT network.

Figure 75 Total SPT transmission connected generation capacity, Steady Progression (MW)

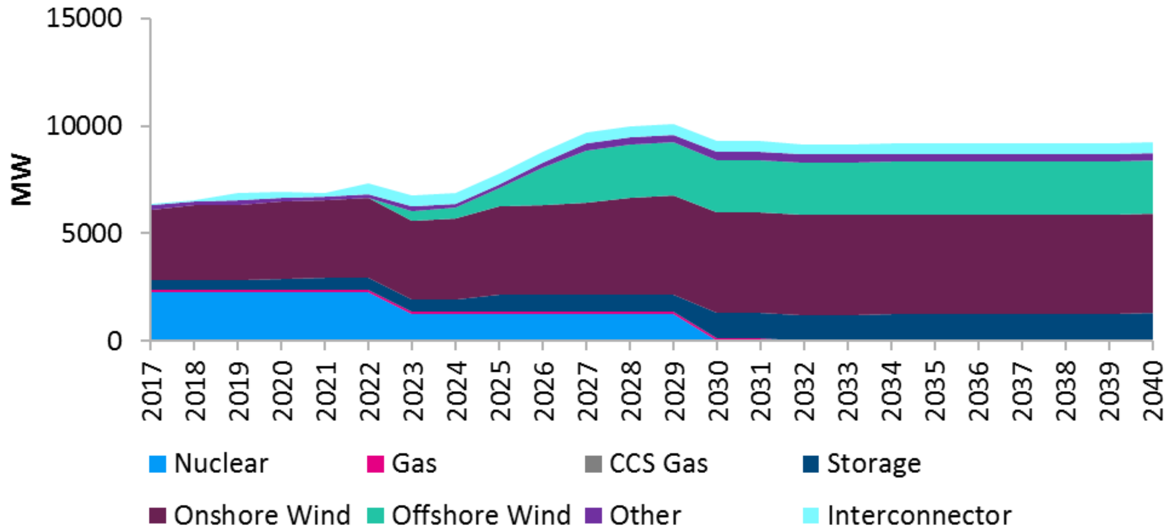

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Figure 76 Total SPT transmission connected generation capacity, Consumer Evolution (MW)

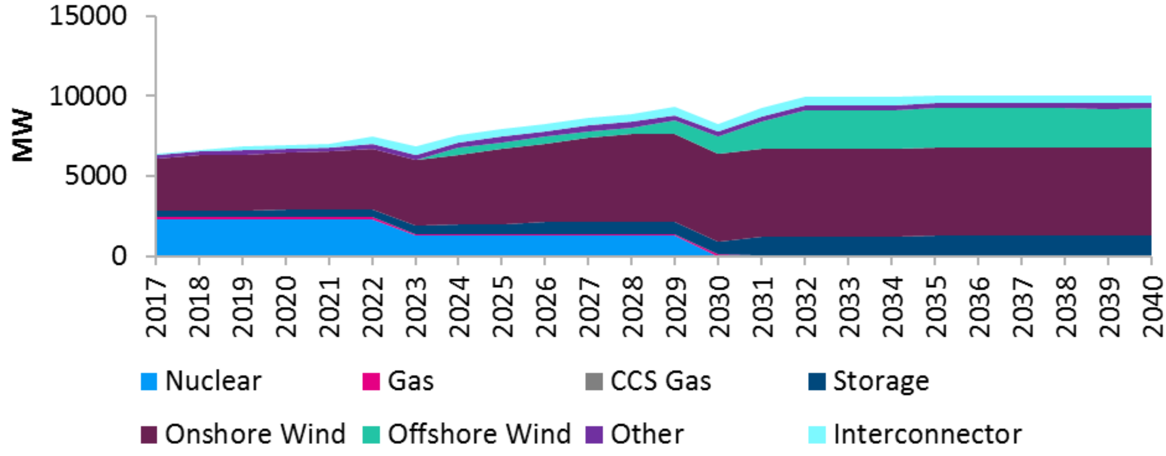

Figure 77 Total SPT transmission connected generation capacity, Two Degrees (MW)

