Distributed generation and demand study

Technology growth scenarios to 2032

Scottish and Southern Electricity Networks southern licence area

Scottish & Southern Electricity Networks

Powering our community

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Acronym	Definition
CfD	Contract for Difference
CHP	Combined Heat and Power
DSO	Distribution System Operator
EfW	Energy from Waste
ESA	Electricity Supply Area
EV	Electric Vehicle
FES	Future Energy Scenarios
FIT	Feed in Tariff
GIS	Geographic Information System
GW	Gigawatt
ha	Hectares
kW	kilowatt
kWh	kilowatt hour
MW	Megawatt
PEV	Pure Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaics
RHI	Renewable Heat Incentive
RO	Renewables Obligation
SSEN	Scottish and Southern Electricity Network
SSEN South	SSEN southern licence area

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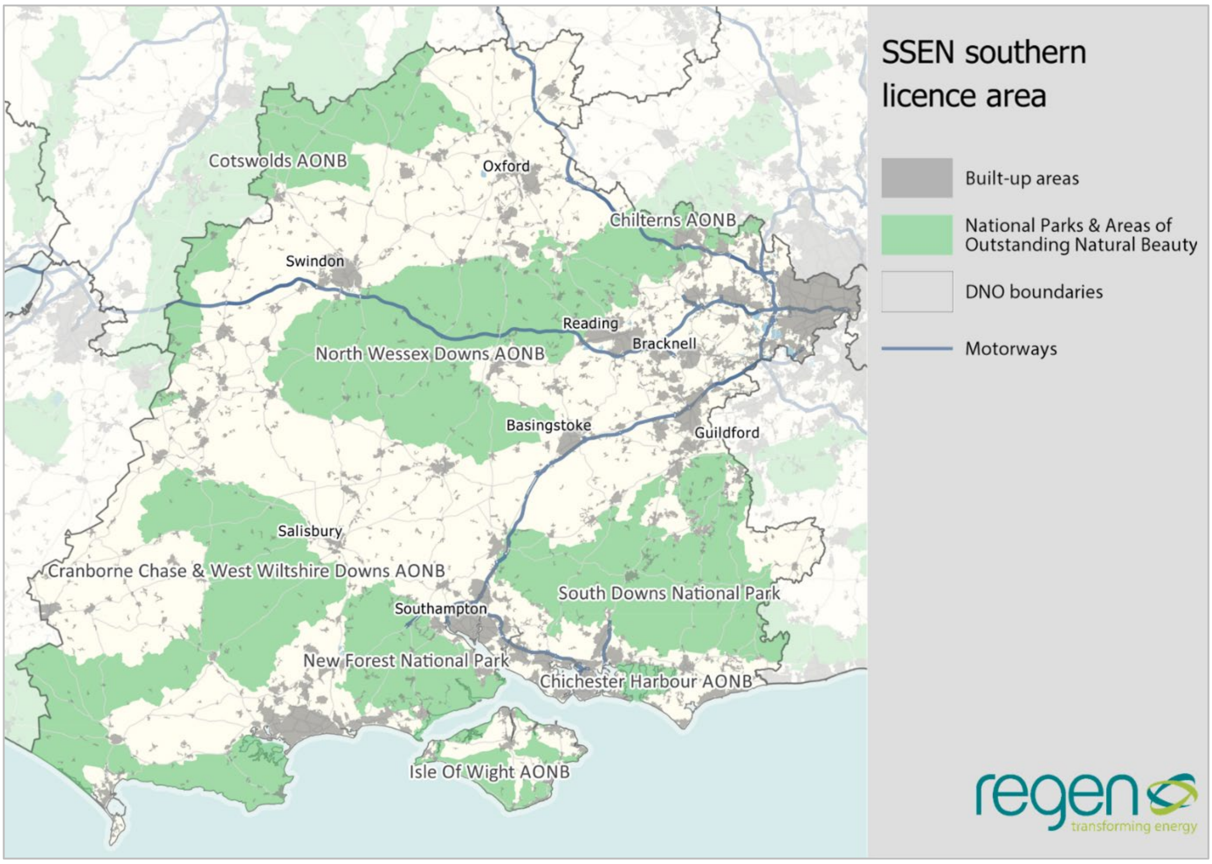
1. Introduction

The UK energy system has changed at an unprecedented rate in the last ten years. Renewable energy now provides over 30% of our power, and across the UK there are now nearly a million households, communities and businesses generating their own energy[1]. Further rapid change is inevitable as low-carbon technologies such as batteries and electric vehicles become mainstream and the UK moves towards its 2050 decarbonisation targets.

Figure 1-1: Designated and built up areas in the SSEN southern licence area



This shifting energy system has manifested itself in different ways across the UK. Scottish and Southern Electricity Networks southern licence area has experienced significant growth of distributed generation which now totals 3.4 GW of capacity. This is dominated by solar photovoltaics (PV), which reached 1.8 GW of ground-mounted PV and over 300 MW of rooftop solar PV in 2018. Notably though, unlike parts of the country such as Western Power Distribution's south west licence area, the SSEN southern licence area has seen very little onshore wind deployment.

The growth in distributed generation, at the same time as a reduction in underlying electricity demand, has caused network constraints for new generation thus restricting new connections in the south and east of the licence area. (see Figure 1-3)

There is now an expectation that demand may start to increase again due to new housing and the increased electrification of heat, cooling and transport. High levels of electrification will start to make

[1] Regen analysis, Ofgem FiT and RHI data

new demands on the distribution network. Extensive domestic charging of electric vehicles at peak times or a high penetration of heat pumps could cause problems for local sub-stations.

Aims of this study

SSEN commissioned Regen to develop scenarios for the growth of new sources of demand and distributed generation in their southern licence area between 2018 and 2032. The analysis uses National Grid's four Future Energy Scenarios (FES) as a framework. The areas included in the scope of the study are:

- sources of demand: electric vehicles, heat pumps and air conditioning and strategic new housing and commercial developments;
- distributed generation: both renewable and fossil fuel;
- battery storage.

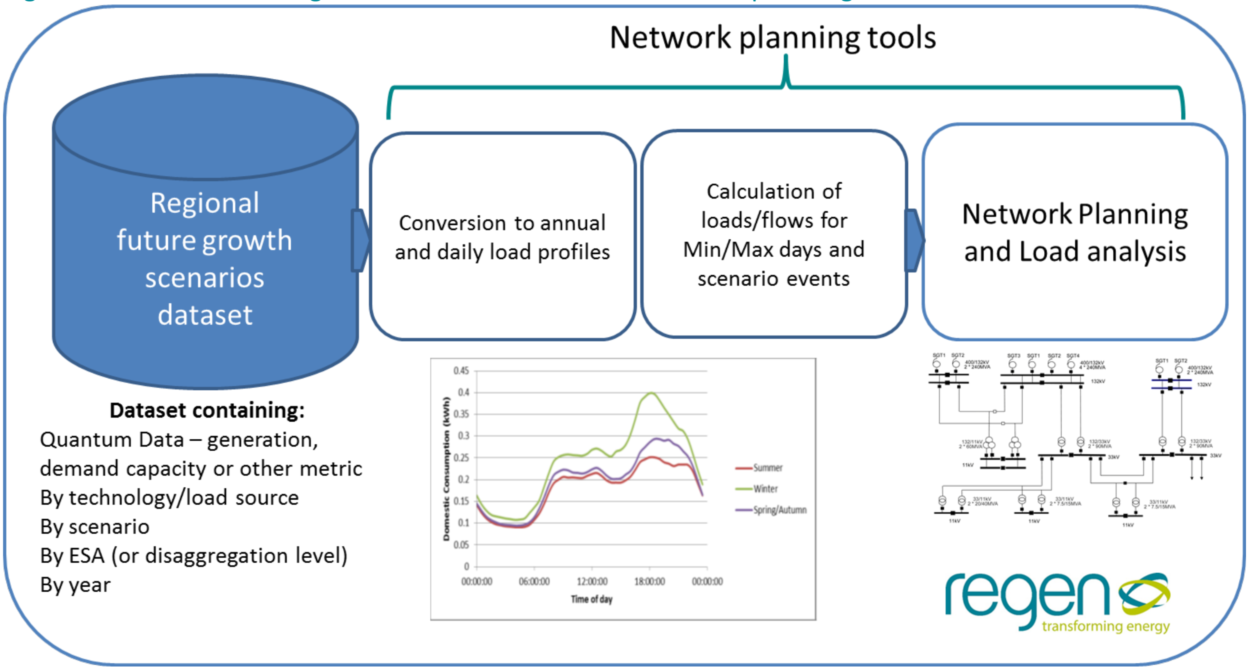
Projections about underlying household and business energy demand or energy efficiency are not included in the analysis, as these are already included in SSEN's underlying network projections.

The study is an important step in the process of SSEN becoming a Distribution System Operator (DSO). It is part of providing better visibility of the network for market participants as SSEN works to deliver a smarter grid.

Going forward SSEN intends to analyse how these distributed demand and generation connections, will operate and identify potential services they can provide. This will give a picture of the cumulative impact of the four scenarios on their network, both identifying the potential network constraints that result and the opportunities for mitigating those constraints through flexibility.

This understanding will then be used to assess the costs and benefits of the full range of network solutions, from investment in new assets, to managing constraints through securing flexibility services.

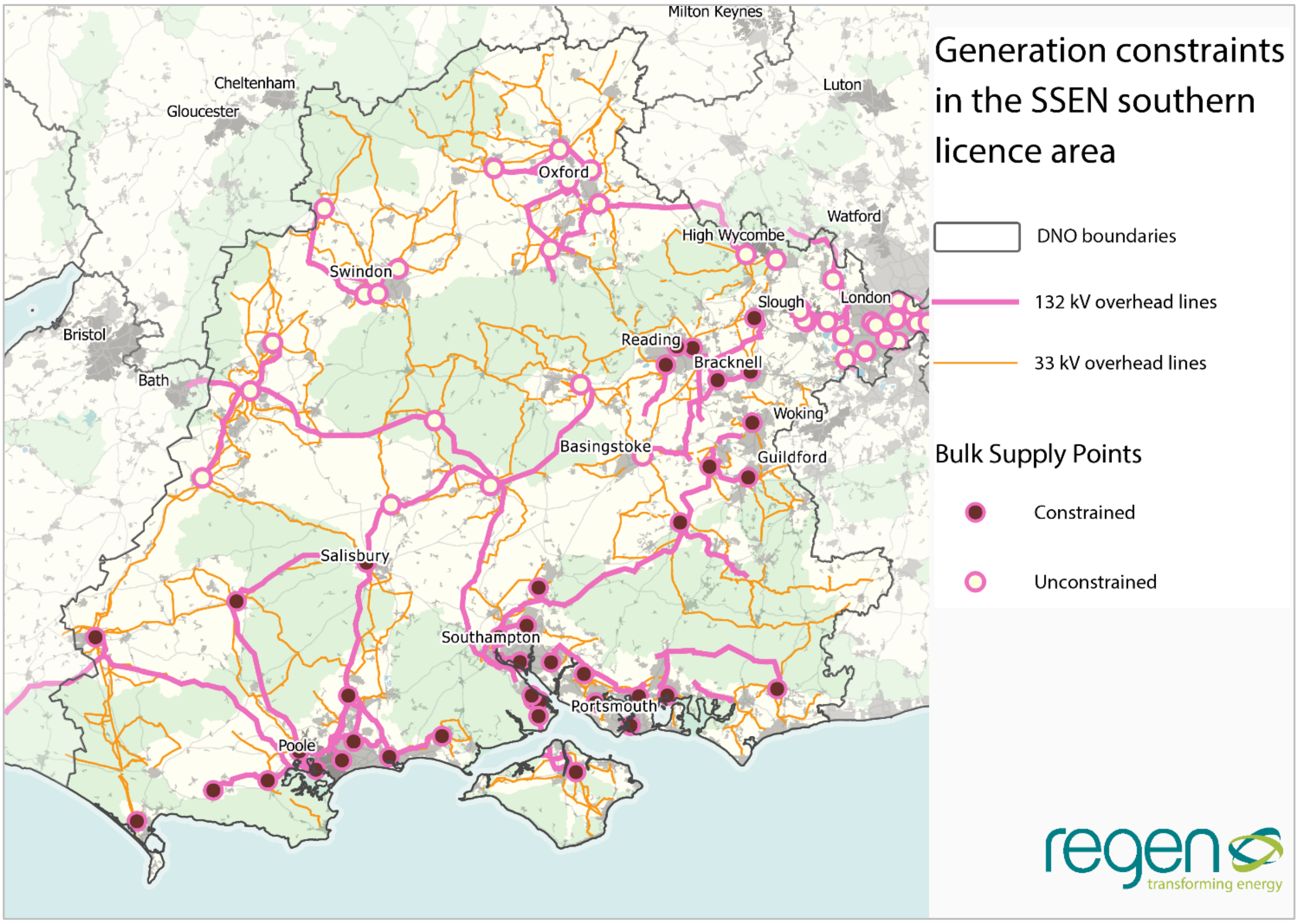
Figure 1-2: Role of future growth scenarios dataset in network planning



The output of the study is a large dataset that sets out the potential growth of each technology analysed in each of the four scenarios, broken down into 168 geographical areas within the SSEN southern licence area.

This report sets out the methodology used in the study and summarises some key findings of interest to stakeholders. For further detailed information on the analysis results or methodology please contact SSEN at futurenetworks@sse.com.

Figure 1-3: Summary of high voltage lines and local constraints in the SSEN southern licence area (source SSEN)



Over 280,000 new homes could be built in the SSEN southern licence area by 2032.

This is what a new house built that year might look like, under a Community Renewables scenario.

3,290 kWh demand

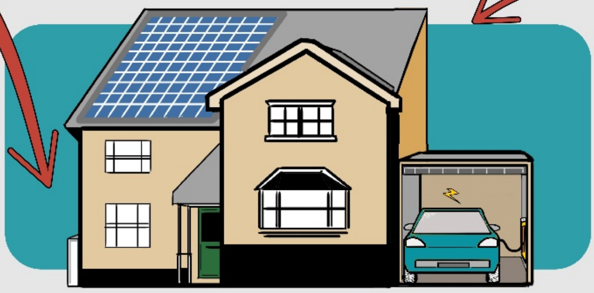
Typical household energy use

Baseline electricity demand per household in 2032 could be around 20% lower than the 4,099 kWh used today.

3.6kW Rooftop solar PV

In 2032 40% of new homes could be built with a 3.6kW rooftop PV system which generates most electricity in the summer.

3,000 kWh supply



10kWth Heat pump

70% of new houses built in 2032 could have a heat-pump system. An efficient system in 2018 uses around 2,500kWh to run.

2,500 kWh demand

Air conditioning

Technology will be minimal as building regulations prioritise passive cooling though some may have reversible heat pumps to use for summer cooling.

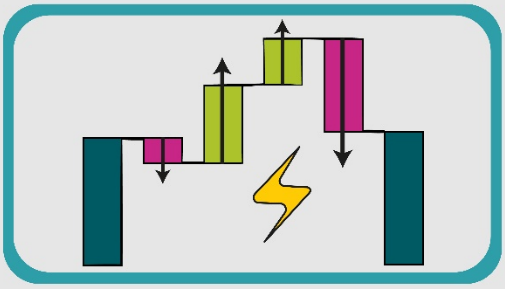
Domestic battery

Nearly 10% of new homes could have a 5kW domestic battery to store solar energy generated from their roofs.

Electric vehicle

By 2032 half of all cars could be electric. All new homes could be built with a 7kW charger. Charging 80% at home could add significantly to a typical household demand.

1,800 kWh demand



Flexibility services

Homes with these technologies could benefit from providing 'flexibility' services to the local electricity network, such as demand side response.

2. Methodology

Regen's analysis uses the Future Energy Scenarios[2] 2018 developed by the National Grid as its starting point.

The FES 2018 framework aligns future scenarios to two key axes: speed of decarbonisation and level of decentralisation. Two of the four scenario pathways meet the UK's 2050 emissions' reduction target of 80% by 2050.

Along with the FES growth pathways, the Regen analysis uses specific local attributes, characteristics and resources along with geographical and social factors to determine likely growth. This means that each licence area will differ in specific ways from the rest of the UK.

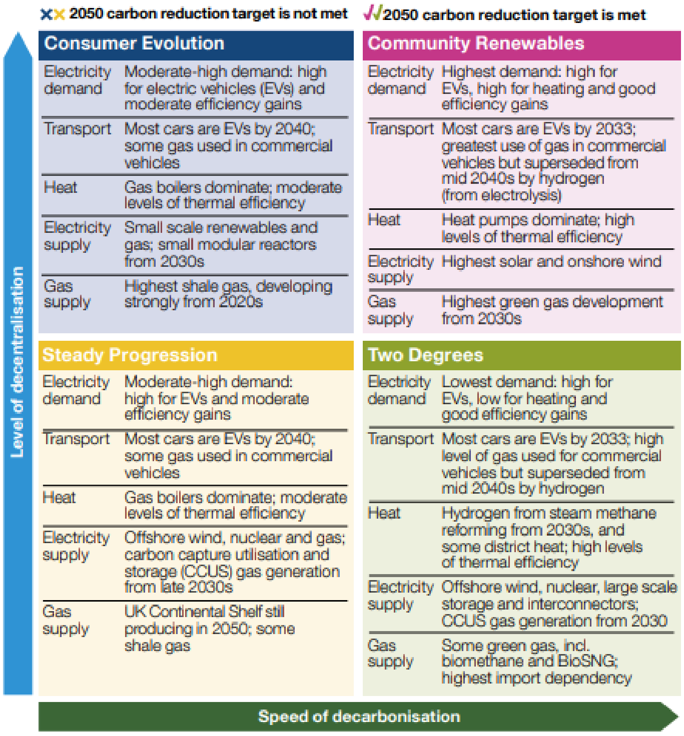


Figure 2-1: National Grid's Future Energy Scenarios Framework.

For example, there may be particularly good resource for a certain technology which means growth will be higher than the FES projection. Others may already have high levels of deployment, which may limit the potential for future growth in cases where for example the feedstock is limited or where there are cumulative impact issues.

