Distributed generation and demand study -Technology growth scenarios to 2030

South Wales licence area

September 2016

Version: Final

Regen SW, The Innovation Centre, Rennes Drive, Exeter, EX4 4RN
T +44 (0)1392 494399 **E** admin@regensw.co.uk **W** http://www.regensw.co.uk

Registered in England No: 04554636

This report was produced for	Western Power Distribution
Issue date	September 2016
Version	Final
Written by:	Cheryl Hiles, Hazel Williams, Johnny Gowdy and Joel Venn

Approved by:

Cheryl Hiles

Regen SW, The Innovation Centre, Rennes Drive, Exeter, EX4 4RN

T +44 (0)1392 494399 E admin@regensw.co.uk W www.regensw.co.uk

Registered in England No: 04554636

Table of Contents

1 EXECUTIVE SUMMARY 5
1.1 CONTEXT 5
1.2 STRATEGIC NETWORK INVESTMENT 5
1.3 OBJECTIVE AND METHODOLOGY 6
1.4 RESULTS 7
1.5 GEOGRAPHIC SPREAD OF DISTRIBUTED GENERATION AND DEMAND TECHNOLOGIES 7
2 INTRODUCTION AND CONTEXT 9
2.1 CONTEXT - GROWTH OF DISTRIBUTED GENERATION 9
2.2 STRATEGIC DISTRIBUTION NETWORK REINFORCEMENT 11
2.3 BUILDING A CASE FOR STRATEGIC DISTRIBUTION NETWORK REINFORCEMENT 11
2.4 A SMARTER ENERGY FUTURE FOR WALES 12
3 DISTRIBUTED GENERATION AND DEMAND TECHNOLOGY SCENARIOS – OBJECTIVES, METHOD AND RESULTS OVERVIEW 15
3.1 OBJECTIVES AND OUTPUT 15
3.2 ASSESSMENT SCOPE 15
3.3 SUMMARY OF METHODOLOGY 17
3.4 SUMMARY OF RESULTS 18
4 ANALYSIS AND RESULTS - ONSHORE WIND TECHNOLOGY GROWTH SCENARIOS 21
4.1 SUMMARY ONSHORE WIND GROWTH SCENARIO 2016-2030 21
4.2 ONSHORE WIND – FUTURE ENERGY POTENTIAL 22
4.3 HISTORIC GROWTH AND BASELINE CAPACITY 24
4.4 SCENARIO GROWTH ANALYSIS 2020-2030 29
4.5 KEY GROWTH DRIVERS AND CONSTRAINTS IN THE SOUTH WALES LICENCE AREA TO 2030 33
4.6 GEOGRAPHIC DISTRIBUTION OF ONSHORE WIND ACROSS ESAS 34
5 ANALYSIS AND RESULTS - SOLAR PV TECHNOLOGY GROWTH SCENARIOS 36
5.1 SUMMARY DISTRIBUTED GENERATION GROWTH SCENARIOS 2016-2030 36
5.2 SOLAR PV – FUTURE ENERGY AND GROWTH POTENTIAL 37
5.3 HISTORIC GROWTH AND BASELINE CAPACITY 41
5.4 SOLAR PV PIPELINE PROJECTION TO 2017 42
5.5 SOLAR PV SCENARIO GROWTH ANALYSIS 2017-2030 45
5.6 KEY GROWTH DRIVERS AND CONSTRAINTS IN THE SOUTH WALES LICENCE AREA TO 2030 49
5.7 GEOGRAPHIC DISTRIBUTION OF SOLAR PV DISTRIBUTED GENERATION 2030 50
6 ANALYSIS AND RESULTS - OFFSHORE ENERGY TECHNOLOGY GROWTH SCENARIOS 53
6.1 OFFSHORE ENERGY SCOPE AND CONTEXT 53
6.2 OFFSHORE ENERGY – FUTURE ENERGY POTENTIAL 54
6.3 OFFSHORE ENERGY SCENARIO BASELINE, PIPELINE AND GROWTH ANALYSIS 2016-2030 55
6.4 KEY GROWTH DRIVERS AND CONSTRAINTS IN SOUTH WALES TO 2030 57
6.5 GEOGRAPHIC DISTRIBUTION OF OFFSHORE ENERGY DISTRIBUTED GENERATION 58
7 ANALYSIS AND RESULTS - ANAEROBIC DIGESTION TECHNOLOGY GROWTH SCENARIOS 60
7.1 BASELINE 61
7.2 PIPELINE 61
7.3 FUTURE GROWTH POTENTIAL 61
7.4 SCENARIOS 61

8 ANALYSIS AND RESULTS - HYDROPOWER TECHNOLOGY GROWTH SCENARIOS 64
8.1 BASELINE 65
8.2 PIPELINE 65
8.3 FUTURE GROWTH POTENTIAL 65
8.4 SCENARIOS 67
9 ANALYSIS AND RESULTS - ENERGY FROM WASTE TECHNOLOGY GROWTH SCENARIOS 68
9.1 BASELINE 68
9.2 PIPELINE 68
9.3 FUTURE GROWTH POTENTIAL 68
9.4 SCENARIOS 69
10 ANALYSIS AND RESULTS - DEEP GEOTHERMAL 70
11 ANALYSIS AND RESULTS - ENERGY STORAGE TECHNOLOGY GROWTH SCENARIOS 71
11.1 TECHNOLOGY OVERVIEW AND FUTURE GROWTH POTENTIAL 71
11.2 CURRENT WELSH ENERGY STORAGE BASELINE AND PIPELINE APPLICATIONS 77
11.3 ENERGY STORAGE GROWTH IN SOUTH WALES BY SCENARIO ANALYSIS TO 2030 79
12 ANALYSIS AND RESULTS - ELECTRIC VEHICLES TECHNOLOGY GROWTH SCENARIOS 84
12.1 BASELINE 84
12.2 FUTURE GROWTH POTENTIAL AND SCENARIOS 85
13 ANALYSIS AND RESULTS - HEAT PUMPS TECHNOLOGY GROWTH SCENARIOS 89
13.1 SUMMARY DISTRIBUTED GENERATION GROWTH SCENARIOS 2016-2030 89
13.2 HEAT PUMPS – FUTURE ENERGY POTENTIAL 90
13.3 SOUTH WALES HISTORIC GROWTH AND BASELINE CAPACITY TO 2016 91
13.4 SCENARIO GROWTH ANALYSIS 2017-2030 91
13.5 HEAT PUMP DISTRIBUTION BY ESA 93
13.6 HEAT PUMP CAPACITY IMPACT ON ELECTRICITY DEMAND 95
14 CONCLUSION 96

1 Executive summary

1.1 Context

The demands on our energy system are changing. In recent years there has been rapid growth in distributed generation capacity, including in Wales. Disruptive new technologies are emerging including the development of electricity storage and the increased take up of electric vehicles.