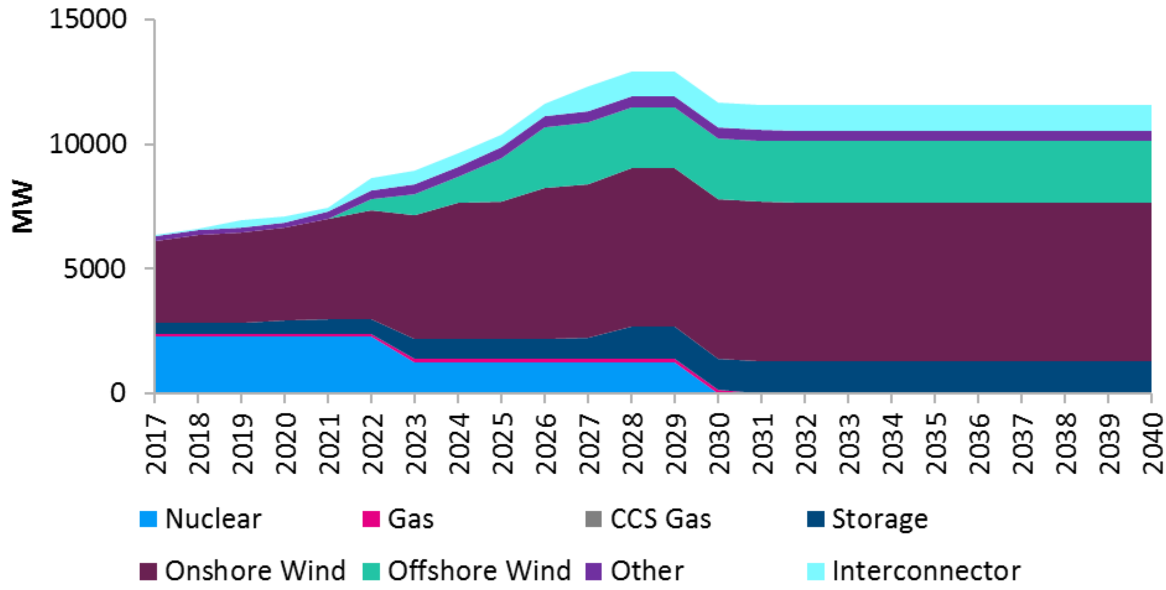

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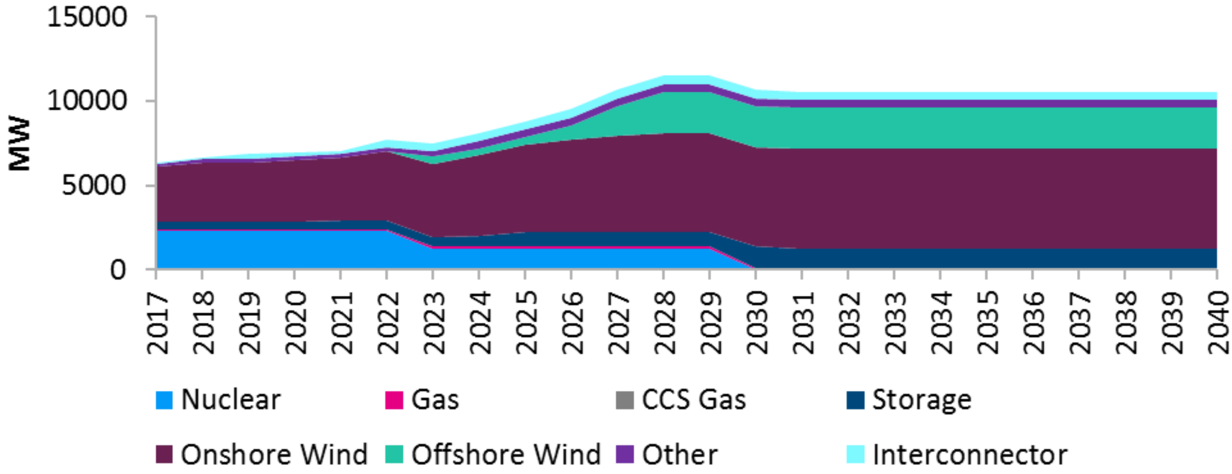
Figure 78 Total SPT transmission connected generation capacity, Community Renewables (MW)