The four scenarios, in summary, are:

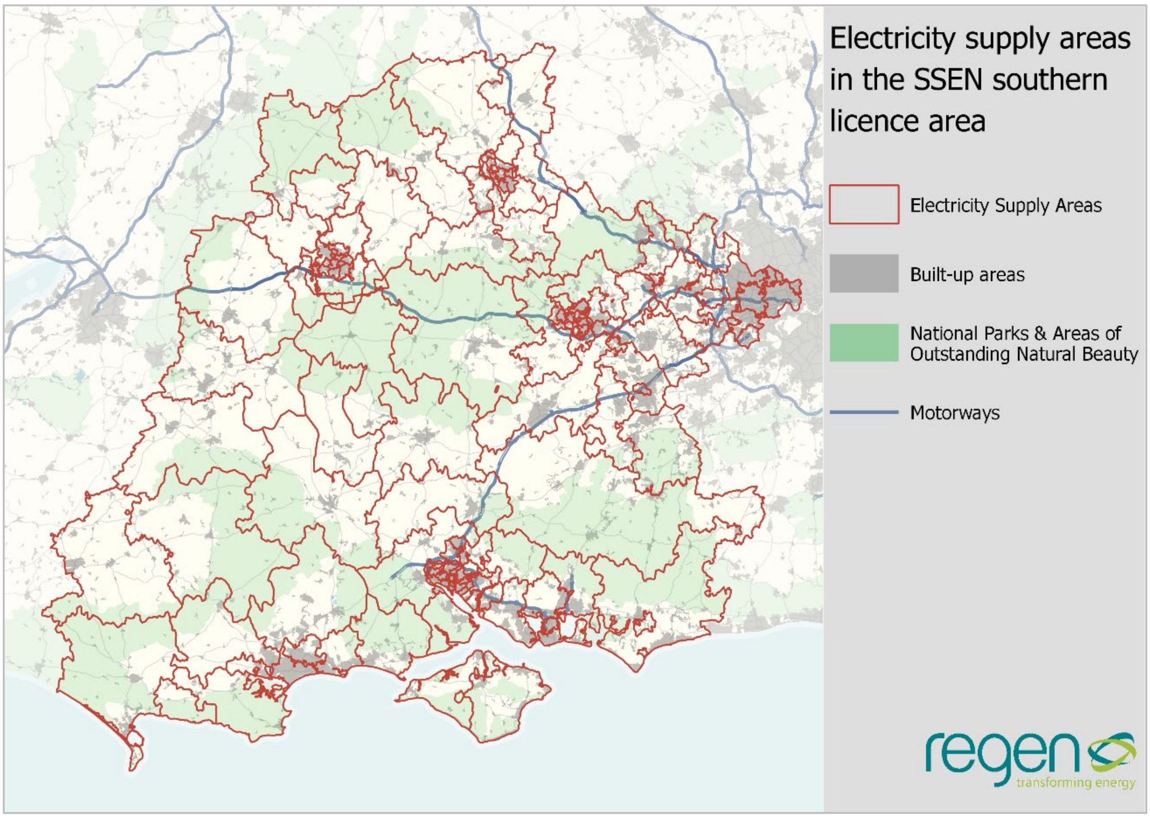
- **Community Renewables,** which explores how the 2050 decarbonisation target can be achieved through a more decentralised energy landscape with high levels of smaller scale, local and domestic activity.
- **Two Degrees,** which explores how the decarbonisation target can be achieved with a focus on larger and more centralised technologies. This scenario features changes to the energy landscape such as hydrogen heating networks and large-scale transmission connected generation technologies such as nuclear and offshore wind.
- **Consumer Evolution,** which is a decentralised scenario that makes progress towards the decarbonisation target but fails to achieve the 80% reduction by 2050. Deployment is focused on smaller scale, local and domestic projects.
- **Steady Progression,** which is a centralised scenario that makes progress towards, but does not meet, the 2050 decarbonisation target. In the timescale of this study, the scenario sees very low deployment of renewable technologies with gas generation continuing to play a significant role.

[2] http://fes.nationalgrid.com/fes-document/ assumptions underpinning the FES 2018 scenarios are published by National Grid in a workbook.

Electricity Supply Areas

The analysis for this report has been framed around Electricity Supply Areas (ESAs) which have been defined through SSEN's network infrastructure and hierarchy. ESAs are defined as geographic areas served by the same upstream network infrastructure.[3] There are 168 ESAs in the SSEN southern licence area.

Figure 2-2: Electricity supply areas in the SSEN southern licence area:



Scenario process

Using the ESAs the following three stage analysis is undertaken for both generation and demand technologies:

Stage 1 - A baseline and resource assessment. Baselines and historic growth rates are calculated from SSEN's network connection database taken at the end of September 2018. This information is then reconciled with Regen's project database and desktop research is undertaken to address any gaps or inconsistencies.

Stage 2 - A pipeline assessment. SSEN's network connection agreement database is reconciled with the BEIS planning database, along with further desktop research and an understanding of the current market conditions. This allows an assessment of which projects may go ahead and in what timescale. The domestic scale and demand technologies do not have a pipeline.

Stage 3 - A scenario projection to 2032. The scenarios are based on FES 2018 and interpreted for specific local resources, constraints and market conditions. Locational data from various data sources and GIS analysis is

[3] These were created by mapping data on individual substations and the upstream network points using Geographic Information System (GIS) software.

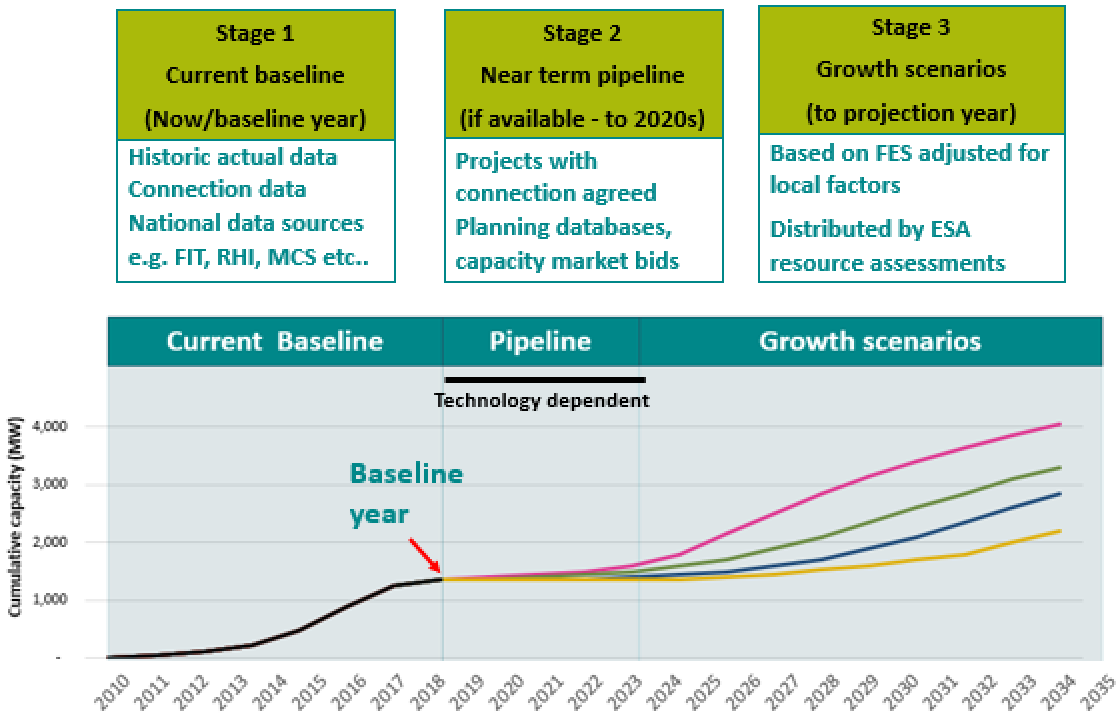
used to understand the geographical distribution, local attributes, constraints and potential for technologies to develop within the licence area and each ESA.

When projecting where new projects are likely to connect, consideration is also given to existing constraints on network capacity which may reduce growth in generation in the short term; however, as this analysis is to help SSEN understand where network investment is likely to be needed, existing network constraints are not considered as a factor in the medium- and longer-term projections.

Scenarios are created for new domestic and commercial development using local authority plans and supporting documents. These are analysed to identify sites, numbers and build rates for new build in the licence area.

Stakeholder consultation. Important to the process is a local consultation event where initial outcomes were presented for feedback from local stakeholders. In this instance a stakeholder consultation was held in Reading on 15 November 2018.

Figure 2-3: Summary of methodology



3. Distributed generation

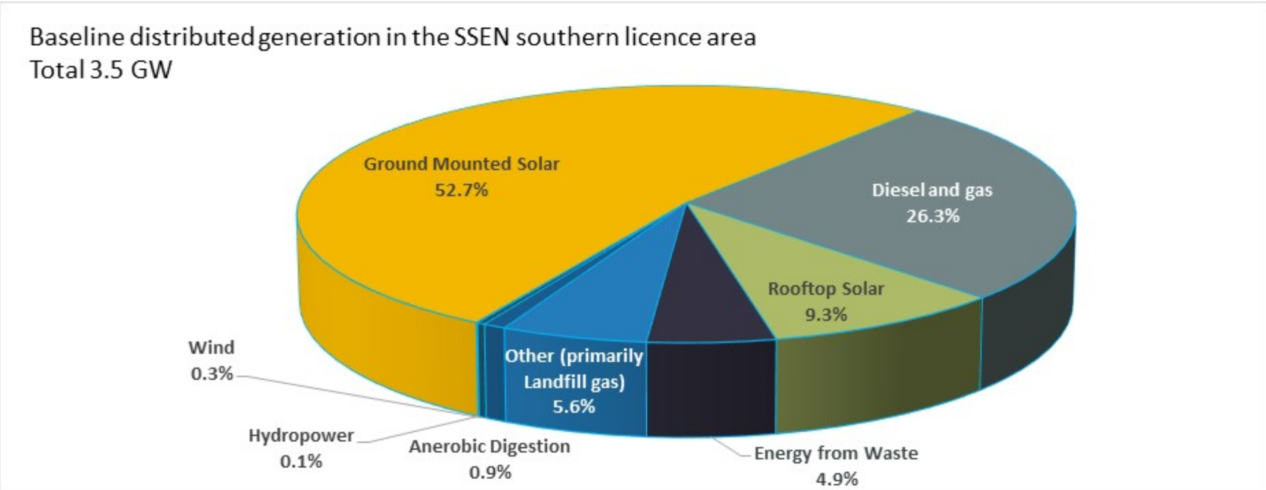
3.1. Baseline

There is 3.6 GW of distributed generation[4] capacity in the SSEN southern licence area as of the middle of 2018. 915 MW is fossil fuel generation and around 2.5 GW is low carbon and renewable. Over half of the generation capacity is solar photovoltaic (PV).

By the middle of 2018, the UK's renewable electricity capacity totalled 42.2 GW, an increase of 10% from 2017. Low carbon and renewable distributed generation in the licence area, therefore, contribute around 5% of the UKs renewable energy capacity.

Most noticeably there is no significant onshore wind in the licence area. Onshore wind accounts for over 30% of the UK renewable capacity but has a very small footprint in the licence area despite a relatively good wind resource and land availability.

Figure 3-1: Baseline distributed generation in the SSEN southern licence area in 2018



[4] Generation that connects to the distribution network as opposed to the transmission network.

3.2. Growth in distributed generation

Pipeline

To understand likely near-term growth in the licence area, Regen analysed accepted-not-yet-connected projects in the SSEN southern licence area connection database, along with national planning databases and entries into the Capacity Market. The pipeline was found to be dominated by plans to develop battery storage projects, along with large numbers of diesel and gas generators. There were relatively few renewable energy projects.

Future growth

The impact of the UK government reducing support for renewables has had a dramatic effect on deployment with little increase in capacity in most renewable technologies since 2016. The exception being offshore wind where the key remaining policy, Contracts for Difference (CfD)[5], is currently focused. There are no current plans to support onshore wind or solar projects. Less developed technologies, such as geothermal and marine, can apply for contracts but are unable to compete in the existing system.

For small scale renewables, after announcing the closure of the feed-in and export tariffs in 2018, BEIS have proposed a replacement, the Smart Export Guarantee[6]. This new export tariff would put a requirement on large suppliers to provide small-scale generators (under 5 MW) with a payment for their export. Suppliers will be free to decide the rate and no floor price has been proposed, save for the requirement that generators will not have to pay suppliers in the event of negative pricing.

Financing new generation, low carbon or otherwise, has become increasingly problematic without a level of guaranteed income. The price of power on the electricity market is becoming more variable and there are regulatory uncertainties such as future costs for using the network. As a result, a price guarantee mechanism such as a CfD is important to provide a level of fixed income for developers. Without this certainty, risk and cost of capital can become prohibitive for new projects being constructed to sell electricity into the market.

New business models are being developed to help electricity generation projects access more stable revenue streams, for example by selling power directly to corporates. In particular, solar developers have restarted development activity in large ground-mounted schemes and new projects are starting to come forward for connections to the network.

The experience of the rapid growth of distributed and renewable generation in recent years indicates that growth is rarely linear, that tipping points can be reached and that the following factors are key:

- **Technology costs:** The potential for continuing falls in the costs and efficiencies of renewable technologies, including the cost of installation and maintenance.
- **Government price support:** Holding of future auctions to enable technologies to access price support through CfDs or other similar mechanisms.

[5] Contract for Difference which guarantees a certain level of income for generators should the market price drop below the level required for the generator to operate profitably. Prospective generators bid into a periodic auction to receive support at a specified price level

[6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/769601/The_future_for_small-scale_low-carbon_generation_SEG.pdf

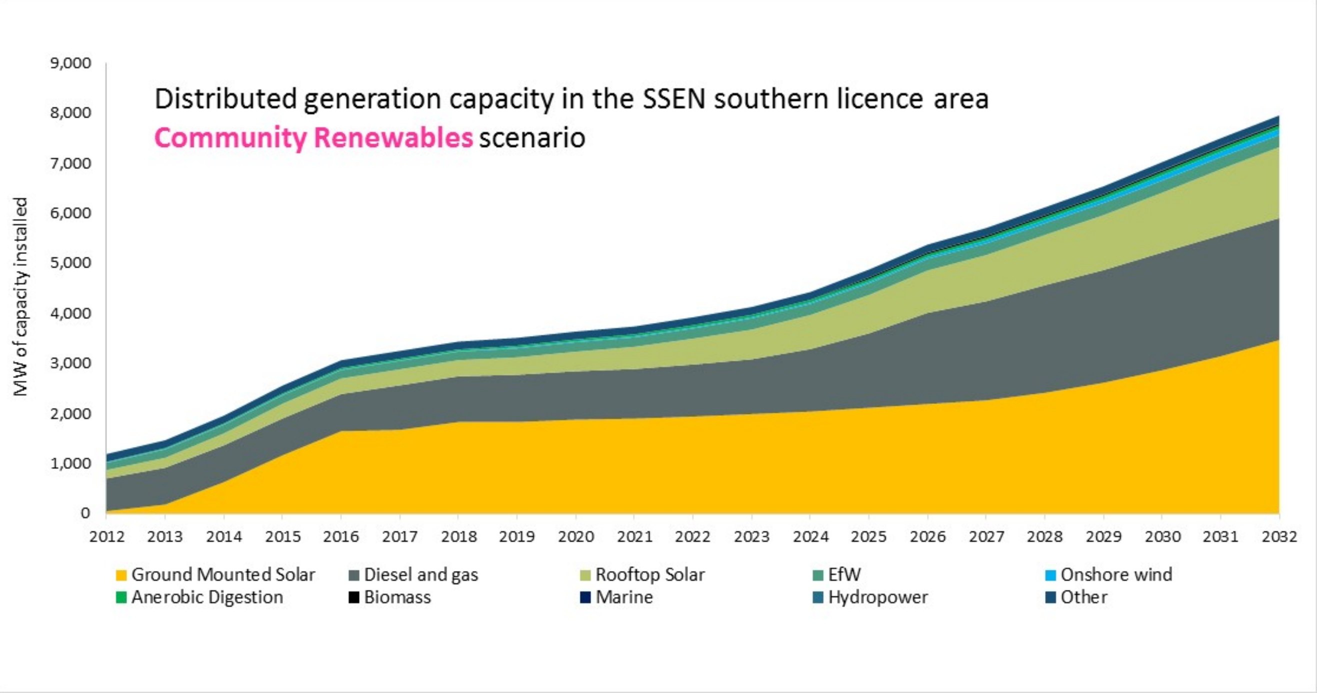
- **Network capacity and charging:** Changes to charging methodologies could unlock more capacity for new projects but may undermine business cases for behind-the-meter assets.
- **Local planning policies:** Higher levels of deployment will need changes to the local planning process to be more supportive of distributed generation.

Table 3-1 shows the growth in generation expected by 2032 in the four scenarios[7] along with the projected storage capacity. These numbers are based on the FES 2018 trajectories along with a detailed bottom up analysis of the resources of the licence area, known pipeline projects and expectations of potential growth.

Table 3-1: Scenarios for the increase in generation capacity and battery storage.

Generation capacity (MW)	2018	2032	Increase (%)	Solar (%)	Fossil (%)	Storage battery capacity (GW)
Two Degrees	3,481	6,787	95%	68%	23%	1.1
Community Renewables	3,481	7,965	129%	61%	31%	1.4
Consumer Evolution	3,481	6,387	83%	52%	39%	0.8
Steady Progression	3,481	4,611	32%	58%	33%	0.5

Figure 3-2: Community Renewables scenario of generation capacity by 2032



[7] The percentage of battery capacity as a proportion of capacity is also shown but storage capacity not included in the total capacity number.

Key findings from the generation scenarios include:

- **Ground-mounted solar PV** remains the dominant generation capacity in the licence area increasing nearly 2 GW to 3.8 GW in the Two Degrees scenario.

- **Rooftop solar PV** could quadruple in the Community Renewables scenario to 1.4 GW from 323 MW in 2018. In Two Degrees rooftop solar PV capacity more than doubles within the same time frame.

- **Diesel and gas** are already significant sources of generation in the licence area with over 900 MW baseline and 33 projects in the pipeline. Diesel is expected to decline in all scenarios by 2032.

- Though the **decentralised gas capacity** is projected to more than double in both Community Renewables and Consumer Evolution, these assets are expected to only generate sporadically to support intermittent generation when required.

- Another technology predicted to see growth in all scenarios is **battery storage** with a baseline of around 8 MW connected in 2018. There are 58 projects totalling 1.6 GW in the pipeline.

- **Onshore wind** remains at a very small scale with few new sites coming forward beyond a 10 MW project expected to be operational in 2019. This is largely due to local concerns about visual and landscape impacts.

- **Energy from Waste (EfW)** is a relatively significant technology in the area with 171 MW of generation in 2018. There is expected to be growth in both EfW and the newer Advanced Conversion Technologies in the near term. The highest growth scenario is Consumer Evolution, where over 100 MW of further capacity is expected from a combination of the technologies by 2032.

- **Anaerobic digestion** has a baseline of 30 MW. Increases are expected to be modest due to the limitations on feedstock. The highest growth scenario is Consumer Evolution where by 2032 a further 50 MW will be developed.

- There are currently no dedicated **biomass CHP** plants in the licence area, though schemes have been suggested in locations including Southampton. In the Two Degrees scenario, a 100 MW plant could be developed in Southampton, with smaller schemes totalling 30 MW developed in Consumer Renewables by 2032.

- **Hydro** has a small footprint in the area with 2 MW installed to date. There is limited developable resource, but several small community schemes could increase the capacity to 3 MW in Consumer Renewables by 2032.

- **Marine** also has limited resource in the licence area. One 10 MW tidal stream project could be built in Consumer Renewables off St Catherine's point on the Isle of Wight where a connection agreement and marine licence already exists.