These new challenges are changing the role of Distribution Network Operators (DNOs), including in Western Power Distribution's (WPD) South Wales licence area. BEIS and Ofgem have issued a call for evidence on 'A Smart and Flexible Energy System' that states 'In the immediate term, DNOs need to transition to Distribution System Operator (DSO) roles'. This will require the operators to undertake enhanced monitoring, forecasting and planning to ensure they assess and anticipate the changing requirements of their networks and are ready to respond.

1.2 Strategic network investment

To improve their understanding of the future demands on their network, WPD has developed an approach to identify, assess and provide a business case justification for future strategic reinforcement proposals. This follows a five step methodology.

Strategic network investment business case development	
Step 1. Distributed generation and demand growth scenarios *(this report)*	Assessing the potential growth in distributed generation and demand by technology type, Electricity Supply Area (ESA) location and year, by scenario
Step 2. Network constraint modelling	Identifying thermal, voltage and fault level constraints that result from scenario modelling
Step 3. Identify and assess options • **Estimate the capacity provided by these solutions** • **Assess cost/timescale of these solutions**	Identify and cost a small number of potential network reinforcement strategic investments Identify future network solutions (including required National Grid electricity transmission upgrades)
Step 4. Assess alternative options	Assess the potential for demand side response (DSR), energy storage or generation constraint take up, given the cost of network solutions
Step 5. Present business case and options	Present business case and recommended investment options

The analysis presented in this report is the first step of this approach.

1.3 Objective and Methodology

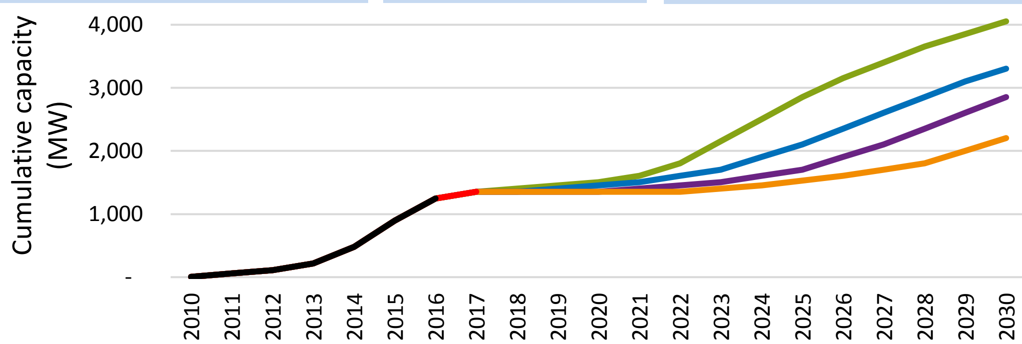
The overall objective of this distributed generation and demand growth scenarios assessment is to assess the potential for deployment of distributed generation and new electricity demanding energy technologies in the WPD South Wales licence area from 2016 to 2030, using as a starting point, the Future Energy Scenarios (FES)[1] developed by the National Grid.

The end output of the assessment is a data set accompanied by this analytical report, which gives an annual capacity growth projection from 2016-2030 by Electricity Supply Area, technology type and scenario.

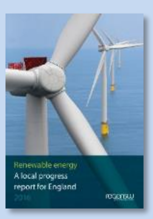
Forecasting the long term growth of any generation or demand technology is extremely difficult and complex owing to the multiple variables that can affect the market and determine growth. In particular, devolution of powers to the Welsh Government could have significant impacts on growth of generation and demand technologies.

The approach taken to assess distributed generation and demand technology growth has been to take, as far as possible, a bottom-up approach to quantify the current baseline and the short term pipeline projection for each technology. An overall scenario based growth projection to 2030 was then estimated, based on the four Future Energy Scenarios that have been developed by the National Grid.

Current baseline up to 2016	Pipeline 2016 -2017/2020	Growth scenarios 2020 - 2030



Current baseline
WPD's connection data and Regen's extensive renewables project database



Pipeline projection (to 2017/2020)
Analysis of current projects in the planning system and which have accepted Connection Offers from WPD for large scale technologies.

Growth scenarios (to 2030)
Growth scenarios based on National Grid's FES - applied at a local level.

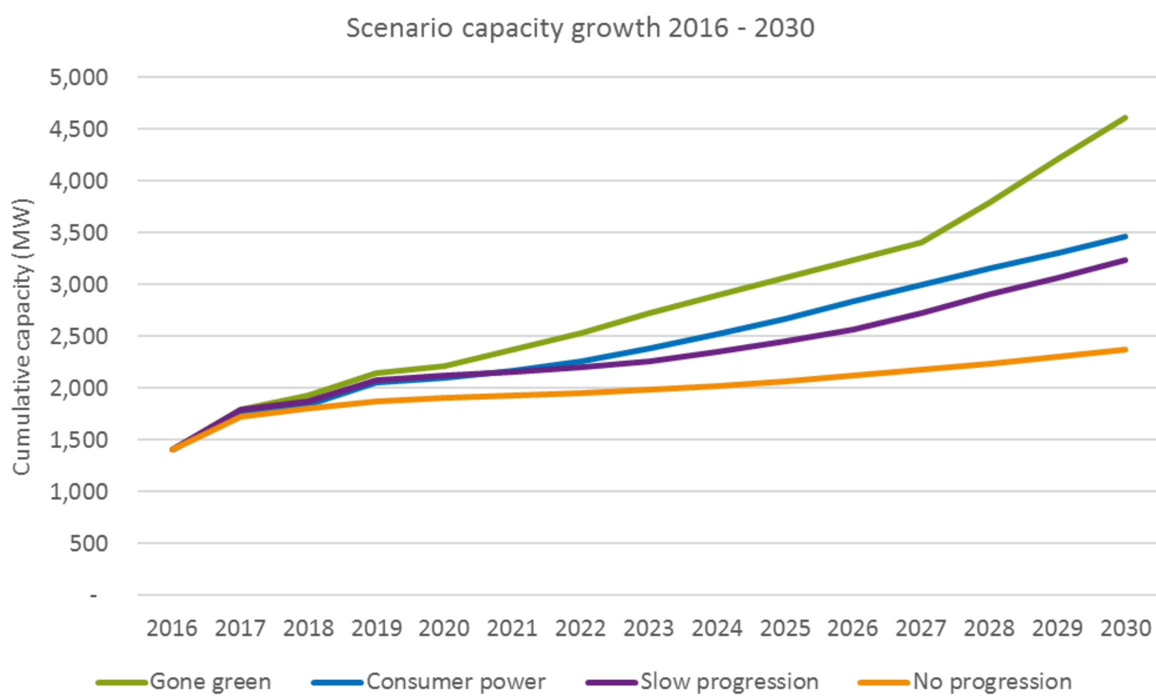
- **Gone Green** (green)
- **Consumer Power** (blue)
- **Slow Progression** (purple)
- **No Progression** (orange)