3.6 Conclusions

We have used the 2018 FES to build a scenario tool for load planning on the SPT network. We have developed a methodology that uses the FES assumptions as a starting point, then refines these in a numbers of ways to better reflect the SPT area.

Both the methodology and high level assumptions have been validated through stakeholder engagement and against independent sources of projections.

The results presented here show the following key insights:

- There is a wide range in the levels of demand and supply in the long term scenarios, but most change at an aggregate level happens from late 2020s onwards i.e. after RIIO-T2
- The aggregate SPT level changes mask some sizeable and significant changes at a small number of GSPs over the RIIO-T2 period
- Network planning through RIIO-T2 needs to ensure it can accommodate more rapid changes affecting many GSPs in the early part of T3
- The level of flexible demand (e.g. from EVs, HPs) that can be accessed is highly uncertain but is one of the main drivers of the need for reinforcement (or not)
- The high decarbonisation scenarios broadly match the Scottish Government's ambitions for renewable electricity generation and electric vehicle uptake, while the slower decarbonisation scenarios fall short
- All scenarios have lower uptake of heat pumps than is implied by the Scottish Government ambitions for low carbon heat

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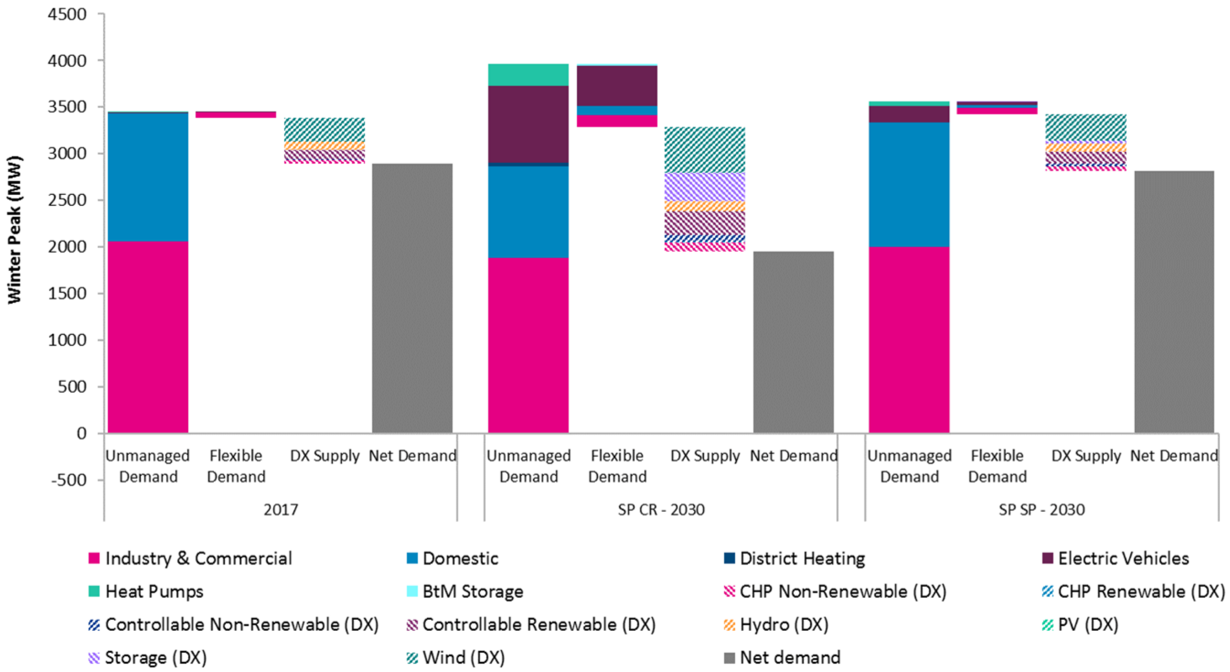
- On the demand side, the largest changes come from domestic demand (potential for reductions due to increased efficiency) and electric vehicles (potential for large increases if not managed). There is expected to be less of an impact from heat pumps.
- On the supply side, the key technologies are wind (providing intermittent energy output in most periods) and flexible storage and controllable thermal generation (providing power in peak periods, as shown in Figure 79Figure 4), with a large impact on net transmission demand and large variation across scenarios