FOCUS: BATTERY STORAGE

The SSEN southern licence area currently has 8.2 MW of battery storage connected and a total of 58 pipeline applications for battery storage connections totalling 1.6 GW.

Within these applications, large sites accounted for around 1 GW. Five were 100 MW and 10 at around 50 MW. The 100 MW sites would require Nationally Significant Infrastructure planning approval[8] and, if built, would be the biggest battery sites in Europe, on a par with the Australian 'mega' battery delivered by Tesla in 2017[9]. The majority of the largest sites are believed to be related to national electric vehicle charging locations such as the ones proposed by Pivot Power[10].

In order to get an understanding of which pipeline projects were most likely to go ahead and when, Regen analysed Capacity Market and local authority planning portals for evidence of activity in developing a business case for the projects. Those with activity are considered more likely to go ahead in the shorter term. Those with little information were deferred towards the end of the analysis period.

The majority of battery projects by 2032 are expected be either providing network services (response and reserve) or be behind-the-meter batteries (high energy users) looking to manage their electricity usage at peak times. Around 10% of the capacity is expected to be co-located with renewables with the aim of selling low-cost electricity at higher price periods[11].

MW capacity of battery storage	2018	2020	2025	2032	Response & reserve (%)	High energy user (%)	Co-location (%)
Two Degrees	8.2	271	792	1109	45%	32%	13%
Community Renewables		505	795	1410	39%	31%	14%
Consumer Evolution		127	468	760	46%	16%	11%
Steady Progressions		91	396	495	61%	7%	9%

[8] https://infrastructure.planninginspectorate.gov.uk/
[9] https://www.bbc.co.uk/news/world-australia-42190358
[10] https://www.greentechmedia.com/articles/read/pivot-powers-plan-to-fund-a-u-k-supercharger-network#gs.M1pbntc
[11] These storage business models are explored in the Regen Report 'Storage, the Next Wave' 2017, https://www.regen.co.uk/wp-content/uploads/REGEN_Energy_Storage-web_Final.pdf (p.9)

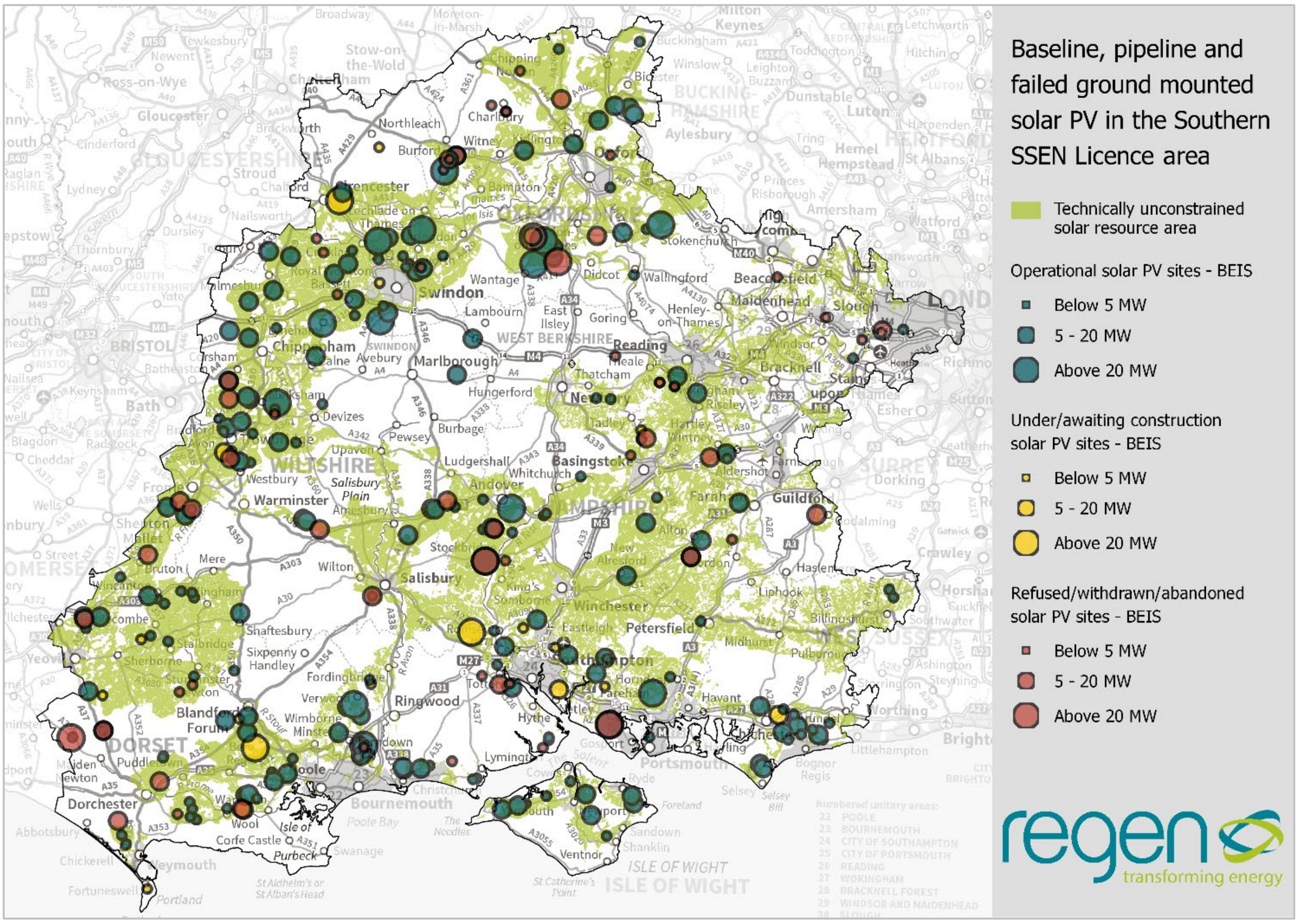
3.3. Location of new generation

Regen's analysis uses local geographical and attribute information to determine where future generation projects are most likely to connect. This information is combined with historic growth rates for each technology and the pipeline of expected new projects. The database developed for SSEN assigns potential generation capacities to each ESA for each technology, scenario and year out to 2032. This level of granularity is key to effective network planning. Examples are given below of some of the information and factors that are considered in this process.

Example 1: Solar ground mounted PV resource and land availability

Figure 3-3 illustrates the technically available land for solar ground-mount projects along with rejected, existing and pipeline sites. The assessment of 'technical availability' includes factors such as proximity to high voltage lines, land gradients, agricultural land rating and designated landscapes. Regen's projections then use these outputs to determine where growth is most likely to be seen up to 2032. The analysis also anticipates a 'saturation' point where longer-term growth is expected to be lower in sites with existing high penetration of solar.

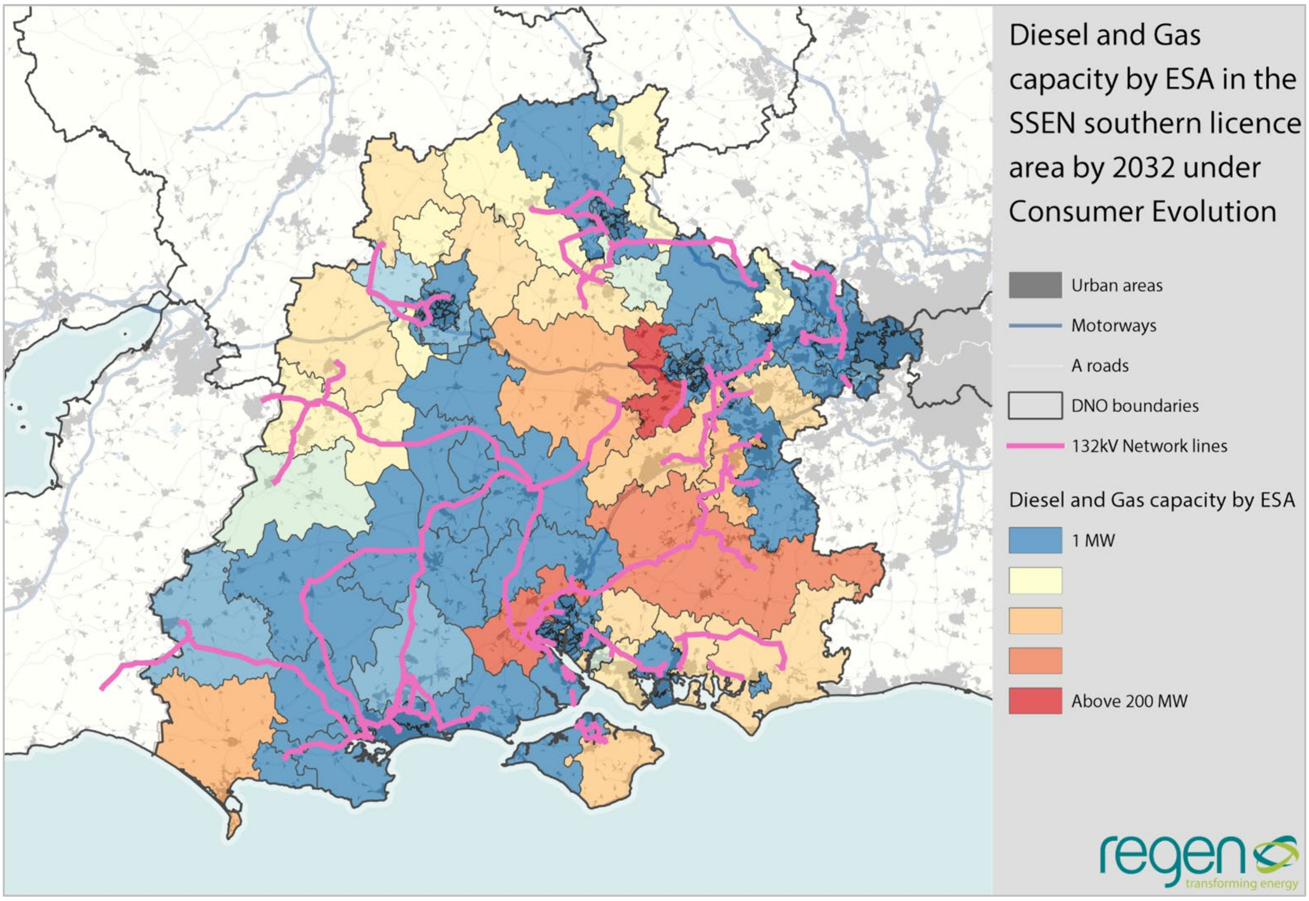
Figure 3-3: Ground-mounted solar PV technically unconstrained areas for future projects.



Example 2: Diesel and gas proximity to high voltage network

Access to high voltage network infrastructure is particularly important for battery, diesel and gas sites which are likely to be targeting network services as part of their business case. Figure 3-4 shows high voltage lines and a heat map of the capacities expected by ESA by 2032 for fossil fuel generation under a Consumer Evolution scenario.

Figure 3-4: Consumer Evolution 2032 diesel and gas capacity by ESA

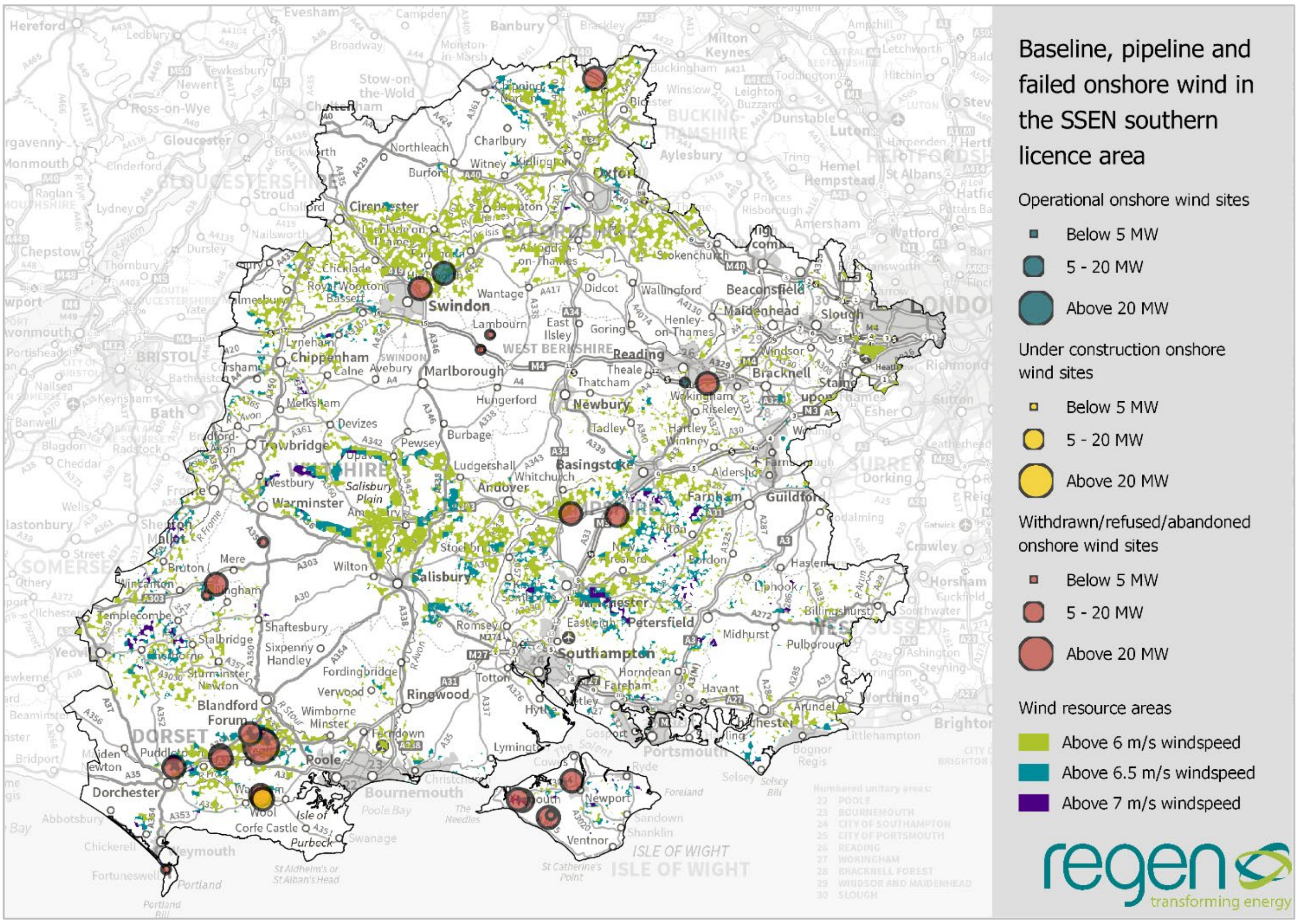


Example 3: Onshore wind - local politics and planning

Despite good resources in some areas, the ability to get planning permission is often the deciding factor in the growth and distribution of renewable energy and is the key factor for siting of new onshore wind projects[12]. Figure 3-5 illustrates the rejected, built and pipeline onshore wind sites in the licence area, overlaid on the technically unconstrained wind resource.

The historic opposition to both onshore and offshore wind is likely to mean developers will be cautious in bringing forward new projects in the area. As a result, the scenarios predict growth in onshore wind generation to be low in all scenarios to 2032.

Figure 3-5: Onshore wind technically unconstrained sites with rejected and accepted projects.

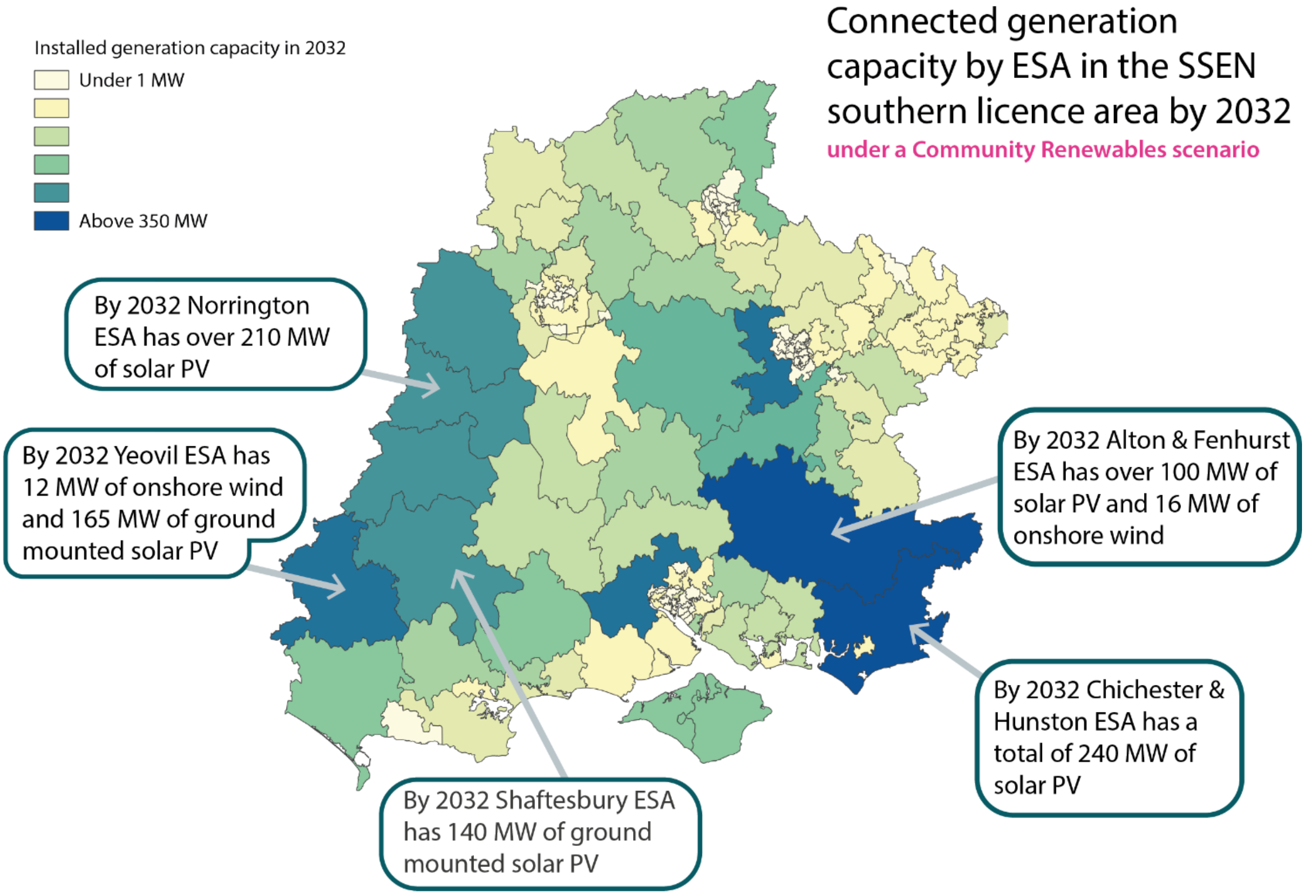


[12] The Navitus Bay offshore wind project with a capacity of around 900MW was rejected by the Secretary of State in 2015.