[1] National Grid Future Energy Scenarios 2016

1.4 Results

The summary results of the distributed generation scenarios are shown in the tables below and show a growth from a current (March 2016) renewable energy baseline capacity of circa 1.4 GW to circa 4.6 GW by 2030 under the most ambitious Gone Green scenario. Growth estimates for the other scenarios, Consumer Power, Slow Progression and No Progression are lower overall. However, even under the lowest No Progression scenario, there is an expected growth pathway to 2.4 GW of distributed renewable generation capacity by 2030.

Distributed renewable generation capacity growth by scenario in the South Wales licence area



1.5 Geographic spread of distributed generation and demand technologies

A key challenge of the assessment has been to understand and forecast the likely geographic spread of generation and demand technologies within the South Wales licence area.

To do this, the study has used Geographic Information System (GIS) analysis to map existing capacity within the network Electricity Supply Areas (see section 3.2.2) and then to forecast future growth, based on a number of geographic factors. The Electricity Supply Area analysis has produced a further level of detail and a greater understanding of what factors determine where certain types of electricity generation technologies projects are likely to be located.

For ground mounted solar PV, for example, the overriding factor is access to the distribution network. For onshore wind, access to the network is important, but areas of high wind resource (velocity), planning policies, undesignated land space and distance from dwellings are the key determinants of project location.

For other technologies – heat pumps, roof mounted solar and AD for example – other factors come into play such as the relative density of households, off-gas grid properties, agricultural activity and even relative affluence.

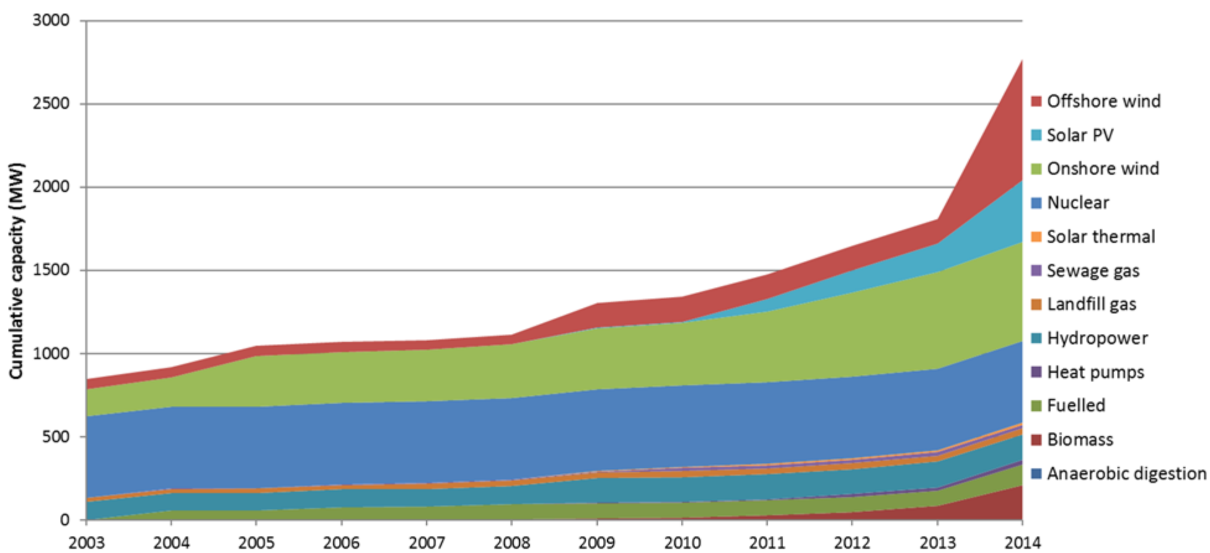
2 Introduction and context

2.1 Context - growth of distributed generation

In common with other Distribution Network Operators (DNOs), in the past three years Western Power Distribution (WPD) has seen a significant growth in both connected distributed generation capacity and accepted connection offers for distributed generation technologies.

The Welsh Government's 'Low Carbon Generation in Wales'[2] report (produced by Regen SW in 2015) shows renewable electricity capacity in Wales has grown steadily.

Low carbon energy capacity in Wales, Welsh Government 2014



WPD's South Wales licence area has seen significant growth in levels of distributed generation of all types. This growth, together with a small reduction in levels of demand in the area, has reduced the network capacity available for distributed generation connections in much of the licence area.

2.1.1 Managing existing distribution network constraints

Both WPD and Ofgem are looking at a number of measures that could mitigate or alleviate the current network constraints. In February 2015, Ofgem also issued a consultation on 'Quicker and More Efficient

[2] http://gov.wales/docs/desh/publications/151120-updated-study-of-low-carbon-energy-en.pdf

Distribution Connections'[3]. Potential measures include more effective queue management (managing the pipeline of projects with or awaiting network connection offers) and encouraging project developers to collaborate together in consortia to share reinforcement costs and realise economies of scale.