Figure 79 Key drivers of expected transmission net demand at winter peak



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Most of the results presented in this report are at the aggregate SPT level, however the full granularity set of results that this reports summarises have been shared with SPEN as part of this project to all SPEN to perform detailed network investment planning.

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Appendix A Stakeholder Engagement Log

Table 5 Stakeholder Engagement Log to inform scenario analysis

Organisation	Organisation type	Engagement purpose			Engagement type						
		Shaping methodology	Data	Explain methodology and outputs	Email request	Bilateral call / meeting	Internal progress session	External progress session	Briefing note	Public Webinar	NG customer seminar
SPT	Home TO	✓	✓	✓	✓	✓	✓	✓	✓	✓	
SPD	Home DNO	✓	✓	✓	✓	✓	✓	✓	✓		
SP Renewables	Renewable developer					✓					✓
SSEN	Neighbour TO / DNO	✓		✓		✓		✓	✓		
NG TO	Neighbour TO	✓		✓		✓					
NG ESO	SO / FES provider		✓	✓	✓	✓				✓	
WPD	DNO	✓				✓					
Scottish Government	Government		✓	✓	✓	✓				✓	
Transport Scotland	Government agency			✓		✓					
Glasgow City Council	Local Government			✓		✓				✓	
Scottish Renewables	Industry association			✓		✓					
SGN	Gas DNO			✓		✓					
Assoc. of Decentralised Energy	Industry association			✓		✓					
Citizens Advice Scotland	Consumer group			✓				✓	✓		
Ofgem	Regulator			✓				✓	✓	✓	
Falkirk Council	Local Government			✓				✓	✓		
Scottish Enterprise	Development agency			✓				✓	✓		
Energy Skills Partnership	Industrial skills body			✓				✓	✓		
Univerity of Strathclyde	Academia			✓				✓	✓		
Burloh	Consultant engineers			✓						✓	
Ineos	Chemical manufacturer			✓						✓	
ipower UK	Renewable developer			✓						✓	
BEIS	Government			✓						✓	
Nexans	Manufacturer			✓						✓	
Balfour Beatty	Construction			✓						✓	
Siemens	Manufacturer			✓						✓	
Scottish Power	Supplier			✓						✓	
David Simpson Consuting	Energy consultant			✓							✓
Various renewable developers	Renewable developer			✓							✓

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Appendix B SPT Stakeholder Feedback

In this appendix we summarise the feedback received as part of the SP Transmission Stakeholder workshop, held in March 2018. Feedback was gathered by:

- Small round table discussion, managed by Baringa and with facilitators and scribes from SPEN
    - b. Stakeholders were given a short presentation on the topic to be discussed and then given a series of questions to kick start the debate
    - c. SPEN, Baringa and Element Energy employees were impartial listeners or facilitators and did not lead the discussion or give their views, so as to not bias the stakeholder feedback
- Live polls, using Slido
    - d. After the round table discussions Stakeholders were presented with a range of scenarios for technology capacities in 2030 and were asked to select the one they believed was most likely using an app on their smartphone
    - e. Results were kept hidden until all stakeholders had responded so that there was no risk of "group think"
- Post workshop survey
    - f. Stakeholders were given the opportunity to give any further feedback after the event via an online survey, shared within the presentation and later via email

Stakeholders were shown a range of technology capacity projections during discussion and for the purposes of polls, using the 2017 FES and other data sources. The 2018 FES were not available at the time of the stakeholder event.