Distributed generation in SSEN southern licence area under the Community Renewables scenario

Figure 3-6 shows the total predicted generation capacity in each ESA by 2032 in a Community Renewables scenario, the highest scenario for the growth of distributed generation. The map illustrates the high level of potential growth in the east and west of the licence area and the top five ESAs for distributed generation capacity.

Figure 3-6: Total generation connections by 2032 in Community Renewables.



4. Commercial and industrial

Introduction

This section summarises the key findings from the analysis that are relevant to non-domestic, commercial and industrial electricity users in the SSEN southern licence area. It covers rooftop solar PV and batteries along with non-domestic new builds.

There are around 280,000 non-domestic buildings in the SSEN southern licence area[13]. The major categories include industry, retail and office buildings which account for around 63% of the total.

The annual average electricity usage for non-domestic users, similarly to domestic sector, has reduced by 9% between 2010 and 2016. The average non-domestic user had a demand of just over 66,000kWh a year in 2016, reducing from over 75,000 kWh in 2010[14].

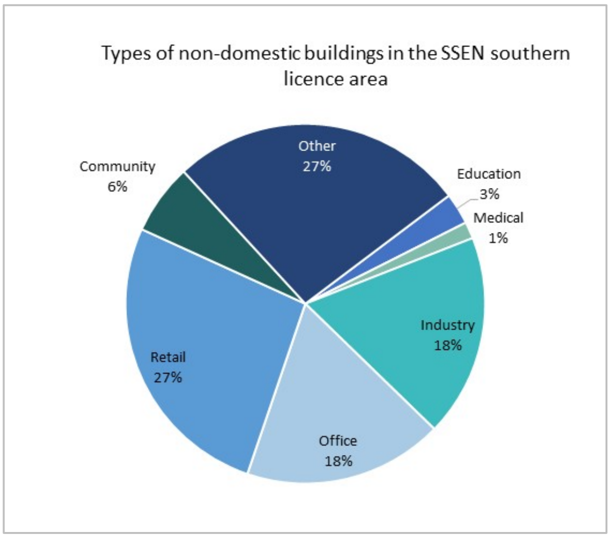


Figure 4-1: Types of non-domestic building in SSEN southern licence area

4.1. Non-domestic new developments

The growth in new non-domestic development sites is captured by square meters of the commercial buildings to be constructed.

[13] Source: Addressbase

[14] Source: BEIS sub-national electricity statistics

Table 4-1 shows the local authorities expecting the largest number of sites and planned development area up to 2032. The highest is the Vale of the White Horse in Oxfordshire with nearly 2.5 million square meters. Figure 4-2 shows the results of the analysis by ESA and highlighting the top 20 non-domestic development sites in the licence area.

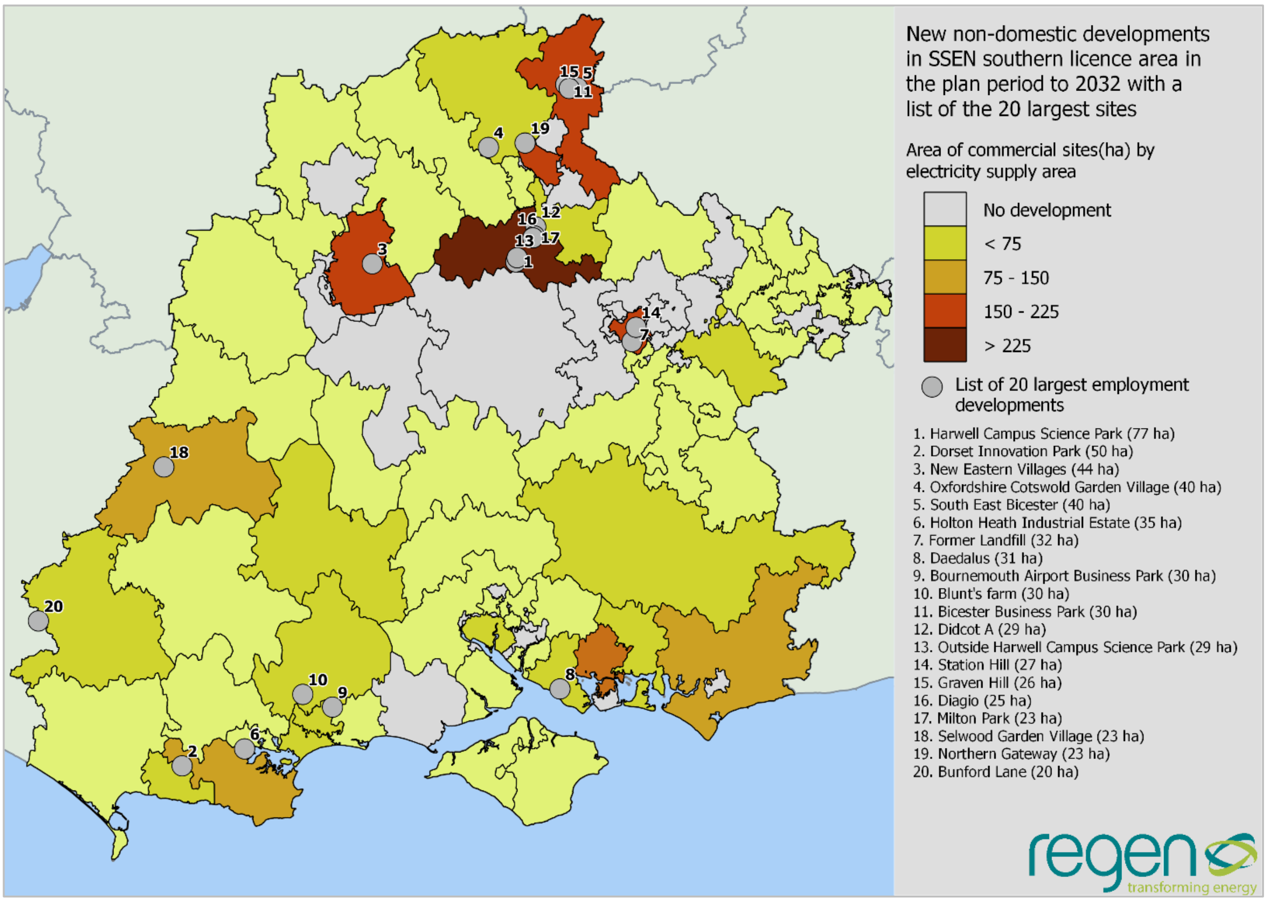
There are 637 strategic commercial development sites in the licence area totalling over 22 million square meters of build area.

Expected developments are classified by broad categories. The largest being office developments at 33% followed by factory and warehouse at 27%. Educational developments account for around 16% of the number of developments. Many are to be developed in and around substantial areas of new housing.

Table 4-1: Top 10 local authorities by total site area by 2032.

Rank	Local Authority	Number of strategic sites	Square meters of non-domestic new build
1	Vale of White Horse	30	2,447,400
2	Cherwell	26	1,943,500
3	Reading	34	1,736,578
4	Swindon	37	1,602,000
5	Oxford	32	1,292,143
6	Wiltshire	35	1,258,000
7	Purbeck	19	1,211,000
8	Portsmouth	26	868,894
9	West Oxfordshire	11	636,200
10	Winchester	19	607,900

Figure 4-2: Top 20 new commercial developments in SSEN southern licence area by 2032.



4.2. Commercial rooftop solar PV

Rooftop solar PV installed on commercial property is likely to be a key growth area for generation. There is around 40 MW of commercial rooftop solar PV in the licence area from just under 2,000 FIT and RO registered installations. The length of time to achieve a payback on investment is key to future installations. Despite the removal of subsidies, a commercial model where systems are sized appropriately, and all electricity is used on site can provide a payback within 5-6 years[15]. Some commercial sites can achieve significant economies of scale. In 2018, the Port of Southampton installed c.5 MW solar on a cruise terminal building[16].

It is notable that during the recent period of attractive subsidies and rapid growth of solar in other applications, take up in the commercial sector has remained relatively slow with less than 1% of non-domestic properties in SSEN's southern licence area having installed solar. The complexities of different building owners and tenants and other practical challenges have acted as break on development.

It is expected that this sector could grow to 222 MW with the number of installations quadrupling by 2032 in the Consumer Renewables scenario. Lower growth scenarios have commercial rooftop solar PV capacity doubling in the next 14 years.

Table 4-2: Non-domestic rooftop solar PV scenario results

Non-domestic rooftop solar PV by 2032	Number of installations	MW capacity	Non-domestic properties (%)
Baseline 2018	1,920	39	0.8%
Two Degrees	6,346	159	2.7%
Community Renewables	8,661	222	3.6%
Consumer Evolution	3,605	85	1.5%
Steady Progression	2,920	67	1.2%

[15] Regen sources
[16] http://www.abports.co.uk/newsarticle/613/

4.3. Commercial batteries

The scenarios predict that the total capacity of commercial batteries in the licence area could be between 165 MW and 660 MW by 2032. Unlike household batteries, which are likely to be linked with rooftop solar PV, it is expected that commercial batteries will be located with high energy users who may look to have stand-alone batteries to provide back-up power. They may also be used for 'peak shaving' to avoid periods of high network cost and usage charges. However, as the system that currently sets the network costs for high industrial energy users is being revised over the next few years, the level of investment in commercial batteries is likely to partly depend on the outcome of these reviews (Ofgem's Charging Futures process and Targeted Charging Review[17].)

Table 4-3: Commercial batteries installed by high-energy users by scenario

High energy users with batteries by 2032	Number of installations	MW capacity	High energy users (%)
Two Degrees	1,257	629	1.9%
Community Renewables	1,319	660	2.0%
Consumer Evolution	660	330	1.0%
Steady Progression	330	165	0.5%

[17] http://www.chargingfutures.com/

5. Electric vehicles and chargers

Planning for a distribution network that will allow a large number of electric vehicles to charge regularly is a key challenge for SSEN. As well as projecting the number of electric vehicles, the study also examined where and how many chargers might be installed in the licence area up to 2032. Given the importance of this topic, the report sets out the findings and specific methodology for this demand technology.

With significant motorway infrastructure including the M3, M4 and M27, along with Heathrow Airport and two major ports, Portsmouth and Southampton, transport infrastructure is a key feature of the licence area. The SSEN southern licence area hosts 10% of GB households but has a higher proportion of both vehicles registered (12.2% of GB total) and total annual mileage driven (11.4% of GB total).

5.1. Electric vehicle baseline

Although EVs still make up less than 1% of all vehicles, the SSEN southern licence area has seen a more rapid uptake of electric vehicles (EVs) compared to the GB average. Table 5-1 summarises the current baseline of mileage, vehicles registered and type of EV vehicles registered in the first quarter of 2018. There are over 26,000 EVs registered in the licence area which represents 16.9% of the total EVs registered in GB[18].

Table 5-1: Baseline of total and electric vehicles in the SSEN southern licence area – Source DfT Q1 2018

Proportion of vehicles in the SSEN southern licence area	All Vehicles	Cars	LGVs	HGVs	Buses & Coaches	Motor-cycles
All Vehicles in SSEN South	4,588,666	3,803,122	550,011	54,299	19,155	162,079
% of all GB vehicles in licence area	12%	12%	14%	11%	12%	12%
Electric Vehicles in SSEN South	26,152	25,140	652	84	26	250
SSEN South % of GB electric vehicles	17%	17%	14%	20%	8%	20%

5.2. Future electric vehicle growth projections

The National Grid FES 2018 presents a much higher growth projection for electric vehicles than the previous FES 2017, reflecting the UK government's[19] proposed ban on new diesel and petrol vehicles in 2040. The key question is now about the speed of up-take in the short and medium term. Regen's recent market insight paper Harnessing the EV Revolution 2018[21] discussed the factors influencing this including the level of investment by manufacturers leading to greater model choice and lower cost of electric vehicle.

[18] Note: the definition of an EV in the DfT dataset corresponds to "plug-in" vehicles and is not split out in the same way as the FES 2018 vehicle types.
[19] E.g. UK Government Road to Zero Strategy 2018

Both Two Degrees and Community Renewables scenarios show a growth to around 15 million EV cars[20] by 2032 rising to over 38 million by 2038.

In addition to the four FES scenarios, Regen has developed an additional 'Explosive Growth' scenario with a higher scale and speed of take up in 2020s, reflecting a watershed effect where cost, range, choice and desirability of EVs leads to a tipping point[21] after which EV adoption becomes ubiquitous.

In the modelling assumptions, EV uptake in the licence area is expected to stay ahead of the national average uptake of EVs in the short and medium term. This assumption reflects key factors driving early adoption such as; affluence levels, off-street parking and second car ownership along with emission reduction initiatives in and around urban centres[22].

5.3. Summary scenario growth results and distribution

The summary scenario results in Table 5-2 show that, in a high growth scenario, the SSEN southern licence area could have over 2 million electric vehicles by 2032, and almost 3 million in an Explosive Growth scenario. The bulk of these would be EV cars and Light Goods Vehicles (LGV)[23] with electric buses and HGVs making up a small but significant contribution.

Table 5-2: EV growth in the SSEN southern licence area - all vehicle types

EV Growth All Vehicles	Baseline Q1 2018	2020	2025	2032
Explosive Growth	26,152	116,658	885,728	2,927,404
Two Degrees		106,053	466,173	2,091,003
Community Renewables		120,773	534,023	2,153,117
Consumer Evolution		45,895	138,707	615,816
Steady Progression		45,458	138,481	633,157

Table 5-3: EV growth in the SSEN southern licence area by vehicle type in 2032

EV Growth by 2032	All Vehicles	Cars (BEV)	LGVs	HGVs	Buses/ Coach	Motor-cycles	Hybrid Cars	Hybrid LGVs
Explosive Growth	2,927,404	2,453,121	34,939	4,820	1,443	77,114	352,209	3,759
Two Degrees	2,091,003	1,752,229	24,956	3,443	1,031	55,082	251,578	2,685
Community Renewables	2,153,117	1,781,074	24,956	3,448	1,033	55,082	284,672	2,852
Consumer Evolution	615,816	519,618	7,532	960	295	28,230	57,897	1,282
Steady Progression	633,157	540,062	7,532	960	306	28,230	54,784	1,282

[20] Pure Battery EV and Hybrid

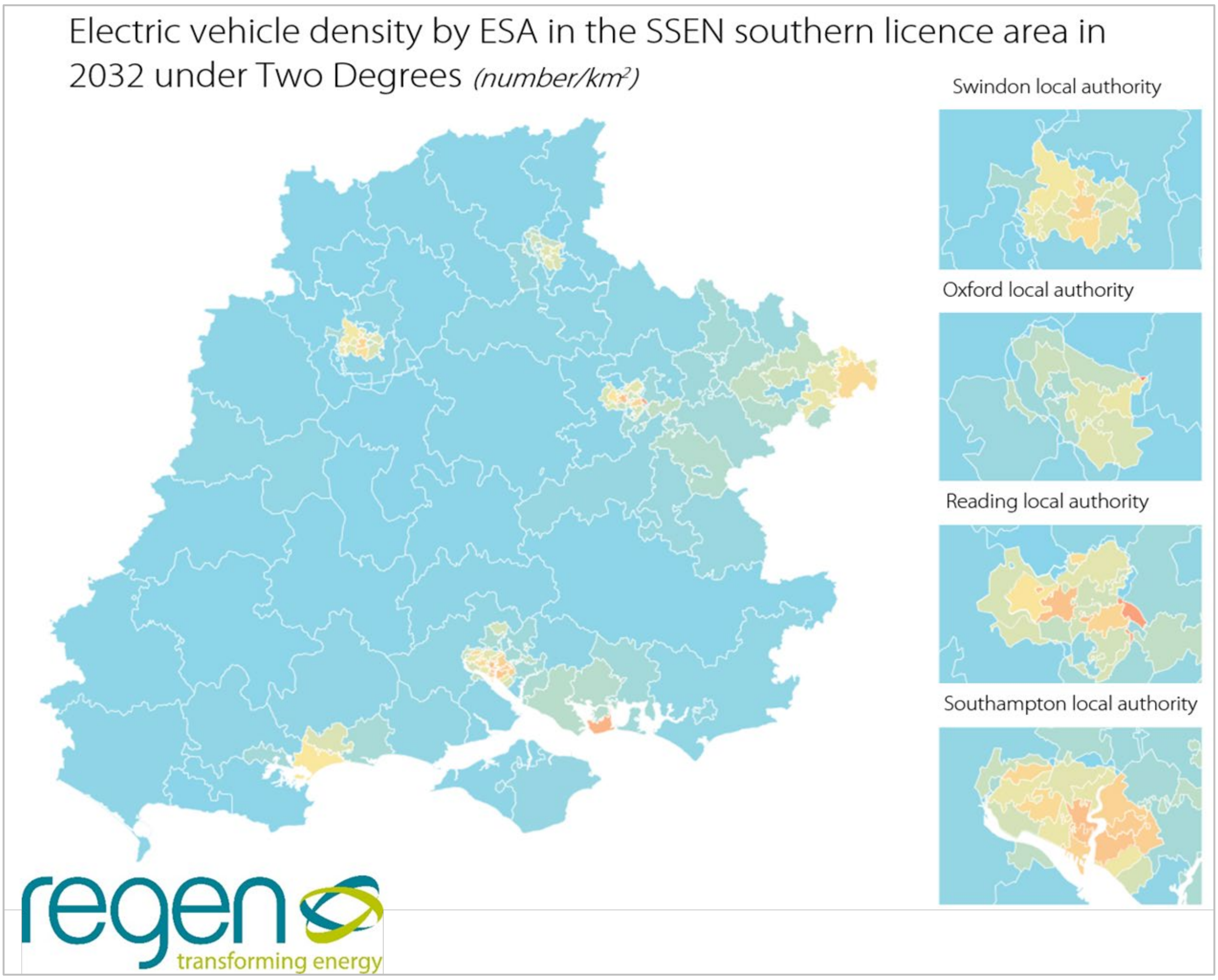
[21] As outlined in Regen's Harnessing the EV Revolution paper

[22] For example current proposals in Oxford, Reading and Southampton as well as new clean air plans being developed in Surry, Guilford, Rushmoor and Fareham.

[23] The proportion of hybrid vehicles, which is currently very high, is expected to fall significantly as consumers adopt pure electric, hybrid incentives are removed and emission controls are increased

As expected, the overall distribution of electric vehicles largely reflects the current distribution of vehicle types with a strong weighting towards urban areas, affluent areas and those with higher level of commercial and industrial development. The distribution by ESA shown in Figure 5-1 identifies the higher density clustering effect towards, and within, urban areas such as Oxford, Reading, Southampton, Swindon and areas to the west of London.

Figure 5-1: Electric Vehicle density (EVs per km^2 in 2032 - Two Degrees scenario)



5.4. Electric vehicle charging

For SSEN as a distribution system operator, the number and location of electric vehicles is an important indication of new electricity demand, but it is the electric chargers that deliver energy to vehicles which will directly impact on the network.