The picture in the South Wales licence area as elsewhere is complicated by the large number of projects that are currently in the pipeline, either having an accepted a connection offer but are not yet connected, or with a connection agreement offer (Offered-not-yet-Accepted).

If all the 'Offered-not-yet-Accepted' connections were taken up, the distributed generation capacity in South Wales would exceed 3.65 GVA. This outcome is unlikely since many of these projects will not proceed and are likely to drop out of the pipeline owing to the planning consenting process or other commercial issues. The drop-out rate is itself likely to increase as the result of policy changes introduced last year, namely the reduction and removal of subsidy support. Understanding the potential rate of drop out and managing the queue of remaining projects has, therefore, become a key priority.

WPD is also rolling out a range of alternative connection methods[4] in South Wales, including 'timed connections' and 'constrained connections' that can allow connection offers to be made with constraints on the time or voltage outputs. This reduces the income from generating plants by restricting their export, but can be feasible for some generation technologies. WPD is also beginning to roll out more sophisticated Active Network Management connections[5] that rely on WPD having real time information on network behaviour, to allow generators to connect to the network and generate, but reduce their output or be disconnected in response to constraints. Active Network Management is planned to be deployed in South Wales, including in the areas of Swansea, Pembroke, Pyle and Abergavenny, throughout the next few years.

In the longer term, the deployment of smart grid solutions, including demand side response, will help to reduce supply/demand imbalances in the network. Energy storage solutions are also developing rapidly and are becoming commercially viable.

Summary of WPD grid mitigation measures:

- Queue management/capacity recovery
- Alternative connection offers – export limiting, timed and soft-intertrip
- Active Network Management
- Consortia/grid collaboration
- Smart solutions, such as demand side response
- Energy storage solutions
- Strategic network investment options

[3] https://www.ofgem.gov.uk/publications-and-updates/quicker-and-more-efficient-distribution-connections

[4] https://www.westernpower.co.uk/Connections/Generation/Alternative-Connections.aspx

[5] https://www.westernpower.co.uk/Connections/Generation/Alternative-Connections/ANM-Further-Info.aspx

2.2 Strategic distribution network reinforcement

Smart solutions, energy storage and Active Network Management will help to alleviate network capacity constraints; however, there is a recognition that significant network reinforcement, and investment in network infrastructure, will still be required.

The existing business plans and current regulatory environment in which the DNOs operate allow for a very limited amount of strategic network reinforcement. It is also still the case that, in principle, any network reinforcement costs must be borne directly by energy generators. While this approach has limited the potential cost to consumers of network reinforcement, it has also inhibited long term strategic investment to meet future requirements and has arguably prevented DNOs taking advantage of significant economies of scale. There is a growing recognition that the current approach is no longer fit for purpose and that there is a need to look at new business models that would allow DNOs to carry out strategic reinforcement where there is clear evidence of future demand. As a result, Ofgem added a question to their consultation, 'Quicker and more efficient distribution Connections', on whether the rules should be changed to enable DNOs to carry out strategic reinforcements based on evidence of demand and to address the corollary question of "who should pay?"[6].

Previous Department of Energy and Climate Change Secretary of State, Amber Rudd, also indicated that in the future, strategic or pre-emptive investment may be supported – "*Earlier this year, Ofgem through its Quicker and more efficient connections consultation, set out* ***options for enabling more anticipatory investment****, which could help speed up connection times by creating capacity earlier, and sought views on other ways of improving the connection process."* Amber Rudd to the Energy and Climate Change select committee, September 2015.

2.3 Building a case for strategic distribution network reinforcement

In anticipation that the rules and regulatory model governing network reinforcement may be changed, WPD have begun to develop an approach to identify, assess and provide a business case justification for future strategic reinforcement proposals.

While network reinforcement decisions will need to be justified on a case-by-case basis, it is likely that the starting point to identify strategic investment options will be to identify the network areas with:

- Currently low or no spare capacity
- A viable network reinforcement opportunity
- High potential for growth of future distributed generation
- Least risk of investment regret or stranded assets
- A strong supporting business case for investment, potentially backed by local stakeholders
- A clear model for cost recovery

[6] https://www.ofgem.gov.uk/sites/default/files/docs/2015/02/quicker_and_more_efficient_distribution_connections_-_final_0.pdf

To identify and provide an evidence base to support strategic investment options, WPD has set out a 5 step methodology.

Strategic network investment business case development	
Step 1. Distributed generation and demand growth scenarios *(this report)*	Assessing the potential growth in distributed generation and demand by technology type, Electricity Supply Area (ESA) location and year, by scenario
Step 2. Network constraint modelling	Identifying thermal, voltage and fault level constraints that result from scenario modelling
Step 3. Identify and assess options • **Estimate the capacity provided by these solutions** • **Assess cost/timescale of these solutions**	Identify and cost a small number of potential network reinforcement strategic investments Identify future network solutions (including required National Grid electricity transmission upgrades)
Step 4. Assess alternative options	Assess the potential for demand side response (DSR), energy storage or generation constraint take up, given the cost of network solutions
Step 5. Present business case and options	Present business case and recommended investment options

The analysis presented in the remainder of this report is focused on the first step of this approach. It is intended to enable WPD to assess future potential growth of distributed generation and demand, providing the key inputs to help WPD identify areas of the network (at Electricity Supply Area level- see section 3.2.2) that require network reinforcement and to make a business case for 'least risk' investment.

2.4 A smarter energy future for Wales

A significant number of legislative and policy changes in Wales, including the Planning (Wales) Act 2015[7], Energy Act (2016)[8], Wellbeing of Future Generations (Wales) Act 2015[9] and the Wales Bill 2016-2017[10] are impacting, and will continue to impact upon, how decisions on energy issues will be made in the future across the South Wales licence area. They will in turn have a significant impact upon deployment

[7] http://gov.wales/topics/planning/legislation/planning-wales-act-2015/?lang=en

[8] http://services.parliament.uk/bills/2015-16/energy.html

[9] http://gov.wales/topics/people-and-communities/people/future-generations-act/?lang=en

[10] http://services.parliament.uk/bills/2016-17/wales.html

rates and the timing of distributed generation coming forward in South Wales and have been taken into consideration as far as possible in the shaping of the scenarios for this licence area.