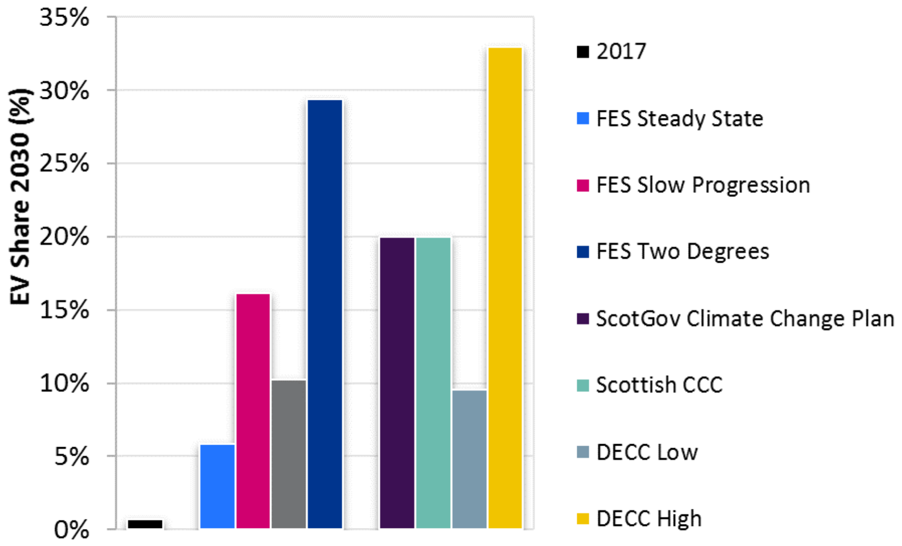
B.1 Electric Vehicles

3. Uptake
    a. There was a general view that change could occur very quickly if/when it happens
    b. It was noted that there is large uncertainty in what uptake would be, though most stakeholders were optimistic of growth in line with Scottish Government targets
    c. Suggestion that SPEN work with LAs and ScotGov to find a trial area for implementing EVs, potentially areas with declining industrial activity and therefore lots of DX capacity
    d. Fleet uptake may be key
4. How is Scotland different to GB average?
    a. Most stakeholders did not think there was a big difference between SPT area and GB average
    b. Range anxiety for rural areas / bad weather will be a deterrent

c. But Edinburgh, Dundee and Glasgow are pursuing low emissions zones and EV infrastructure
d. High % of flats in SPT area will mean on street charging and/or rapid charging stations are required

5. Barriers to development
    a. Cost of EVS
    b. Manufacturer ability to meet demand
    c. Second hand market – will EVs keep their value?
    d. Charging infrastructure
    e. Network constraints

- Poll
    - 42% of respondents believed the capacity scenario in the Scottish Government Climate Change Plan and CCC Scotland report was the most likely, with a further 17% for both the Two Degrees scenario (higher uptake) and Slow Progression scenario (lower uptake)



Which view of the share of EVs in 2030 is most likely?