Data from early trials such as Electric Nation and My Electric Avenue indicate that a significant proportion of EV charging will take place at home, using 7kW chargers or even simple 3 kW 3-pin plugs. These trials however are with early adopters and therefore are likely to involve a relatively high number of second car users with off-street parking. There is still significant uncertainty about how future charging infrastructure will be developed, and how and where charging will take place when EVs become more mainstream.

Key questions that remain include:

- The degree to which vehicle owners will continue to charge at home. Most scenarios assume that those with home charging do so for over 80% of their energy requirements.
- Whether successful on-street residential charging solutions will be developed for those without off-street parking.
- The impacts that might come from new ownership and business models such as car shares, car clubs and "Uber" type mobility services.
- Impacts of Vehicle to Grid type applications where the EV battery provides services to the local electricity network.

Regen charger forecast model

Regen's EV Charger Capacity Growth forecast model uses anticipated electricity demand by vehicle along with different potential charger usage and utilisation scenarios. These are then modelled to provide an estimate of the charger capacity that might be needed in a particular geographical area. The model forecasts chargers using nine typical charger types; domestic off street (3 & 7 kW), on street, workplace, depot, en route local, en route national, destination and car park chargers.

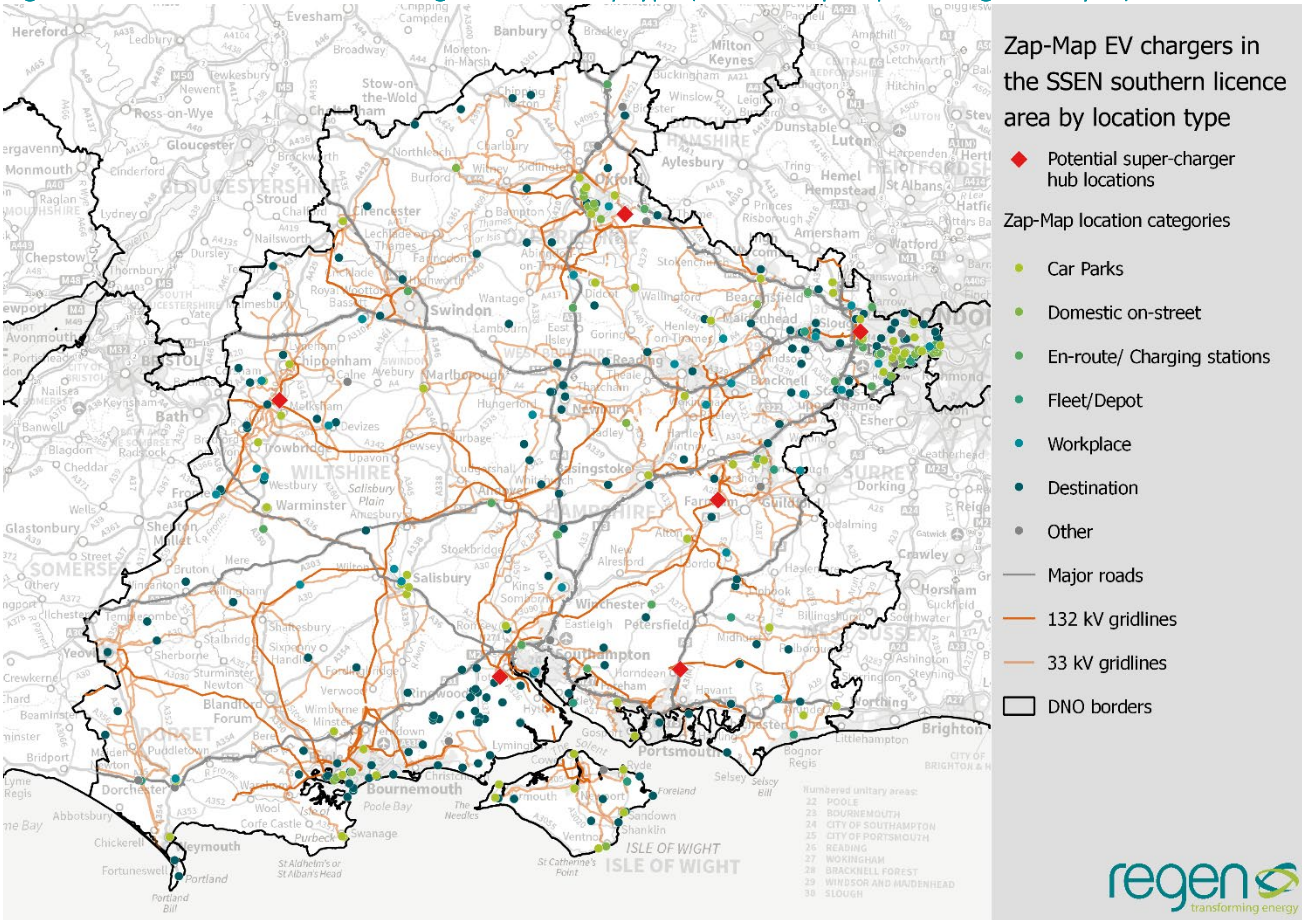
Baseline of electric vehicle chargers

Figure 5-2 shows the number of existing chargers and their type. There are currently just over 900 public EV chargers in the SSEN southern licence area, of which around 200 were classed as rapid chargers. The map shows that the location of public changing tends to follow major routes and urban areas. There is also a concentration of chargers associated with hotels and tourist attractions along the south coast.

Also included in the map are the six super-hub charger locations[24]. These have been proposed around Oxford, Southampton, Portsmouth, Slough along with Farnham and near Chippenham.

[24] See Pivot Power – proposal for up to 50 super hub charging sites across the GB mainly connected to the transmission network

Figure 5-2: Q1 2018 baseline of charger locations by type (Source: ZapMap and Regen analysis)



5.5. Electric vehicle charger deployment

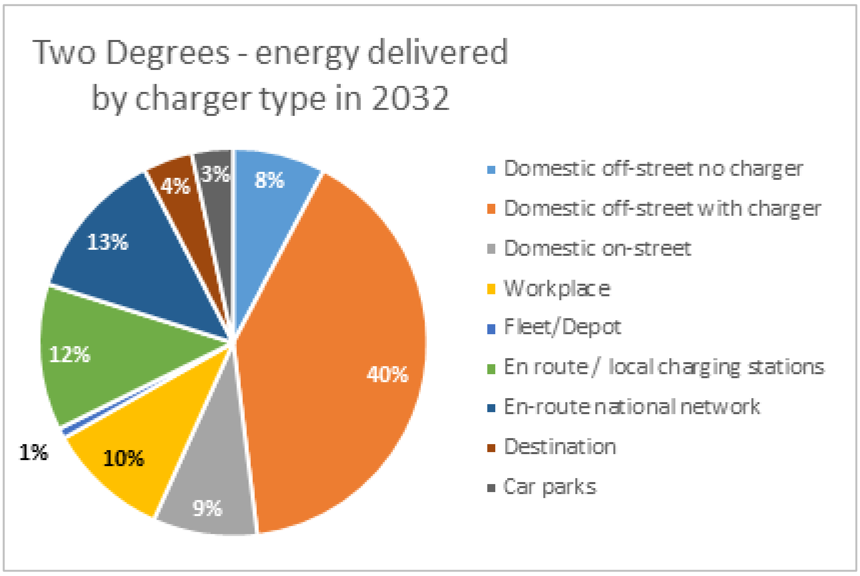
The analysis used Regen's Charger Growth Forecast Model to estimate the rate of growth of electricity demand and subsequent charger capacity by charger type. This capacity was then distributed to ESAs.

Table 5-4: Energy delivered by charger type by scenario by 2032

Energy delivered by charger type in MWh by 2032	Domestic off street 3kW and 7kW	Domestic on-street	Workplace and Depot	En route local and national	Destination and car parks	Total Energy (TWh)
Explosive Growth	2,526,278	454,376	575,028	1,295,134	395,471	5.2
Two Degrees	1,794,641	324,554	410,734	925,095	282,479	3.7
Community Renewables	2,071,404	313,077	477,145	687,692	269,112	3.8
Consumer Evolution	599,347	92,869	136,554	196,480	77,299	1.1
Steady Progression	582,653	110,815	140,673	225,983	79,930	1.1

Depending on the EV growth scenario, electricity to charge EVs is expected to grow to c.3.8 TWh under a high growth scenario and could reach as high as 5 TWh under an Explosive Growth scenario.

By 2032 in a Two Degrees scenario, despite a high deployment of en route charging stations, it is estimated that around 50% of this energy requirement would still be met by home-based chargers. The balance being provided by a combination of on-street, workplace, en route, car park and destination chargers.



Charger capacity and numbers

Making key assumptions around charger costs, utilisation rates and the return on investment required by charger owners suggest that a total theoretical charger capacity of between 5 and 7 GW under the highest growth scenarios.

The bulk of this nominal capacity is delivered by a very large number of home-based charger units with a relatively low average utilisation[25]. Between 20,000 and 30,000 on street chargers could provide local charging for those without off-street parking. Lower capacity but much higher utilisation would be provided by workplace, en route and destination-based chargers. In total "public" chargers could require between 600 and 900 MW of network capacity.

[25] Charger utilisation rates vary greatly. By 2032 home based chargers may still have utilisation rates of less than 5% while commercial en route chargers, with smart management controls, that are dedicated to creating a commercial return may be expected to achieve utilisation rates of 30-40% or more. Destination, work place, car park and on street chargers may achieve lower rates if their purpose is to provide additional customer service, civic or employee benefits. Although todays rates are very low, overall our modelling shows that utilisation rates are expected to increase over time.

Table 5-5: Charger capacity growth in the SSEN southern licence area by 2032

Implied charger capacity by 2032 (MW)	Domestic Home Based	On Street	Workplace and Depot	En route - national and Local	Destination and Car Park	Total Public
Explosive Growth	7,161	222	302	457	241	**920**
Two Degrees	5,086	158	216	326	172	**657**
Community Renewables	5,871	222	308	243	205	**670**
Consumer Evolution	1,699	45	72	69	47	**162**
Steady Progression	1,651	54	74	80	49	**183**

By applying industry benchmarks for typical charger capacity, it is possible to estimate the approximate number of charger units that this capacity would entail.

Table 5-6 Estimated charger unit numbers by 2032 based on a typical capacity per charger type

Nominal charger unit number growth by 2032	Private, Domestic Home Based	Public, On Street	Private, Workplace and Depot	Public, en route - national and Local	Public, Destination and Car Park	Total Public
Capacity per charger	5.9	7.0	15.3	104.2	14.5	17.5
Explosive Growth	1,222,513	31,658	19,716	4,384	16,621	52,664
Two Degrees	869,175	22,613	14,083	3,132	11,872	37,617
Community Renewables	1,002,999	31,729	20,530	2,339	14,144	48,212
Consumer Evolution	290,208	6,471	4,720	666	3,250	10,387
Steady Progression	282,188	7,721	4,863	794	3,360	11,875

5.6. EV charger distribution

By applying a range of distribution factors, charger capacity has been distributed to SSEN's ESAs as below:

- The distribution of domestic and on street chargers closely follows the overall distribution of households and electric vehicles.
- Workplace and depots chargers closely align with the location of relevant commercial and industrial activities. En route charging stations tend to follow the main road network and transport hubs.
- Using more detailed AddressBase analysis the distribution of destination and car park charging is weighted towards the location of public car parks and destination locations such as shopping centres, tourist attractions etc

6. Household disruptive demand and generation

This section summarises the scenario analysis and findings for technologies that could affect the demand of households in the licence area. The analysis looks at the take up of solar PV, electric vehicles, batteries, heat pumps and air conditioning up to 2032, and where that might be connected. The results of this growth are then presented by four urban areas where low voltage ESAs have been created to understand the changes at local authority level.

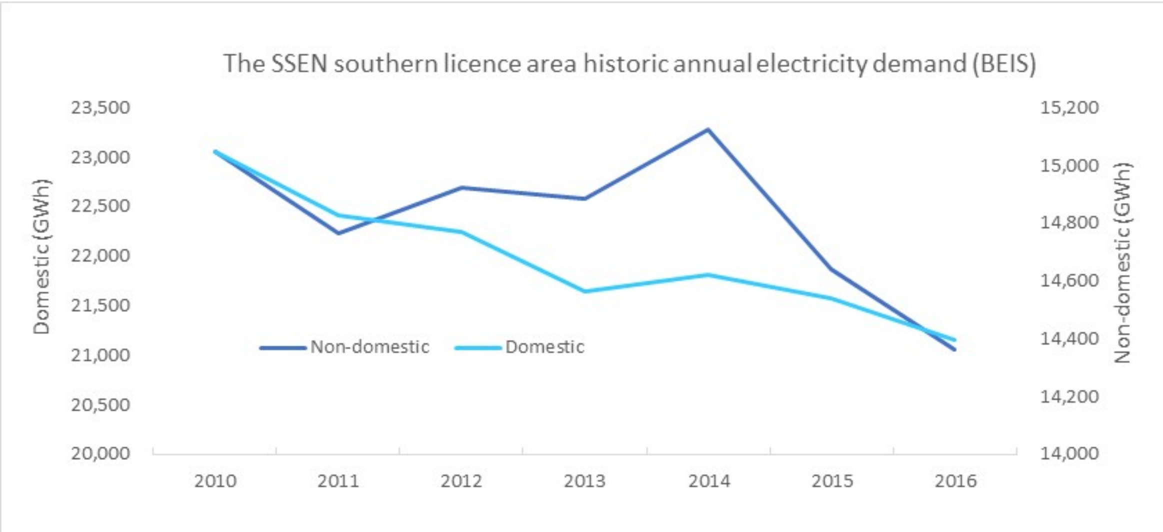
6.1. Baseline

The SSEN southern licence area has 2.7 million households. The area is characterised by large regional towns and cities alongside the western fringe of London, which make up a large proportion of the population. There are also significant protected and sparsely populated landscapes such as the New Forest and Salisbury Plain.

The licence area accounts for around 10% of the UK's total electricity consumption and around 10% of the UK homes. On average, domestic consumption in the licence area is slightly above the rest of the UK, with commercial annual consumption slightly below other areas.[26]

Figure 6-1 shows the reducing trend in end user demand in the last decade in the licence area. A combination of increasing energy efficiency and low economic growth has reduced total domestic demand by 4%, with demand per house falling by 8% , between 2010 and 2016. However, with electrification of heat and transport expected to accelerate during the 2020s, the FES 2018 scenarios expect this declining consumption to slow or reverse in all but Community Renewables scenario by 2032.

Figure 6-1: Mean electricity use in SSEN southern licence area since 2010, domestic and non-domestic. [27]



[26] Source: Regen analysis of BEIS, sub-national electricity sales and numbers of customers 2005 – 2016. (https://www.gov.uk/government/collections/sub-national-electricity-consumption-data)
[27] Source: BEIS, sub-national electricity sales and numbers of customers 2005 – 2016.

Summary of low carbon technologies take-up by households in 2018

- Of the 2.7 million homes currently in the licence area over 77,000 already have FIT registered solar rooftop solar PV accounting for 2.9% of homes[28]. The total capacity of domestic rooftop solar PV in 2018 was 282 MW.
- Other technologies such as electric vehicles and heat pumps are starting from much lower levels. Air conditioning is assumed to be in just over 1% of homes[29].
- Less than 1% of households are EV owners but the take-up of electric vehicles is above the UK average with 25,000 electric vehicles registered as of Q1 2018, equivalent to around 17% of all electric vehicles registered in the UK.
- Domestic batteries are assessed to be close to zero, with just a small amount of properties with these already installed. There is very limited reliable data available on the installation of household batteries from which to establish a firm baseline.

6.2. Growth in household generation and demand

Although each technology has particular drivers and barriers, the most important factors that will determine the level of growth in domestic generation, heat pumps, EVs and batteries are:

- **Technology costs:** The potential for future falls in technology price and running costs versus the incumbent technologies, such as petrol and diesel vehicles or gas central heating.
- **Government policy:** The likely level of government support for take-up of technologies including subsidies and where they might be focused.
- **Building regulations:** New build or other regulations around which will influence the take up of air conditioning or electrification of heat and transport in new homes.
- **Smart and flexible technologies:** Smart and connected technologies will allow households to minimise energy usage. They can also help manage the growth in domestic demand by providing paid for flexibility services to the network.

Though technology costs are expected to fall in the next decade, questions remain over how far these costs may have fallen by 2032. In addition, government policy remains ambiguous about future direction or commitment to maintain existing policies such as subsidies for new electric vehicles. The result of these uncertainties means that there are large differences in the highest and lowest scenarios.

Table 6-1 shows the growth in the domestic technologies expected by 2032 in the four scenarios. These numbers are based on the FES 2018 trajectories combined with a detailed bottom up assessment of the characteristics of the licence area and existing baseline and take-up.

[28] South West has around 3.9% and South East around 2.2% (Source Regen)
[29] Based on the FES 2018 distribution

Summary of scenarios:

- Rooftop solar PV is expected to increase significantly in the greener scenarios by 2032, doubling installations in Two Degrees and quadrupling in Community Renewables.
- In the Two Degrees scenario over 50% of the area's 3.8 million vehicles will be electric by 2032. In the lower growth scenarios this figure is around 15%.
- Electrification of heat is an important step in energy decarbonisation. The Community Renewables scenario sees nearly 20% of houses fully or partially electrically heated through a heat pump.[30]
- Air conditioning remains at a relatively low level within the study period to 2032 reaching nearly 6% in the less green scenarios. FES 2018 expects the level to rise considerably in the less-green scenarios by 2050 driven by rising temperatures.

Table 6-1: Percentage and numbers of households with low carbon technologies in 2032 by scenario

All homes by 2032	Electric vehicles (% of all cars)	Heat pumps	Air conditioning	Rooftop solar PV	Domestic Battery
Baseline	0.7%	0.35%	1.1%	2.86%	0%
Two Degrees	50%	14%	1.5%	5.4%	0.5%
Community Renewables	52%	19%	3.1%	10.4%	1.3%
Consumer Evolution	15%	5%	5.9%	3.9%	0.4%
Steady Progression	15%	2%	5.9%	3.6%	0.2%

Numbers installed in all homes by 2032	Electric vehicles	Heat pumps	Air conditioning	Rooftop solar PV	Domestic Battery
Baseline	25,140	9,422	20,900	77,765	0
Two Degrees	2,003,816	411,810	44,464	168,677	14,400
Community Renewables	2,065,746	581,116	93,497	321,877	35,000
Consumer Evolution	577,515	157,587	177,732	120,583	11,000
Steady Progression	594,846	70,648	177,732	111,510	6,000

[30] This study does not include scenarios for heat pumps for commercial buildings.

6.3. How take-up by households could vary across the licence area

This section sets out some of the findings and analysis used to determine how the take up of low carbon technologies by households could vary across the SSEN southern licence area.

Example 1: New technologies correlated to new housing developments

Local authorities are projecting a 10% increase in the numbers of houses in the licence area by 2032. As well as adding to underlying demand, new houses are more likely to integrate heat pumps, rooftop solar PV and electric car charging infrastructure[31]. As a result, the scenarios project higher levels of these technologies in areas with higher number of new houses.