Energy is a key issue for devolution in Wales. Through the Wales Bill 2016-2017, the St David's day process established "Powers for a Purpose", the idea being that powers will be devolved that can make a real, practical difference to the lives of the people in Wales. Among the many powers devolved in the Bill are those that will enable the Welsh Government to decide whether fracking should take place and, if so, how it should be regulated; and how planning consent is given for all but the most strategic energy projects (up to 350MW), aside from onshore wind projects, which are being devolved through the 2016 Energy Act.

It is expected that, in time, these powers will enable greater support for the further development of distributed generation. For example, in marine energy, greater consenting powers could complement a Welsh National Marine Plan[11] that strongly favours marine energy development. However, it is not expected that Wales will have its own Levy Control Framework and therefore issues surrounding subsidies will remain the same in Wales as the rest of the UK.

The Wales Bill also aims to streamline the consenting regime for energy projects, proposing a one-stop shop for developers by aligning associated consents with the consents for the main project, so when the Welsh Government makes a decision on a new energy project, it will also be responsible for consenting the new substations, access roads and overhead power lines relating to that project.

How in practice these powers will be implemented and the impact they will have and when is hard to predict, but the key issue for this work is that Wales could, if minded to, create a joined up strategy and delivery plan under local control, and that it has many more levers to 'affect change' than are available to English regions.

The National Assembly for Wales's Environment and Sustainability Committee, produced a report in March 2016[12] reinforcing both the moral case for reducing Wales's carbon emissions and the commitment to legally-binding emissions reduction targets. It highlighted that Wales's only chance of meeting this target is to transform the way it thinks about energy: its generation, distribution, storage and conservation. It also made it clear that there is much that can be done now within the existing devolution settlement, which could lead Wales towards a lower carbon energy future.

In addition to the national devolution agenda, local devolution also has a significant role to play. The city deal for Swansea features significant aspirations for distributed generation, putting forward the concept of the 'Internet of Energy', with the aim of establishing Swansea Bay as a low carbon economy and international centre for renewable energy production and conservation.

---

[11] http://gov.wales/topics/environmentcountryside/marineandfisheries/marine-planning/welsh-national-marine-plan/?lang=en

[12] http://www.assembly.wales/laid%20documents/cr-ld10610/cr-ld10610-e.pdf

We have tested the appetite for a number of the measures outlined above through consultation with Welsh stakeholders and have considered their potential impact in the growth scenarios for South Wales.

For example recommendations in the Environment and Sustainability Committee report include:

- A clear vision for Wales' future energy policy, including a central role for local energy and linking this up with the Wales Infrastructure Investment Plan.
- Annual targets to reduce demand for energy, with national carbon emissions and demand reduction targets becoming local duties delivered through the framework set by the Well-being of Future Generations Act.[13]
- The ambition to meet all of Wales' energy needs from renewable sources and, in the context of the need to reduce carbon emissions by at least 80% by 2050, setting a target date for achieving this.
- Urgently revising Building Regulations to ensure that all new houses are built to 'near zero' energy standards, and on completion of a successful trial of SOLCER type homes[14] at scale, moving to extending energy efficiency requirements for new homes beyond 'near zero' carbon to a level of efficiency where surplus energy is produced.
- Upscaling and extending the Welsh Government's existing retrofitting schemes – NEST and Arbed, adopting a 'warm zones' model to ensure a joined-up approach to delivery in areas where badly insulated housing, fuel poverty and poor health coincide.
- Linking the cost of stamp duty land tax to the energy performance of a house to start to increase the value of energy efficient homes.
- Setting up an umbrella not-for-profit energy service company for local authorities, city regions or communities to offer energy supply locally.
- Providing, attracting and facilitating financial, technical and research support for energy storage, as part of the wider priority to be given to local energy supply.
- Amending planning policy so that it prioritises local and community renewable energy projects and requires the carbon impact of new developments to be a key factor in planning decisions.
- Delivering previous recommendations about streamlining planning and permitting processes in full.
- Establishing loan schemes and support for local and community energy.
- Urging the UK Government to enable Ofgem to allow prioritisation of local supply to local users in Wales.
- Wales having a much greater say over how Distribution Network Operators operate.

---

[13] http://gov.wales/topics/people-and-communities/people/future-generations-act/?lang=en

[14] http://www.specific.eu.com/blog/view/11

3 Distributed generation and demand technology scenarios – objectives, method and results overview

3.1 Objectives and output

The overall objective of this distributed generation and demand growth scenarios assessment is to assess the potential for deployment of distributed generation and new electricity demanding energy technologies in the WPD South Wales licence area from 2016 to 2030, using as a starting point, the Future Energy Scenarios (FES) developed by the National Grid.

The output of the assessment is a dataset accompanied by this analytical report, which gives an annual capacity growth projection from 2016-2030 by Electricity Supply Area (ESA) area, technology type and scenario, including:

- Current (2016) distributed generation capacity connected
- Pipeline analysis of distributed generation capacity (up to 2020 where possible)
- Scenario analysis of distributed generation technology capacity growth from 2020 – 2030, building on the FES
- Scenario analysis of potential future demand resulting from heat pumps and electric vehicles from 2016-2030, building on the FES

Where appropriate, GIS based maps have also been provided to illustrate the spatial distribution of technology deployment growth.

3.2 Assessment scope

3.2.1 Definition of distributed generation

For the purpose of this assessment, the definition of distributed generation is all electricity generating projects connected to WPD's South Wales licence area distribution network. We have also analysed projects connected to or that would connect to SP Manweb ESA due to the impact that this area has on the South Wales network.