Scenario	% of Respondents
FES Steady State	0%
FES Slow Progression	17%
FES Consumer Power	8%
FES Two Degrees	17%
Scottish Government / CCC	42%
DECC Low	8%
DECC High	0%
Higher capacities than all of the above	8%
Lower capacities than all of the above	0%

B.2 Heat Pumps

6. Uptake
    a. Generally stakeholders did not expect strong growth in heat pump installations
    b. Unlikely to occur in on-gas areas – gas is too cheap
        i. If gas prices go up this will also increase electricity prices, so would need to materially rise to make heat pumps economic choice
    c. What uptake does occur likely to be in local authority and housing association properties, but these are fairly limited
    d. There was a feeling that heat pumps could replace oil heating in off-gas areas, but due to lack of consumer engagement this is unlikely to occur soon
    e. UK Government policies seen as key to future uptake – if new builds required to have heat pumps an/or additional incentives given for installation uptake could be rapid
7. How is SPT different to GB average?
    a. More flats mean fewer suitable properties
    b. High degree of single wall buildings in rural areas – unlikely to be suitable for heat pumps
    c. Level of off-gas properties may be higher?
    d. Higher proportion of Local Authority and Housing Association rented properties
8. Barriers to development
    a. Consumers not engaged – very few have heard of a heat pump let alone are interested in purchasing
    b. Skills not developed – need better trained installation workforce, some current installations done badly and have given heatpumps “a bad name”
    c. Cost of installation too high – need huge subsidies to incentivise people
    d. Competing with district heating, which seems to be getting more interest with Scottish Government

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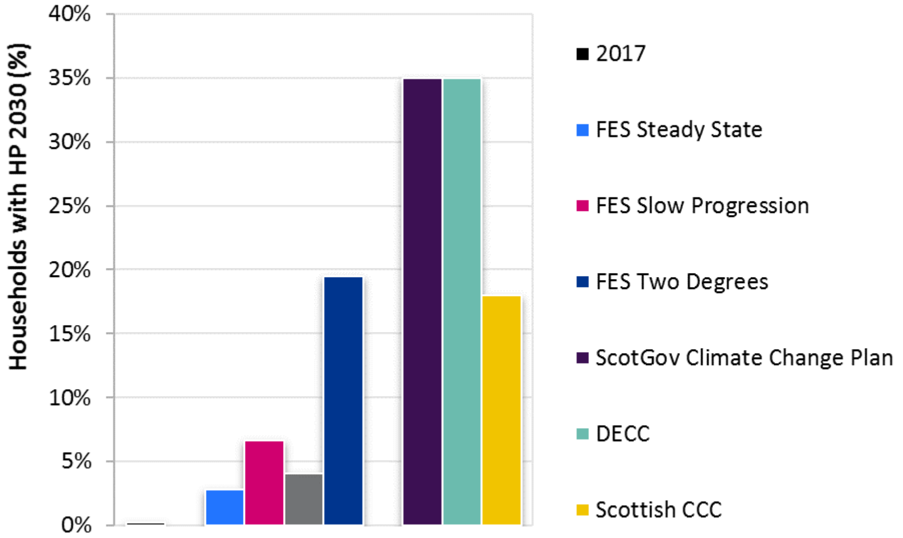
i. Though this could potentially be provided using heat pumps as primary source

- Poll

e. 42% of respondents believed the modest growth in the Slow Progression scenario was the most likely outcome in 2030



Which view of share of heat pumps in 2030 is most likely?

Scenario	% of Respondents
FES Steady State	17%
FES Slow Progression	42%
FES Consumer Power	8%
FES Two Degrees	8%
Scottish Government / DECC	8%
Scottish CCC	17%
Higher capacities than all of the above	0%
Lower capacities than all of the above	0%

B.3 Wind

9. Offshore wind

a. Stakeholders generally expected strong growth in offshore wind, with the construction industry reskilling the workforce in anticipation of future project development demand. While there were lots of potential good offshore wind resources, it was recognised that grid costs remain a key barrier for these projects