To understand what new development and redevelopment[32] sites are expected within the licence area, and to produce growth scenarios, the plans from the 52 local authorities in the SSEN southern licence area were reviewed to collect data on strategic sites for housing and commercial developments expected by 2032[33].

There are 740 strategic housing development sites in the licence area. These could deliver up to 285,000 new homes by 2032.

Table 6-2 shows the local authorities expecting the largest number of new homes in the period. Oxfordshire as a county is expecting the highest levels of growth with over 44,000 by 2032[34].

Table 6-2: Top 10 local authorities by number of new homes by 2032.

Rank	Local Authority	Number of strategic sites	Total number of new homes by 2032
1	Vale of White Horse	26	16,047
2	Swindon	14	13,498
3	South Oxfordshire	14	11,541
4	Wiltshire	17	10,867
5	West Oxfordshire	26	10,366
6	Arun	12	10,199
7	Basingstoke and Deane	20	9,563
8	Eastleigh	8	9,211
9	Hounslow	25	9,083
10	Bracknell Forest	26	8,884

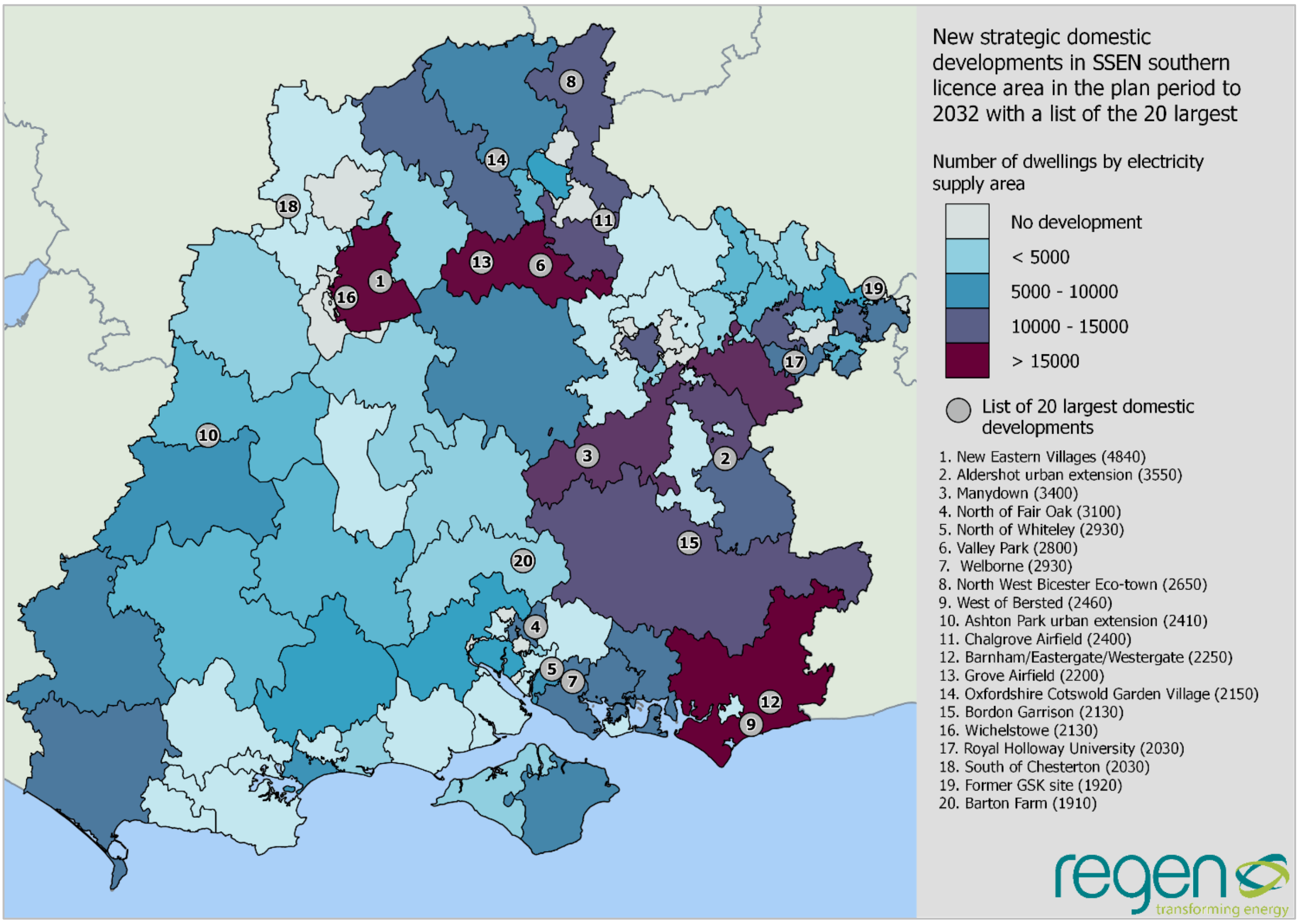
[31] For example, the London Plan https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/draft-new-london-plan/chapter-9-sustainable-infrastructure/policy-si3-energy

[32] Redevelopment and change of use sites are included here and in technology modelling but excluded in the dataset provided as they don't require a new connection. These account for c.15% of new homes.

[33] Strategic defined as: Developments that are classified as strategic or involve over 100 additional dwellings. Previous Regen studies suggest 85% of all new dwellings are from sites defined as strategic.

[34] Oxfordshire has a target for 100,000 new homes. To note this total number excludes parts of Cherwell which has 62% of the land area in the licence area. It also includes only homes on sites that are fully planned as of end 2018.

Figure 6-2. Twenty largest domestic development sites in the SSEN southern licence area



Example 2: Low-carbon technology take-up correlated to affluence

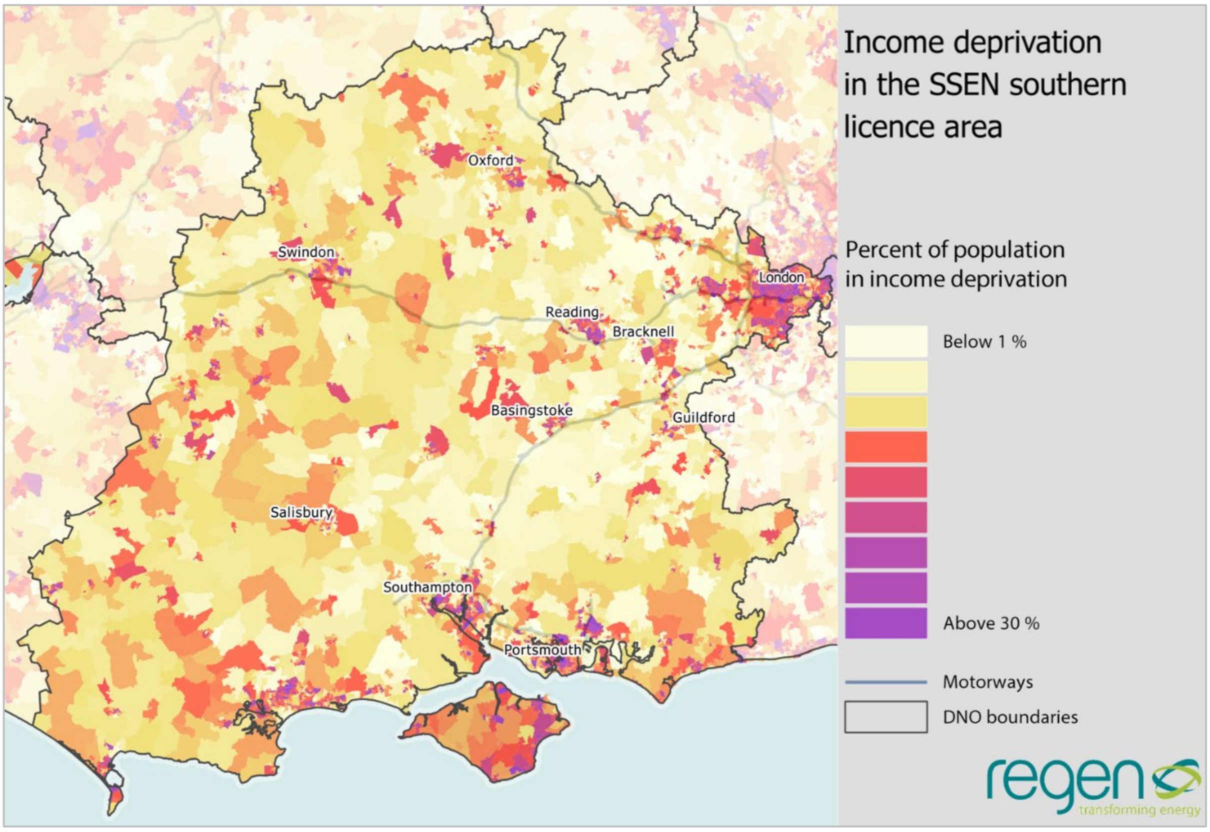
In the scenarios the take-up of low-carbon domestic technologies such as EVs, rooftop solar PV and batteries are correlated towards affluence in the short and medium term. For example, as the price of an EV is currently higher than conventional vehicles and the range remains lower, they are more likely to be purchased by affluent households as second cars.

The SSEN southern licence area is an area with one of the highest affluence levels in the UK. The area has average gross disposable household income of £22,056 in 2016, around 14% above the UK average of £19,432[35].

With high affluence and significant new housing growth, SSEN South is likely to experience high and early take-up of new technologies.

Figure 6-3 shows the pockets of deprivation in the area including around London and some coastal areas. Coastal areas may have lower numbers of electric vehicles owned by residents, but they have potentially high summer demand for EV charging because of tourism or day trips from more affluent areas.

Figure 6-3: Deprivation levels by LSOA in the SSEN southern licence area.



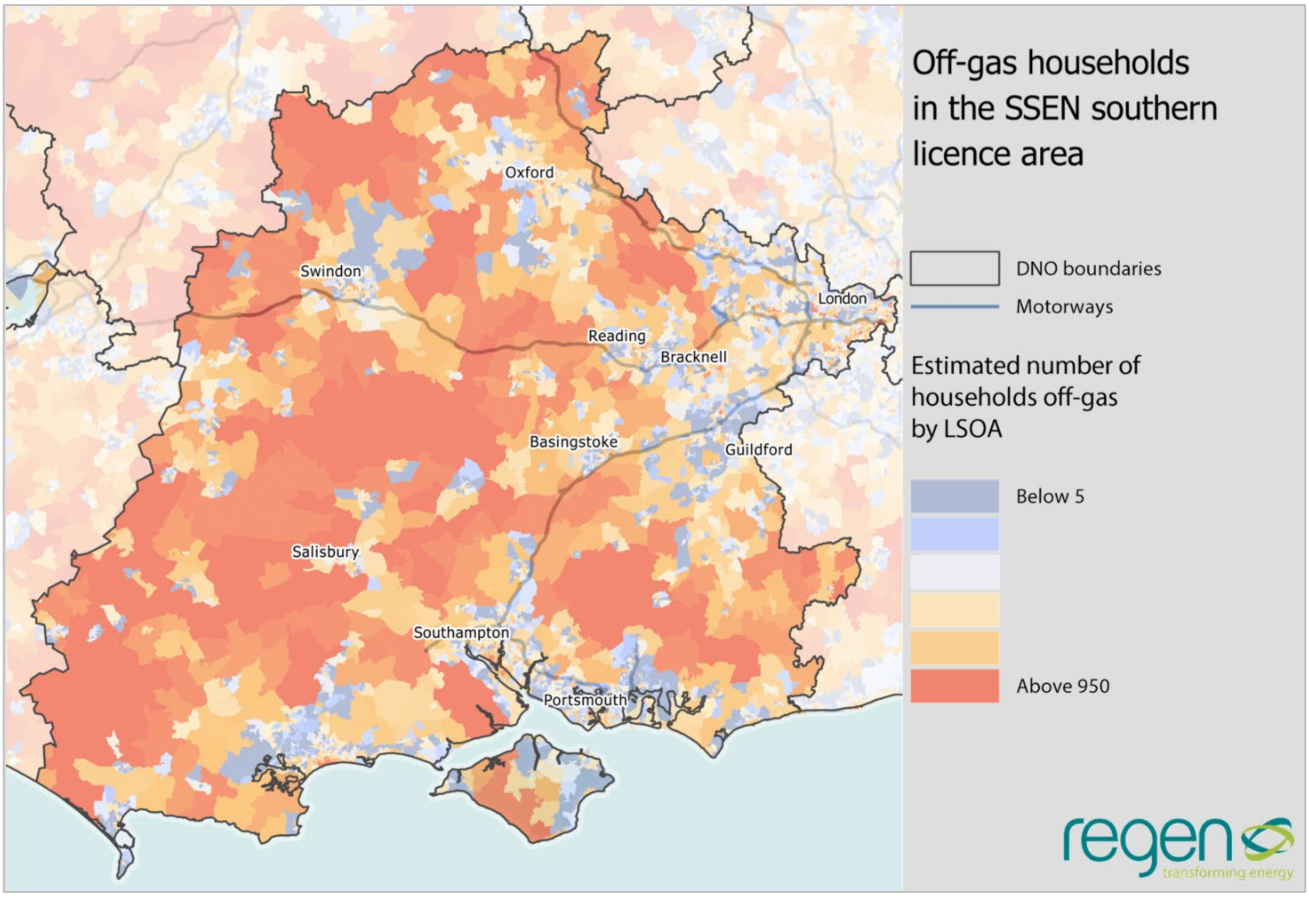
[35] https://www.ons.gov.uk/economy/regionalaccounts/grossdisposablehouseholdincome/bulletins/regionalgrossdisposablehouseholdincomegdhi/1997to2016#analysis-of-nuts1-regions (Regen calculated by weighted average households)

Example 3: Off-gas areas and heat pumps

85% of heat pumps are currently installed in properties without access to mains gas[36]. In this study, the distribution of heat pumps is also correlated towards off-gas areas particularly in the Two Degrees scenario where the government's ambition in the Clean Growth Strategy[37] is to "Phase out the installation of high carbon fossil fuel heating in new and existing off gas grid residential buildings (which are mostly in rural areas) during the 2020s". A 'Call for Evidence' reaffirmed these ambitions in March 2018 and noted that action would be taking place during 2020s.

Heat pumps are also correlated towards areas with new housing developments where building regulations are likely to encourage the installation of low-carbon heating such as heat pumps.

Figure 6-4: Off-gas areas by ESA/LSOA in the SSEN southern licence area.



[36] Regen, 2018. Analysis of RHI monthly statistics tables to July 2018.
[37] P.79, Clean Growth Strategy, (2017) https://www.gov.uk/government/publications/clean-growth-strategy




7. Results in Oxford, Reading, Southampton and Swindon

This section presents some of the results of Regen's analysis looking at four large towns and cities in the licence area, **Oxford**, **Reading**, **Southampton** **and Swindon.** The results cover the key low-carbon technologies expected to have the biggest impact on urban areas, electric cars, rooftop solar PV and heat pumps as well as new developments.

To create scenarios for these geographical areas lower voltage ESAs were made using 11kV network infrastructure corresponding to the relevant local authority boundaries.

New developments

New domestic and commercial developments are likely to see higher levels of low-carbon technologies installed than retrofit buildings, as the technologies can be fitted during construction, significantly reducing the cost of installation. A summary of expected levels of new build in the four areas by 2032 is shown in Table 7-1. Swindon has highest expected levels of new housing development with Reading expecting the most new commercial square meterage. With already dense city centres, both Oxford and Southampton have relatively low levels of new housing within the study period.

Table 7-1: Summary of low voltage areas households and new developments by 2032.

Comparison of areas	Households in 2018	New households by 2032	% increase in housing	New commercial (m^2) by 2032
Oxford	57,422	3,518	6%	1,203,021
Reading	65,193	7,187	11%	1,482,648
Southampton	101,887	3,297	3%	382,116
Swindon	91,627	13,833	15%	1,241,427

Electric vehicles and chargers

In the short and medium term, EV ownership is expected to be related both to the availability of off-street parking and second car ownership. The former allows owners to charge vehicles at home, and the latter means that households can invest in EVs as a second car despite the existing ranges of EVs not yet meeting those of conventional vehicles. Table 7-2 shows the expected level of EVs in the explosive growth scenario and a lower growth scenario by 2032. With high levels of car ownership and off-road parking, Swindon is expected to see the highest numbers of EVs within the plan period.

Table 7-3 shows estimates, by using charger utilisation factors, how many chargers might be installed in the area to provide the expected level of electricity demand from the vehicles in the area. Over 80% of charging is expected to be done at home in all scenarios so the majority of charging infrastruture is expected to be domestic.

Table 7-2: Summary of EV growth and key distribution factors.

Electric vehicles scenarios and attributes	Total registered cars 2018	Electric Vehicles Q1 2018	% without car	% off road parking	EV numbers in Two Degrees	EV numbers in Consumer Evolution
Oxford	51,675	271	33%	25%	41,759	8,192
Reading	66,681	197	28%	19%	54,566	10,699
Southampton	101,546	214	30%	28%	83,071	16,165
Swindon	107,747	4133	22%	35%	90,410	21,218

Table 7-3: Estimated chargers expected in Explosive Growth scenario by urban area

Estimated chargers. Explosive growth scenario by 2032	At home/ off-street	Domestic on street	Car parks or destinations	Workplaces inc. depots	Local & national charge stations
Oxford	19,961	183	280	543	32
Reading	25,459	242	229	378	122
Southampton	39,015	360	632	647	121
Swindon	46,155	494	353	523	148

Rooftop solar PV

Rooftop solar PV will be the predominant form of generation in most urban areas. Table 7-4 shows the level of rooftop solar PV already installed in the four cities and towns, as well as the potential growth under a high and low growth scenario. In FES 2018, the Consumer Renewables scenario has highest levels of rooftop solar PV whereas the other green scenario, Two Degrees, prioritises investment in larger scale generation. In all the scenarios Swindon is expected to have the highest level of rooftop solar PV installed by 2032 due to having a high number of households with rooftop potential and high existing levels.

Table 7-4: Baseline and growth of rooftop solar PV in the focus areas

Rooftop solar PV MW	Baseline MW	Community Renewables		Steady Progression	
		2025	2032	2025	2032
Oxford	14	22	34	16	18
Reading	6	15	32	7	11
Southampton	8	20	37	10	14
Swindon	80	99	149	86	101

Heat pumps

85% of heat pumps are currently installed in properties without access to mains gas[38] and as a result, there are very few heat pumps currently installed in the four urban areas. Though the Renewable Heat Incentive (RHI) subsidy has recently been increased, there remain many barriers to heat pump up-take. The biggest issue for retrofit is the cost and effort to upgrade existing buildings to allow heat pumps to function efficiently. Hybrid heat pumps may provide a partial solution to this issue as they can work more effectively within 'hard to treat' housing, such as historic buildings within Oxford city centre. All scenarios project a relatively high proportion of hybrid heat pumps in retrofit on-gas properties.