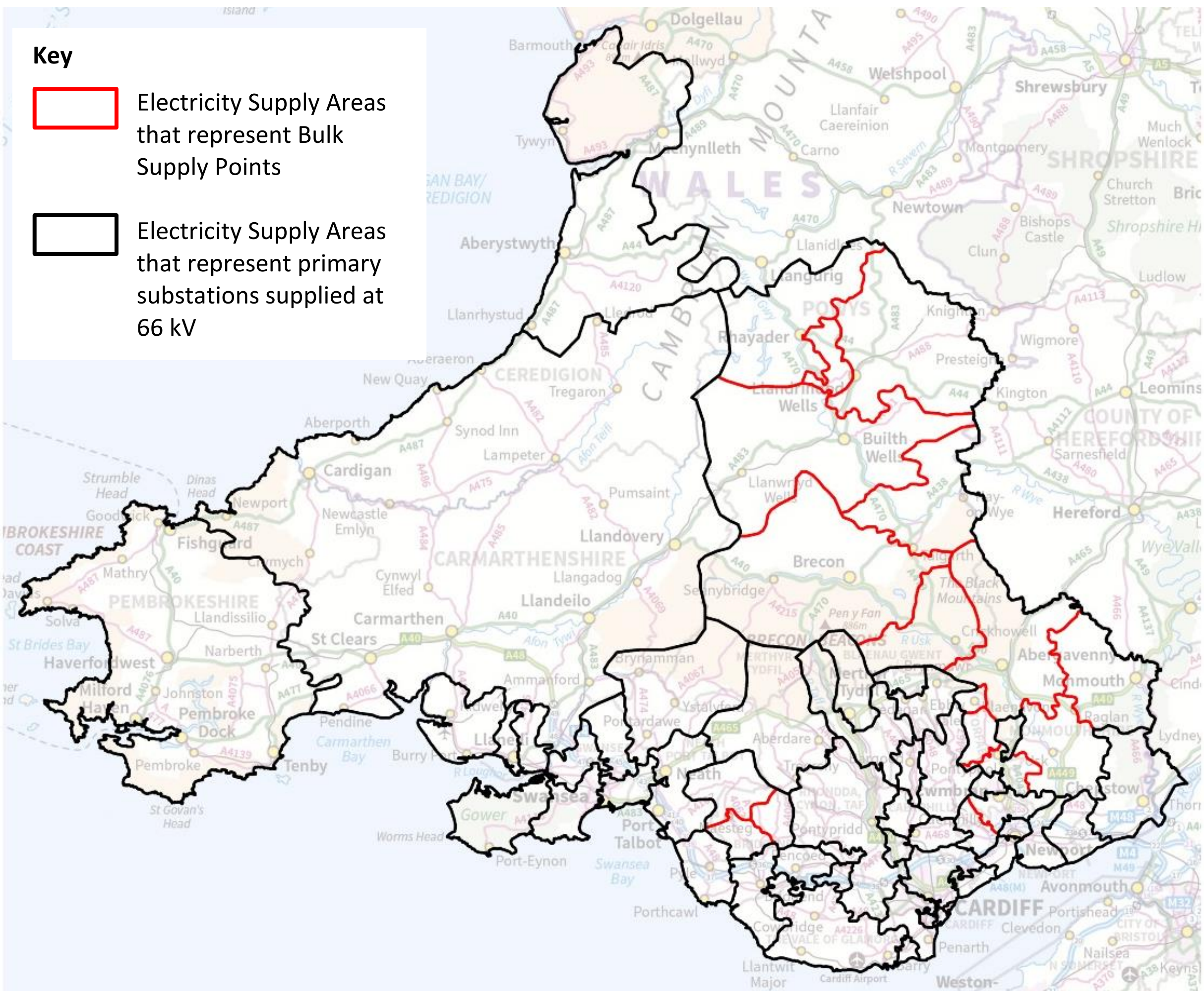
The impact from the growth of other types of large scale generation such as large scale biomass CHP, gas powered turbines, nuclear, tidal lagoons and offshore wind farms connecting directly to National Grid electricity transmission owned assets will need to be assessed on an individual basis.

3.2.2 Geographic scope and ESA mapping

The assessment scope is the WPD South Wales licence area, but the methodology applied can and has been applied to other licence areas[15].

The methodology is intended to support potential strategic network investment to the 132 and 66 kV networks in the South Wales licence area, by analysing growth of renewables in their geographic supply areas. The 66 kV supply areas are included in the study since they serve a similar purpose to both the 33 kV and 132 kV networks, and commonly serve large geographic areas.

ESAs within the South Wales licence area



Therefore, the methodology is intended to support analysis at the Bulk Supply Point level for the 132 kV network, and Primary Substations Areas for the 66 kV network. As a result, the methodology breaks

[15] https://www.westernpower.co.uk/docs/About-us/Our-business/Our-network/Strategic-network-investment/WPD-Regen-DG-Growth-Scenario-Report-RevisionA.aspx

the analysis down to 60 Electricity Supply Areas (ESAs), a general term this report uses to describe the geographic areas analysed in the study.

The ESAs have been created by mapping data on individual substations and the Bulk Supply Point/ Primary Substation Area that they are attributed to. Areas are then formulated around these through GIS mapping and discussions with WPD, shown in the map above.

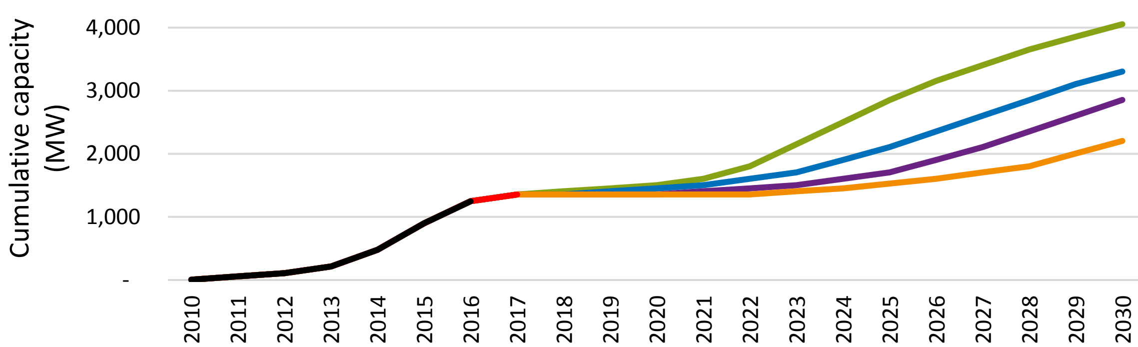
3.3 Summary of methodology

The methodology to assess potential distributed generation and demand growth for each technology is broken down into three phases. For most technologies, the growth assessment has been split into three distinct pieces of analysis:

Stage 1
Current baseline

Stage 2
Pipeline projection
Near term
(where possible to 2020)

Stage 3
Growth scenarios
Longer term (to 2030)



Current baseline
WPD's connection data and Regen's extensive renewables project database

Pipeline projection (to 2017/2020)
Analysis of current projects in the planning system and which have accepted Connection Offers from WPD for large scale technologies.