10. Onshore wind

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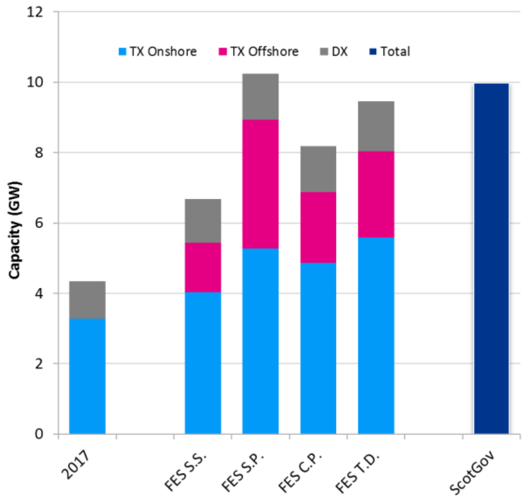
a. There was less agreement here, with some stakeholders expecting historical strong growth rates to continue, and meet Scottish Government targets, while others suggested that a "saturation" point may have been met, with the good sites already gone and planning becoming harder
b. It was noted that government incentives were still key to encouraging onshore wind, and these were being reduced by UK Government. While the Scottish Government is more "pro wind", would they be likely to provide incentives to generators who would be primarily flowing energy to England?

11. Barriers to development
   a. Wind resource in Scotland better than England, but TNUoS charges are higher which offsets this
   b. Grid costs and connection uncertainty is key barrier
   c. Government policy a key driver of decisions – planning and subsidies

- Poll
   d. Most respondents (50%) chose the Scottish Government Climate Change Plan "2.3x" capacity, or the very similar slo



Which view of SPT wind capacities in 2030 is most likely?

Scenario	% of Respondents
FES Steady State	25%
FES Slow Progression	17%
FES Consumer Power	8%
FES Two Degrees	8%
Scottish Government (2.3x)	33%
Higher capacities than all of the above	8%
Lower capacities than all of the above	0%

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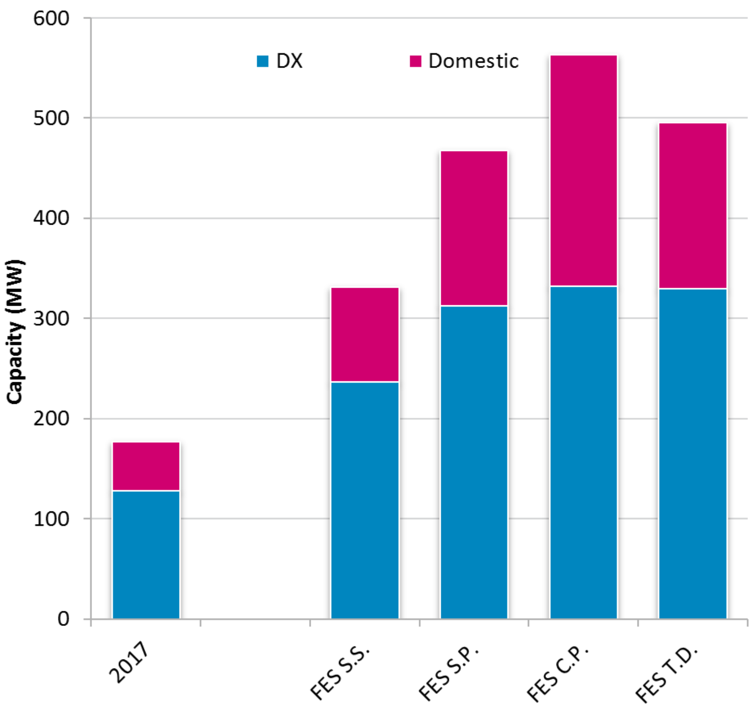
B.4 PV

- Poll
   e. Stakeholders were uncertain over which scenario was most likely, with a relatively even split over Steady State (25%), Slow Progression (33%) and Consumer Power (42%)



Which view of PV capacities in 2030 is most likely?