The FES 2018 scenarios vary considerably in their approaches to electrification of heating, particularly in urban areas. The Community Renewables scenario assumes that heat pumps will be the major source of heating. In Two Degrees, urban areas with an existing gas network would prioritise central more efficient solutions such as CHP or hydrogen heating.

Table 7-5 shows a high and low growth scenario for heat pumps. Though Southampton has a high number of off-gas houses, they are expecting a smaller number of heat pumps to Swindon in 2032 due to the existing heat network in the city and lower levels of new housing.

Table 7-5: Growth of heat pump numbers in the focus areas

Numbers of heat pumps	Households	% off gas houses	Community Renewables		Consumer Evolution	
			2025	2032	2025	2032
Oxford	57,422	16%	2,676	9,442	486	2,461
Reading	65,193	14%	3,233	13,355	584	3,404
Southampton	101,887	22%	4,465	15,422	731	3,916
Swindon	91,627	9%	4,647	20,956	815	5,178

[38] Regen, 2018. Analysis of RHI monthly statistics tables to July 2018.

8. Oxford

Energy in Oxford

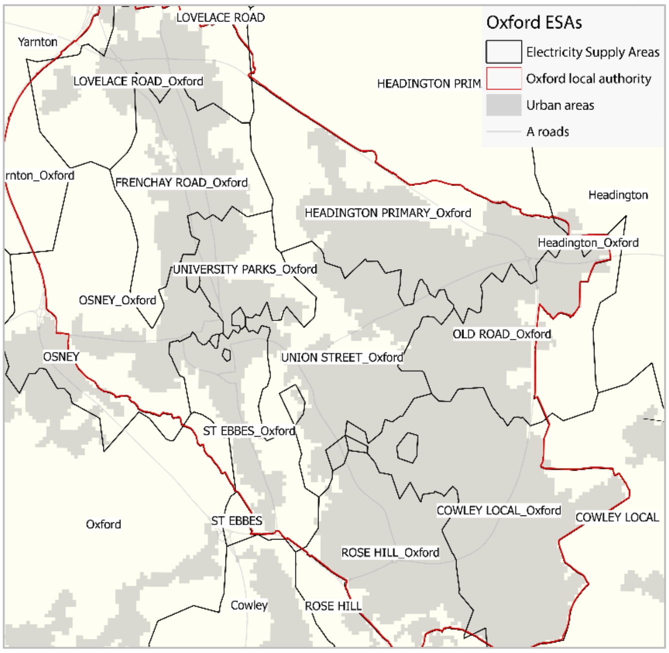
Oxford	2018
Number of households	57,422
Number of cars	51, 675
% household without a car	33%
% with off-street parking	25%
% in income deprivation	10%

Notable generation assets in Oxford include a 3 MW solar roof at the Cowley BMW plant which currently supplies the car manufacturer with behind-the-meter electricity[39] along with a 49kW community owned hydro scheme at Osney Lock[40]. A newly completed 4.5 MW gas CHP supplies energy to both John Radcliffe and Churchill hospitals and includes a 2.2km heat network.

Just outside the city to the north there is a solar farm along with plans for a 49 MW new gas generator. The distribution high voltage network runs past the south of the city, next to another small hydro installation and a sewage treatment works.

In order to present the results of the study for network analysis, Regen and SSEN created 13 low-voltage ESAs shown in Figure 8-1. These areas are all served by the same low-voltage infrastructure.

Figure 8-1: Oxford low-voltage ESAs



Local energy strategies

Oxfordshire's Local Enterprise Partnership Energy Plan[41] sets out an overarching goal to reduce carbon emissions in the county by 50% between 2008 and 2030. The plan aims to reduce electricity demand through energy efficiency as well as facilitating and supporting new clean energy generation in the area. Key to delivering the plan is to ensure that the local network infrastructure is sufficient for new generation and demand.

[39] https://www.greenenergysustainsol.co.uk/bmw
[40] http://www.osneylockhydro.co.uk/
[41] https://www.oxfordshirelep.com/energystrategy

New development sites

The largest five domestic, commercial or mixed-use sites in Oxford are shown in Table 8-1. Oxford is expecting around 3,500 new dwellings to be built by 2032 in 17 new sites[42]. However, this figure is dwarfed by the growth expected in Oxfordshire more broadly. In the parts of Oxfordshire covered by SSEN, up to 48,000 new homes are planned by 2032.

There are also 32 non-domestic development sites with 1.2 million m^2 of commercial space planned by 2032. Oxfordshire local authorities in the SSEN southern licence area account for 116 sites with 6.5 million m^2.

Table 8-1: Oxford ESAs with highest new development growth

Oxford City ESAs with highest expected new developments by 2032	Commercial space (m^2)	No. commercial sites	Dwellings to 2032	No. of domestic sites
COWLEY LOCAL_Oxford 11 kV	309,936	6	610	3
OLD ROAD_Oxford 11 kV	249,997	2	121	1
LOVELACE ROAD_Oxford 11 kV	226,000	2	454	2
ST EBBES_Oxford 11 kV	145,457	6	338	2
ROSE HILL_Oxford 11 kV	128,349	2	248	2
HEADINGTON PRIMARY_Oxford 11 kV	95,582	10	877	2
FRENCHAY ROAD_Oxford 11 kV	6,300	2	455	2

Electric vehicles

At the end of Q1 2018 baseline of electric vehicles in the city was estimated to be around 278. This is a relatively low figure for a city of around 57,000 households and is most likely explained by the low levels of off-road parking available (around 25%) and low car ownership. Around 33% of the city do not own a vehicle, most likely a result of a high student population.

Table 8-2: Growth in number of electric vehicles by scenario

Oxford Electric Vehicles	Q1 2018	2020	2025	2032
Two Degrees	278	1,366	6,399	30,150
Community Renewables		1,563	7,346	31,049
Consumer Evolution		551	1,855	8,709
Steady Progression		545	1,852	8,953

With a large influx of workers commuting to the centre during the working week, transport is a major issue for the city. Congestion and air pollution are also significant concerns. Oxford is hoping to have the first zero emission zone for transport by 2020[43]. If implemented with an exemption for electric vehicles, the number of EVs registered in the area is likely to rise considerably. The highest 'Explosive Growth' scenario suggests the city could see up to 41,000 vehicles by 2032, around 70% of the total vehicles.

Oxford – Explosive Growth Estimated charger Numbers by 2032	2032
Number of electric cars	41,919
Home chargers	19,961
Public charging	463
Charging stations	32

[42] Where new developments were student accommodation this was converted to dwelling numbers using a ratio of 1:4.
[43] https://consultations.oxfordshire.gov.uk/consult.ti/Oxford_ZEZ/consultationHome

With low levels of off-road parking available and an influx of workers during the day, the city is likely to see a high number of public and on-road chargers relative to domestic charge points. High voltage charging stations are also expected in the motorways and roads around the periphery.

Rooftop solar PV and domestic batteries

Oxford has around 14 MW of solar generation within the city. All is assumed to be rooftop solar due to the space restrictions for ground-mounted solar. With the cost of solar panels expected to continue to fall, there is likely to be an increase in capacity of both domestic and commercial rooftop solar PV. Some households with rooftop solar PV are likely to also have a battery installed. In the Consumer Renewables scenario there is approximately 3 MW of domestic battery capacity by 2032.

Table 8-3: Growth in MW of rooftop solar PV in Oxford by scenario

Oxford (MW rooftop solar PV)	2018	2020	2025	2032
Two Degrees	14	14	16	23
Community Renewables		15	22	33
Consumer Evolution		14	15	18
Steady Progression		14	15	17

Electrification of heat

Oxford has a small number of heat pumps currently registered through Renewable Heat Incentive (RHI). The Community Renewables scenario has nearly 10,000 heat pumps by 2032. This will include a significant proportion of hybrid heat pumps in on-gas areas and in ‘hard to treat’ buildings such as the historic buildings in Oxford city centre. Two Degrees puts more focus on centralised heating solutions for urban areas and however 6,500 are heat pumps are still expected to be installed in the city by 2032.

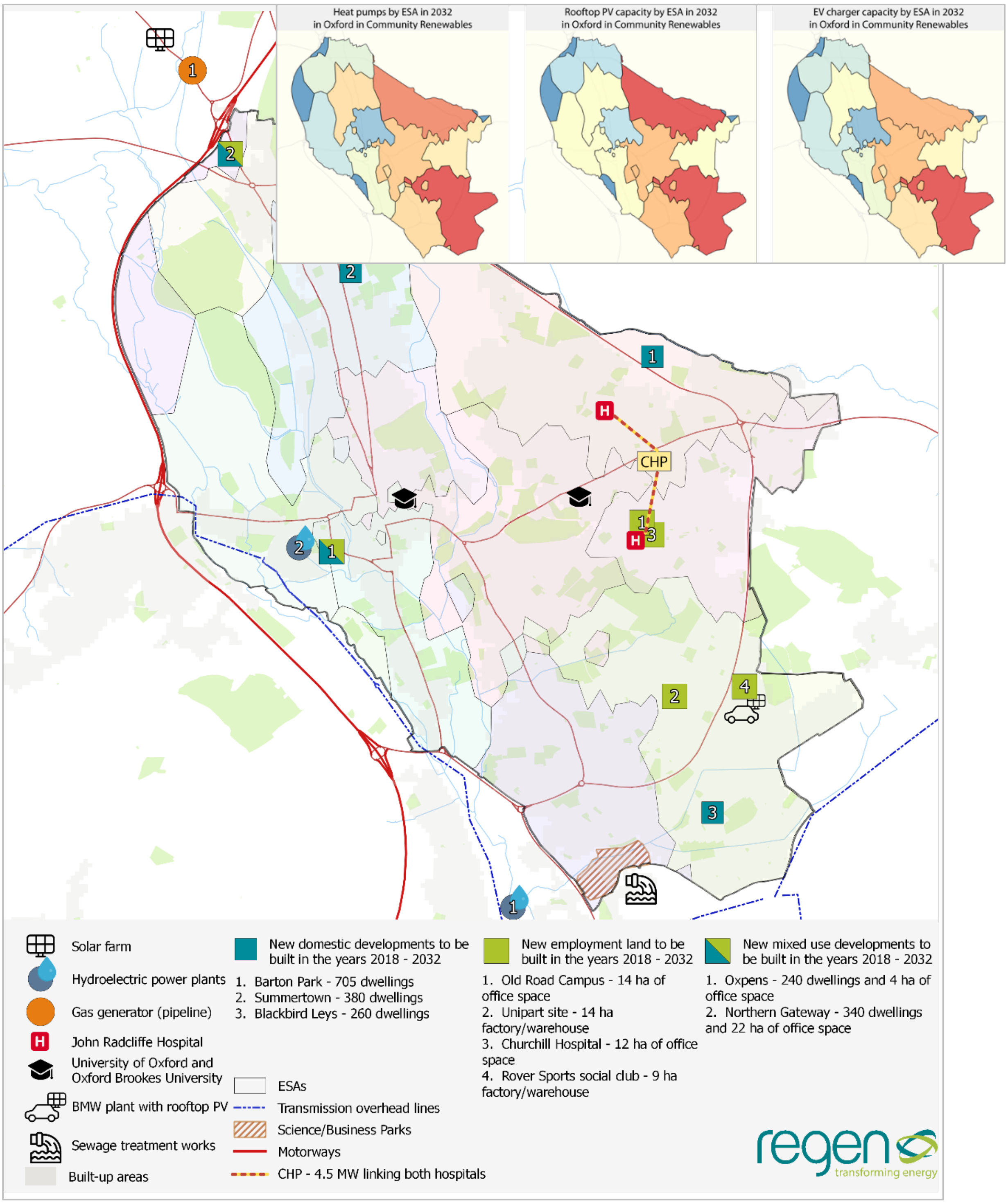
Table 8-4: Growth in numbers of heat pumps by scenario

Oxford (Total heat pumps)	2018	2020	2025	2032
Two Degrees	74	218	1,851	6,468
Community Renewables		289	2,676	9,442
Consumer Evolution		127	486	2,461
Steady Progression		135	368	1,056

Scenario summary

Figure 8-2 shows the existing and pipeline energy infrastructure in the city of Oxford, along with the largest areas of new domestic and commercial development. The insert shows a heat map of growth by 2032 in heat pumps, rooftop solar PV and electric vehicle chargers by 2032 in Community Renewables

Figure 8-2: Scenario summary map of Oxford



9. Reading

Energy in Reading

Electricity generation sites within Reading are limited to a sewage treatment plant, which generates 3.4 MW. Just outside the town there is a gas generator to the south west along with a pipeline project for a further gas generator and battery storage.

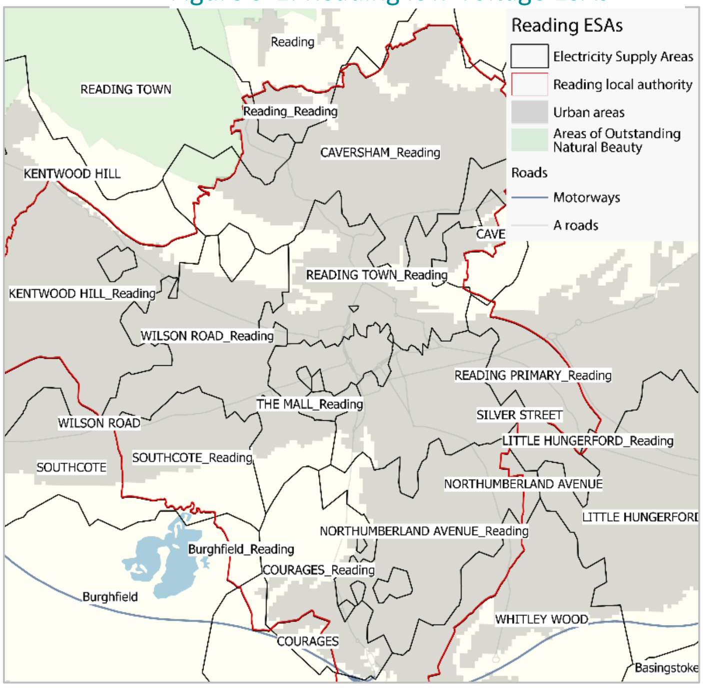
Reading	2018
Number of households	65,193
Number of cars	66,681
% household without a car	28%
% with off-street parking	19%
% in income deprivation	13%

Reading lacks any significant ground-mounted solar PV either in the town or outside. This is in part due to the high-grade agricultural land surrounding the city, particularly to the north[44].

Reading has a relatively low proportion of commercial buildings relative to households. Of those buildings, 42% of non-domestic buildings are associated with retail. However, some large commercial sites are located just outside of the town including the University of Reading and two science parks.

In order to present the results of the study for network analysis, Regen and SSEN created 13 low-voltage ESAs shown in Figure 9-1. These areas are all served by the same low-voltage infrastructure.

Figure 9-1: Reading low-voltage ESAs



Local energy strategy

Reading has a vision for 2050[45], which includes a zero-carbon commitment. The report highlights that achieving the vision requires extensive retrofit of existing buildings, as well as new renewable energy schemes.

With the numbers of households expected to increase around 11% in a high growth scenario, the building standards and low-carbon technologies used in new build developments will be an important feature of future electricity demand.

[44] http://publications.naturalengland.org.uk/publication/141047?category=5954148537204736
[45] https://livingreading.co.uk/understanding-readinghistory-and-growth/reading-2050-vision-launched

New development sites

Reading is expecting a large number of new developments within the period to 2032, over 7,000 new homes in 28 sites. There are expected to be a further 28 sites accounting for 1.5 m^2 of commercial development by 2032. Most of the sites and developments are expected to be within just two of Reading's thirteen 11 kV ESAs.

Table 9-1: Reading ESAs with highest new development growth

Reading ESAs with highest expected new developments by 2032	Commercial space (m^2)	No. commercial sites	Dwellings to 2032	No. of domestic sites
COURAGES_Reading 11 kV	638,281	12	1,324	4
READING TOWN_Reading 11 kV	604,041	10	4,211	14
WHITLEY WOOD_Reading 11 kV	137,745	2		
NORTHUMBERLAND AVENUE_Reading 11 kV	55,716	5	199	2
WILSON ROAD_Reading 11 kV	28,715	2	377	3
THE MALL_Reading 11 kV	18,150	2	675	2

Electric vehicles

There are relatively few electric vehicles currently registered in Reading.

With around 28% of households without a car[46], Reading has a similar level of ownership to the other urban focus areas but has lower levels of off-road parking. Only 19% of dwellings are estimated to have off-road parking which is likely to be a key growth factor in EV growth in the short and medium term.

Reading - Explosive Growth Estimated charger numbers	2032
Number of electric cars	54,238
Home chargers	25,459
Public charging	471
Charging stations	122

Table 9-2: Growth in number of electric cars by scenario

Reading (Electric vehicle numbers)	Q1 2018	2020	2025	2032
Two Degrees	204	1,639	8,248	38,838
Community Renewables		1,902	9,488	39,980
Consumer Evolution		561	2,266	11,209
Steady Progression		553	2,262	11,533

[46] https://www.racfoundation.org/data/car-van-ownership-rates-by-local-authority-england-wales-data

Rooftop solar PV

There is a small amount of rooftop solar PV installed on the 65,000 households in the Reading area. The scenarios anticipate an increase of 3 MW in Steady Progression where there remains little subsidy support and slowing technology cost reductions. In contrast, the Community Renewables scenario has installations increasing to 32 MW by 2032 with over 700 domestic batteries installed.

Table 9-3: Growth in MW rooftop solar PV by scenario

Reading (MW rooftop solar PV)	2018	2020	2025	2032
Two Degrees	5	6	8	16
Community Renewables		6	14	32
Consumer Evolution		5	6	10
Steady Progression		5	6	8

Electrification of heat

Reading has 78 RHI registered heat pumps. In a Community Renewable scenario this could rise to around 13,355 with installations on both new builds and some hybrid heat pumps in retrofit properties in on-gas areas.