Growth scenarios (to 2030) Growth scenarios based on National Grid's FES - applied at a local level.
Gone Green
Consumer Power
Slow Progression
No Progression

- **A baseline assessment** – taken as of end March 2016 – which has a high degree of accuracy based on WPD's network connection database, reconciled with Regen SW's project database.
- **A pipeline assessment** – looking out to either 2017 or 2020 – which has a reasonable degree of accuracy since it is based on a good understanding of the current project pipeline, current

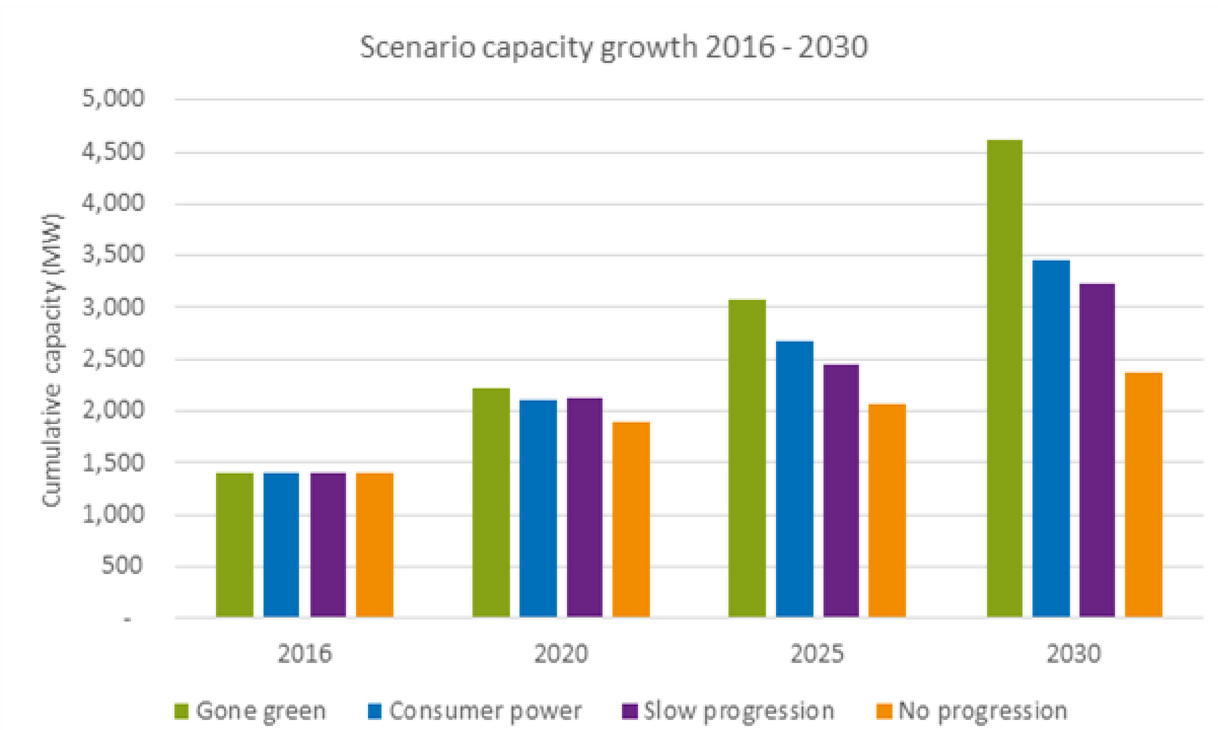
market conditions including the policy changes that have been introduced since the June 2015 election, and reconciled with the DECC planning database and WPD's database of Accepted-not-yet-Connected generators.

- **A scenario projection** – out to 2030 – which is based on the FES scenarios, assessed and interpreted to take into consideration the specific local resources, constraints and opportunities for each technology type in the South Wales licence area.

3.4 Summary of results

The summary results of the distributed generation scenarios are shown in the tables below and show a growth from a current (March 2016) renewable energy baseline capacity of circa 1.4 GW to circa 4.6 GW by 2030 under the most ambitious Gone Green scenario. Growth estimates for the other scenarios, Consumer Power, Slow Progression and No Progression are lower overall. However, even under the lowest No Progression scenario, there is an expected growth pathway to 2.4 GW of distributed renewable generation capacity by 2030.

Distributed renewable generation capacity growth by scenario in the South Wales licence area



Distributed generation capacity growth by technology type (MW) – 2016 to 2030

Technology (MW)	Scenario	2016	2020	2025	2030
Anaerobic digestion	Gone green	2.5	6.1	19.8	39.0
	Consumer power	2.5	5.4	9.0	14.0
	Slow progression	2.5	5.5	11.5	19.0
	No progression	2.5	4.3	5.6	8.0
Energy from waste	Gone green	31.4	50.2	70.2	70.2
	Consumer power	31.4	50.2	50.2	65.2
	Slow progression	31.4	50.2	70.2	70.2
	No progression	31.4	50.2	50.2	50.2
Hydro	Gone green	69.3	73.9	80.0	87.0
	Consumer power	69.3	73.9	74.8	75.8
	Slow progression	69.3	72.1	72.3	72.8
	No progression	69.3	72.1	72.6	72.9
Onshore wind	Gone green	412.9	720.4	825.9	1,303.2
	Consumer power	412.9	620.8	710.8	820.8
	Slow progression	412.9	678.0	748.4	898.0
	No progression	412.9	477.4	494.3	530.4
Solar PV (ground mounted)	Gone green	377.8	793.8	1,245.8	1,941.8
	Consumer power	377.8	657.3	983.8	1,388.8
	Slow progression	377.8	648.3	778.3	1,239.8
	No progression	377.8	634.8	742.8	889.8
Solar PV (rooftop)	Gone green	148.7	192.2	424.2	684.7
	Consumer power	148.7	192.1	371.4	611.6
	Slow progression	148.7	166.1	247.8	393.0
	No progression	148.7	166.1	197.7	288.6
Tidal stream	Gone green	0.4	1.2	30.0	50.0
	Consumer power	0.4	1.2	10.0	10.0
	Slow progression	0.4	1.2	10.0	10.0
	No progression	0.4	1.2	2.0	10.0
Wave	Gone green	-	2.0	30.0	100.0
	Consumer power	-	1.0	15.0	30.0
	Slow progression	-	-	15.0	30.0
	No progression	-	-	5.0	20.0
Other generation	Gone green	526.8	595.8	595.8	595.8
	Consumer power	526.8	595.8	595.8	595.8
	Slow progression	526.8	595.8	595.8	595.8
	No progression	526.8	595.8	595.8	595.8
STOR	Gone green	154.7	279.1	279.1	279.1
	Consumer power	154.7	279.1	279.1	279.1
	Slow progression	154.7	279.1	279.1	279.1
	No progression	154.7	279.1	279.1	279.1
Total	Gone green	1,724.5	2,476.8	3,099.9	3,891.1
	Consumer power	1,724.5	2,714.7	3,600.8	5,150.8
	Slow progression	1,724.5	2,281.0	2,445.1	2,744.8
	No progression	1,724.5	2,496.3	2,828.4	3,607.7