Scenario	% of Respondents
FES Steady State	25%
FES Slow Progression	33%
FES Consumer Power	42%
FES Two Degrees	0%
Higher capacities than all of the above	0%
Lower capacities than all of the above	0%

B.5 Storage

12. Uptake

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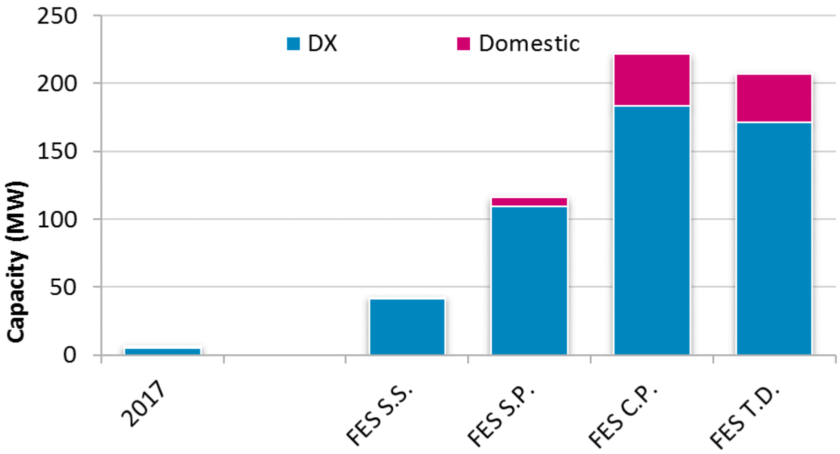
a. In discussion there was perceived uncertainty around what uptake levels would be
b. Stakeholders disagreed over whether behind the meter storage would take off
    i. Some thought that there was consumer interest around home storage, as part of being "self reliant" with behind the meter PV
    ii. Others thought that costs were too high and it was grid level storage that would take off
        1. Industrial users becoming more exposed to peak pricing, so incentive to self balance. Brownfield sites looking at using old warehouses to house storage units (~10MW)
c. Agreement that uptake heavily reliant on government policy decisions
d. Agreement that increasing wind would require more storage capacity to balance it, potentially at site of wind generation
e. Uptake unlikely to be at transmission level, distribution only

- Poll
    f. The majority of respondents (75%) believed that the growth shown in the Slow Progression scenario as the most likely outcome by 2030



Which view of battery capacities in 2030 is most likely?

Scenario	% of Respondents
FES Steady State	0%
FES Slow Progression	75%
FES Consumer Power	8%
FES Two Degrees	0%
Higher capacities than all of the above	8%
Lower capacities than all of the above	8%

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Appendix C Load Factor Assumptions

We have taken annual load factors from the FES 2018. Most technologies show stable load factors across scenarios and years. The exceptions are the thermal renewable technologies (CHP and controllable). The variation is due to these high level technologies being formed from the aggregation of a number more granular technologies, each with a different load factor. As the mix of granular technologies changes, so the overall load factor does too. Here we show load factors from the start and end of the horizon only, but we use annually changing values in the scenario model itself.

Table 6 Distribution connected supply technology load factor assumptions

Technology	Scenario	Winter Peak		Summer Minimum (AM)	
		2017	2040	2017	2040
Wind (DX)	All	25%	25%	47%	47%
PV (DX)	All	0%	0%	5%	5%
Hydro (DX)	All	85%	85%	17%	17%
CHP Renewable (DX)	Community Renewables	68%	75%	58%	62%
	Two Degrees	68%	75%	58%	62%
	Steady Progression	68%	75%	58%	63%
	Consumer Evolution	68%	75%	58%	63%
CHP Non-Renewable (DX)	All	74%	74%	33%	33%
Controllable Renewable (DX)	Community Renewables	70%	81%	54%	58%
	Two Degrees	70%	80%	54%	60%
	Steady Progression	70%	81%	54%	59%
	Consumer Evolution	70%	78%	54%	59%
Controllable Non-Renewable (DX)	All	87%	90%	33%	33%
Storage (DX)	All	87%	87%	0%	0%

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