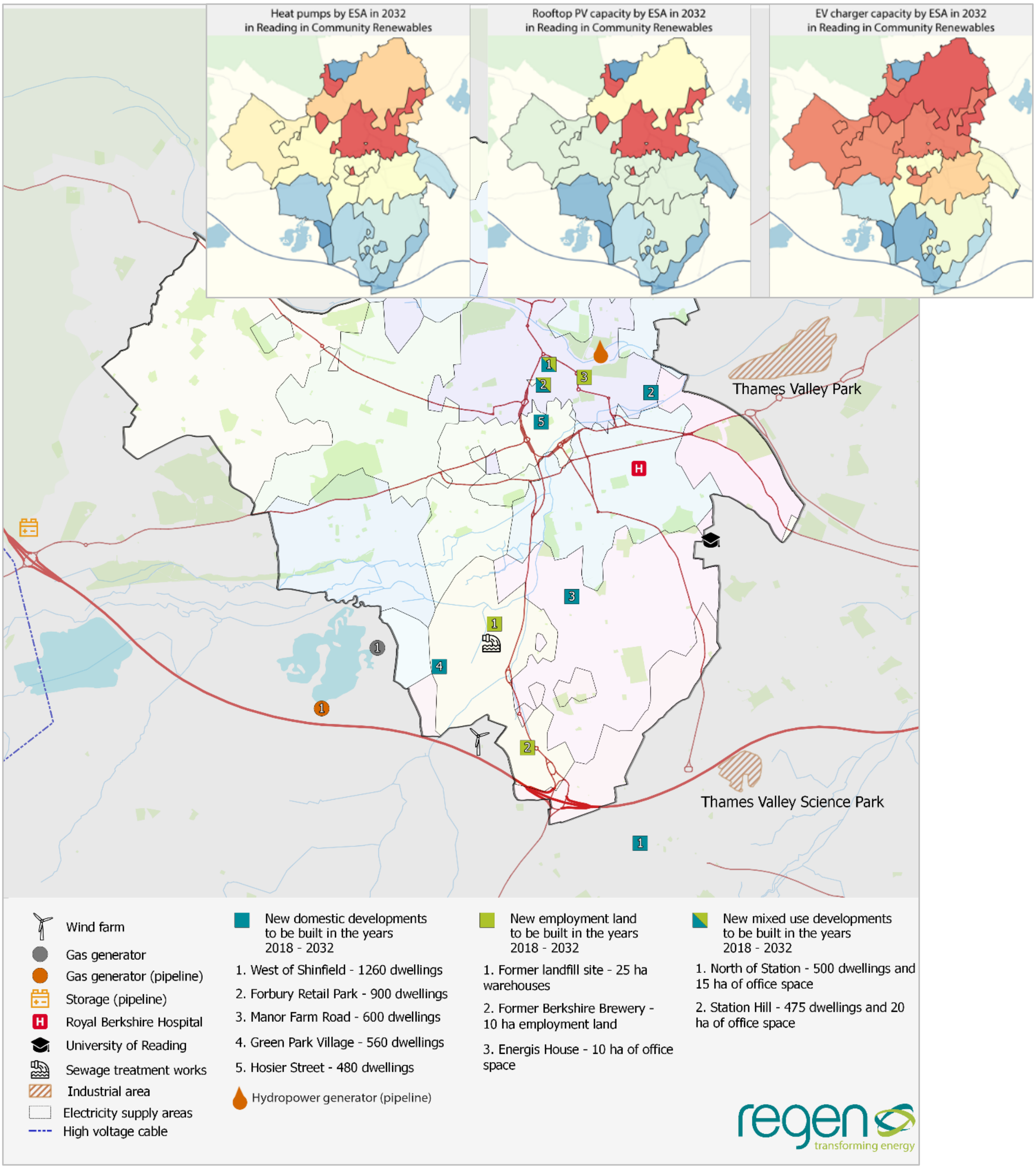
Table 9-4: Growth in numbers of heat pumps by scenario

Reading (Total heat pumps)	2018	2020	2025	2032
Two Degrees	78	253	2,251	8,916
Community Renewables		343	3,233	13,355
Consumer Evolution		146	584	3,404
Steady Progression		154	437	1,408

Scenario summary

Figure 9-2 shows the existing and pipeline energy infrastructure in Reading, along with the largest areas of new domestic and commercial development. The insert shows a heat map of growth by 2032 in heat pumps, rooftop solar PV and electric vehicle chargers by 2032 in Community Renewables.

Figure 9-2: Scenario summary map of Reading



10. Southampton

Energy in Southampton

Southampton	2018
Number of households	101,887
Number of cars	101,546
% household without a car	30%
% with off-street parking	28%
% in income deprivation	23%

Southampton city has a number of generation assets both within and just outside the city. Notably the city has a long-standing district heating scheme powered partly by a geothermal project that was completed in 1987. The scheme currently supplies heat and power to 45 commercial and residential users. [47]

There are two large battery storage projects in the pipeline. One 50 MW battery has received planning permission and is expected to target electric vehicle charging[48]. The developers, Pivot Power, are speaking to Southampton City Council about plans to electrify public transport in the area to help tackle air pollution.

In order to present the results of the study for network analysis, Regen and SSEN created 20 low-voltage ESAs shown in Figure 10-1. These areas are all served by the same low-voltage infrastructure.

Figure 10-1: Southampton low-voltage ESAs

Local energy strategies

Southampton has motorways to the north and west, with the M271 heading into the heart of the city causing significant problems with air quality[49]. This is exacerbated by the level of traffic and HGVs heading into the port, as well as with ships running diesel generators when docked. Though there is no specific energy strategy for the area, there are plans to improve air quality in the city and new developments in Southampton up to 2030 are guided

[47] https://www.engie.co.uk/energy/district-energy/southampton/

[48] https://uk.solarenergyevents.com/2018/10/22/second-pivot-power-battery-green-lit-as-bus-depot-charging-teased-in-southampton/

[49]https://www.southampton.gov.uk/modernGov/documents/s31110/Appendix%201.pdf

by the Southampton City Master Plan[50]. The plan highlights the potential for expanding the existing CHP district heating to decarbonise heating as well as the potential for a biomass power station.

As a significant feature of the City, Southampton port also has plans to decarbonise their operations with new solar photovoltaic installations. They are also looking to provide electrical connections for cruise ships so they do not run diesel generators at port. Each cruise ship is expected to need a connection of between 8-13 MW[51].

New development sites

New developments in Southampton are limited to three ESA areas, despite having almost 20 low voltage ESAs. The area is expecting just over 3,000 new homes by 2032 and 382,000 m^2 of commercial development. The Royal Pier Waterside development is the largest in the city with 600 new homes and 130,000 m^2 of office space being created by 2032 in Western Esplanade ESA.

Table 10-1: Southampton ESAs with highest new development growth

Southampton ESAs with highest expected new developments by 2032	Commercial space (m^2)	No. commercial sites	Dwellings to 2032	No. of domestic sites
Langley_Southampton 11 kV	168,330	3	1,957	8
WESTERN ESPLANADE_Southampton 11 kV	93,786	5	685	4
CHAPEL_Southampton 11 kV			655	2

Electric vehicles

The city currently has over 100,000 registered cars of which only 226 are registered as electric vehicles. Improving air quality in Southampton is an important issue for the city and therefore levels would be expected to increase in all scenarios. Pivot Power is in discussion to electrify the cities buses as a way to support this shift with a related 50 MW battery granted planning permission in 2018[52].

Southampton - Explosive Growth Estimated charger numbers	2032
Number of electric cars	82,316
Home chargers	39,015
Public charging	992
Charging stations	121

Table 10-2: Growth in number of electric vehicles by scenario

Southampton	Q1 2018	2020	2025	2032
Two Degrees	226	2,401	12,436	59,021
Community Renewables		2,798	14,311	60,751
Consumer Evolution		772	3,367	16,971
Steady Progression		760	3,361	17,462

[50] https://www.southampton.gov.uk/planning/planning-policy/supplementary-planning/city-centre-master-plan.aspx
[51] https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/docs/body/environment_factor_en.pdf
[52] https://airqualitynews.com/2018/07/23/plans-for-southampton-battery-and-ev-charging-sites-unveiled/

Rooftop solar PV

There is a total of 7 MW of rooftop solar PV in the city. Southampton's Master Plan notes the high solar irradiance in the area which suggests there is significant potential for further growth in domestic and commercial sites. In 2018 the port installed a 0.5 MW solar roof on a cruise terminal and plans further installations as part of its sustainability initiatives.

Table 10-3: Growth in MW rooftop solar PV by scenario

Southampton (MW rooftop solar PV)	2018	2020	2025	2032
Two Degrees	7	8	11	21
Community Renewables		9	20	36
Consumer Evolution		8	9	13
Steady Progression		8	9	11

Electrification of heat

With a substantial pathfinder project already generating heat and electricity for commercial and residential customers in the city, Southampton has good potential to decarbonise heat in the city through district heating. Central solutions to heat are prioritised in Two Degrees and, as a result, the scenario expects the city to have just over 10,000 heat pumps by 2032. Over 15,000 heat pumps could be installed in Community Renewables.

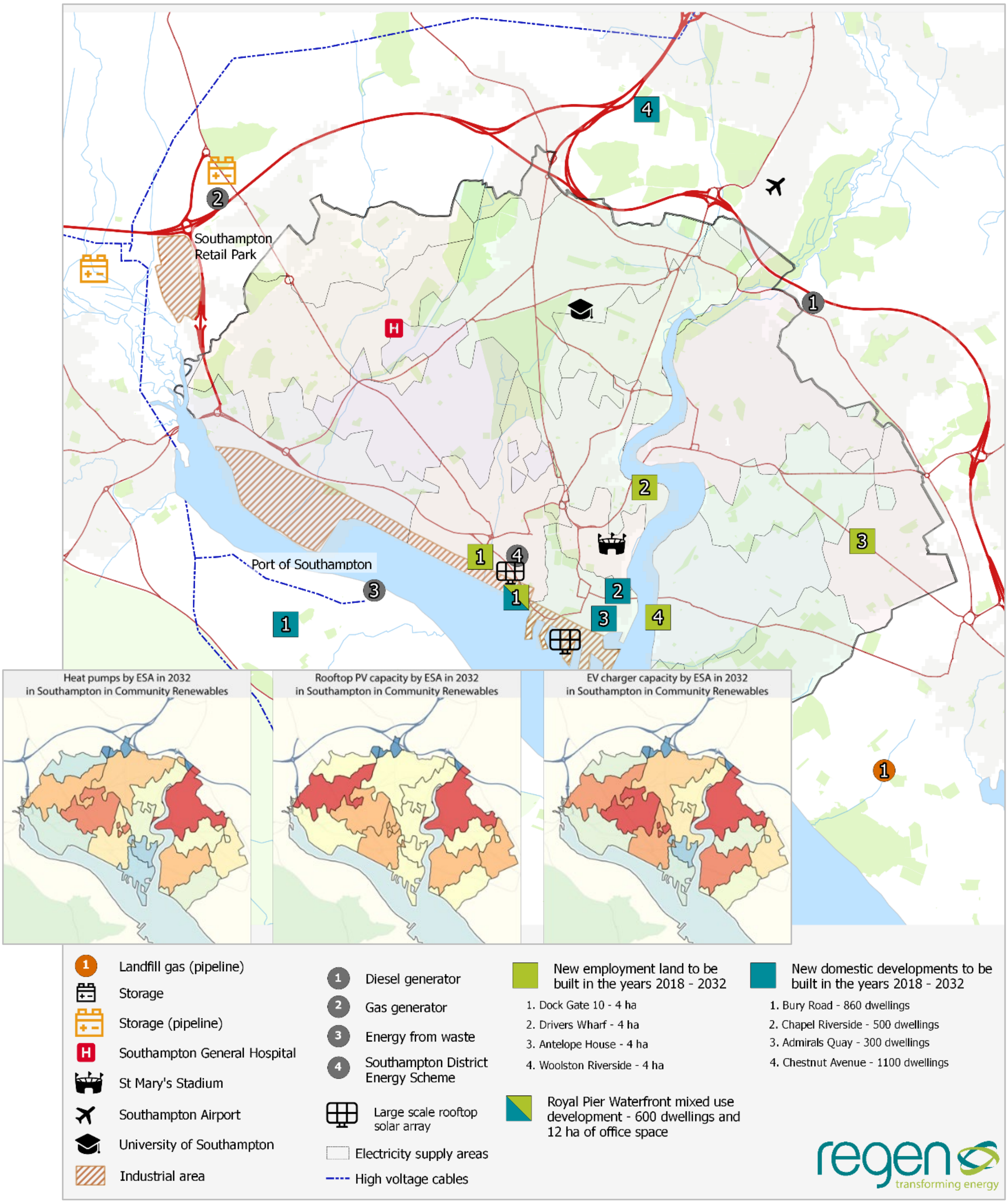
Table 10-4: Growth in numbers of heat pumps by scenario

Southampton (Total heat pumps)	2018	2020	2025	2032
Two Degrees	55	300	2,955	10,096
Community Renewables		431	4,465	15,422
Consumer Evolution		146	731	3,916
Steady Progression		164	546	1,663

Scenario summary

Figure 10-2 shows the existing and pipeline energy infrastructure in Southampton, along with the largest areas of new domestic and commercial development. The insert shows a heat map of growth by 2032 in heat pumps, rooftop solar PV and electric vehicle chargers by 2032 in Community Renewables.

Figure 10-2: Scenario summary map of Southampton



11. Swindon

Energy in Swindon

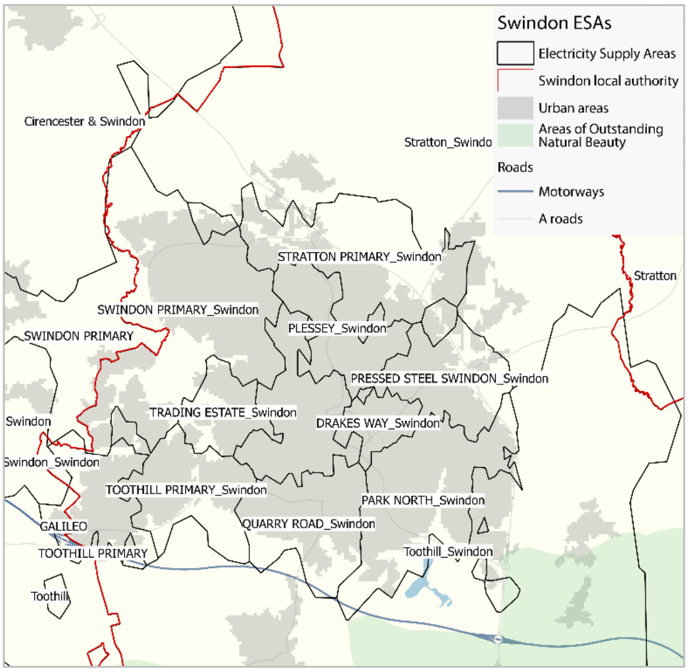
Swindon has a large amount of generation and new development activity along with a significant industrial base. Both Honda and BMW car plants are based in the large town.

Swindon	2018
Number of households	91,627
Number of cars	107,747
% household without a car	22%
% with off-street parking	35%
% in income deprivation	16%

Most notably the town currently has seven solar farms including a 10 MW project which helps power the nearby Honda factory. There is also one 5 MW wind farm[53] just outside Swindon which makes up half the existing baseline in the licence area. In the pipeline there are three battery projects proposed, as well as a gas generator and CHP plant expected to connect.

In order to present the results of the study for network analysis, Regen and SSEN created 13 low-voltage ESAs shown in Figure 11-1. These areas are all served by the same low-voltage infrastructure.

Figure 11-1: Swindon low-voltage ESAs



Local strategies

Swindon has a number of initiatives which are helping to build a more sustainable future energy system. The Swindon and Wiltshire Local Enterprise Partnership is currently developing an energy strategy for the area[54] and Swindon Borough Council's subsidiary Public Power Solutions[55] brings together the public sector and commercial organisations to develop sustainable solutions for waste and energy including developing the Mannington 50 MW battery site next to the Toothill substation[56].

[53] https://www.westmill.coop/westmill-live-production/
[54] https://growthhub.swlep.co.uk/news/news-story/swindon-and-wiltshire-local-energy-strategy-is-underway
[55] https://www.publicpowersolutions.co.uk/
[56]https://www.solarpowerportal.co.uk/news/council_subsidiary_puts_50mw_battery_on_the_market_after_securing_approval

Finally, the Green City Vision project is a collaboration between Wales and West Utilities, UK Power Networks and Scottish and Southern Electricity Networks to look at how both the electricity and gas networks in Swindon can meet the demands of the FES Steady Progression scenario.

New development sites

Swindon is expecting a significant number of new homes by 2032 with nearly 14,000 being built in 20 sites across the area. New commercial development plans are for 1.2 million square meters in 35 sites. Most significant areas are the Toothill and Stratton BSPs which account for around half of the developments expected within Swindon.

Table 11-1: Swindon ESAs with highest new development growth

Swindon ESAs with highest expected new developments by 2032	Commercial space (m^2)	No. commercial sites	Dwellings to 2032	No. of domestic sites
Toothill_Swindon BSP	313,975	10	6,260	5
Stratton_Swindon BSP	278,400	10	2,851	7
STRATTON_Swindon 11 kV	15,000	1	1,633	1
QUARRY ROAD_Swindon 11 kV	65,000	2	834	2
TOOTHILL PRIMARY_Swindon 11 kV	70,565	2	751	1
MANCHESTER ROAD_Swindon 11 kV	120,030	5	408	1
PRESSED STEEL SWINDON_Swindon 11 kV	358,457	2		

Electric vehicles

Swindon has very high numbers of electric vehicles in comparison to the other focus areas, with around 4,000 currently registered in the town. This could be partially explained by Swindon having both the highest level of off-road parking and car ownership of the four focus areas. The Explosive Growth scenario sees the numbers of EVs increasing to around 90,000 in 2032.

Swindon - Explosive Growth Estimated Charger Numbers	2032
Number of Electric Vehicles	93,151
Home chargers	46,155
Public charging	847
Charging stations	148

Swindon is also a hub for hydrogen vehicles with a solar powered hydrogen filling station based at the Honda factory and a second installed in 2018[57].

Table 11-2: Growth in number of electric vehicles by scenario

Swindon (Electric vehicle numbers)	Q1 2018	2020	2025	2032
Two Degrees	4,148	6,602	17,684	67,726
Community Renewables		7,052	19,760	69,616
Consumer Evolution		4,763	7,625	22,341
Steady Progression		4,750	7,618	22,876

[57] http://www.businessbiscuit.com/8-news/5208-new-hydrogen-station

Rooftop solar PV and domestic batteries

Swindon has the highest levels of solar PV installed of the four urban areas with 79 MW. Some of this baseline is likely to be ground-mounted solar in the outskirts of the town. It is expected that rooftop solar PV could increase by 70 MW in Community Renewables by 2032.

Table 11-3: Growth in MW solar PV by scenario

Swindon (MW solar PV)	2018	2020	2025	2032
Two Degrees	79	84	89	114
Community Renewables		86	98	149
Consumer Evolution		84	86	101
Steady Progression		80	85	91

Electrification of heat

With 14,000 new homes expected in the borough by 2032, there is high potential to fit new homes with electric heat pumps. Numbers could be around 21,000 by 2032 in the Consumer Renewables scenario although a Two Degrees scenario prioritise other technologies such as hydrogen in dense urban areas but still have around 13,000 heat pumps installed.

Table 11-4: Growth in numbers of heat pumps by scenario

Swindon (Total heat pumps)	2018	2020	2025	2032
Two Degrees	89	338	3,109	13,176
Community Renewables		470	4,647	20,956
Consumer Evolution		185	815	5,178
Steady Progression		200	609	2,137

Scenario summary

Figure 11-2 shows the existing and pipeline energy infrastructure in Swindon, along with the largest areas of new domestic and commercial development. The insert shows a heat map of growth by 2032 in heat pumps, rooftop solar PV and electric vehicle chargers by 2032 in Community Renewables.

Figure 11-3: Scenario summary map of Swindon