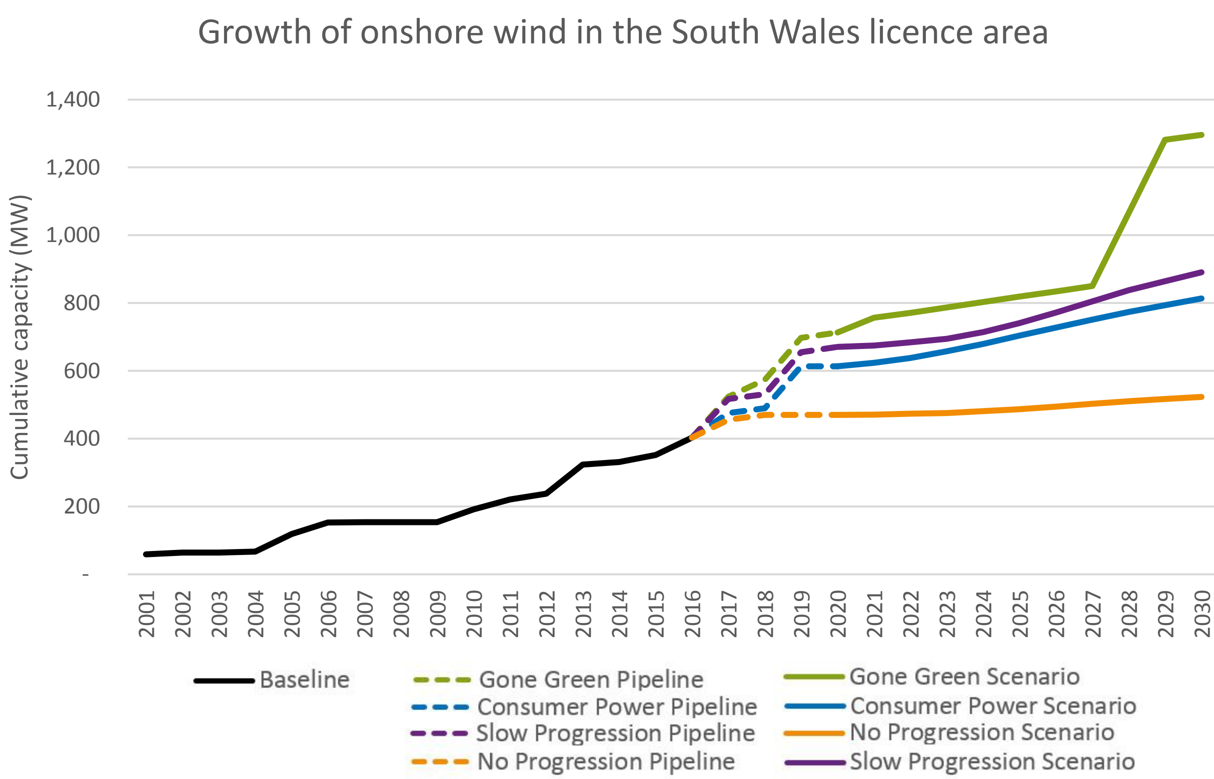
Storage, heat pumps and electric vehicles growth summary

Technology	Scenario	2016	2020	2025	2030
Commercial storage (MW)	Gone green	-	30.0	100.0	300.0
	Consumer power	-	50.0	200.0	400.0
	Slow progression	-	10.0	30.0	100.0
	No progression	-	-	10.0	20.0
Electric vehicles (peak MW)	Gone green	0.9	9.3	40.1	116.8
	Consumer power	0.9	7.0	30.1	80.7
	Slow progression	0.9	4.3	15.2	37.2
	No progression	0.9	3.7	12.5	29.6
Electric vehicles (numbers)	Gone green	1,069	13,051	67,564	192,419
	Consumer power	1,069	8,770	38,050	101,263
	Slow progression	1,069	5,485	21,177	54,254
	No progression	1,069	4,483	14,631	34,423
Heat pumps (electrical MW)	Gone green	8.2	19.1	97.1	202.0
	Consumer power	8.2	15.9	48.7	111.4
	Slow progression	8.2	14.5	61.4	139.3
	No progression	8.2	10.9	19.0	32.4
Heat pumps (numbers)	Gone green	1,928	5,480	32,469	74,631
	Consumer power	1,928	4,440	15,768	39,842
	Slow progression	1,928	3,680	16,699	38,343
	No progression	1,928	2,673	4,947	8,648
Own use storage (MW)	Gone green	-	6.7	33.9	58.0
	Consumer power	-	8.5	35.9	64.3
	Slow progression	-	4.4	17.9	33.4
	No progression	-	2.1	5.9	15.7

4 Analysis and results - onshore wind technology growth scenarios

4.1 Summary onshore wind growth scenario 2016-2030

This section of the report covers the future distributed generation scenarios for onshore wind in the WPD South Wales licence area to 2030. The future energy potential for different scales of wind turbines was considered, and a summary of the total growth can be seen below.



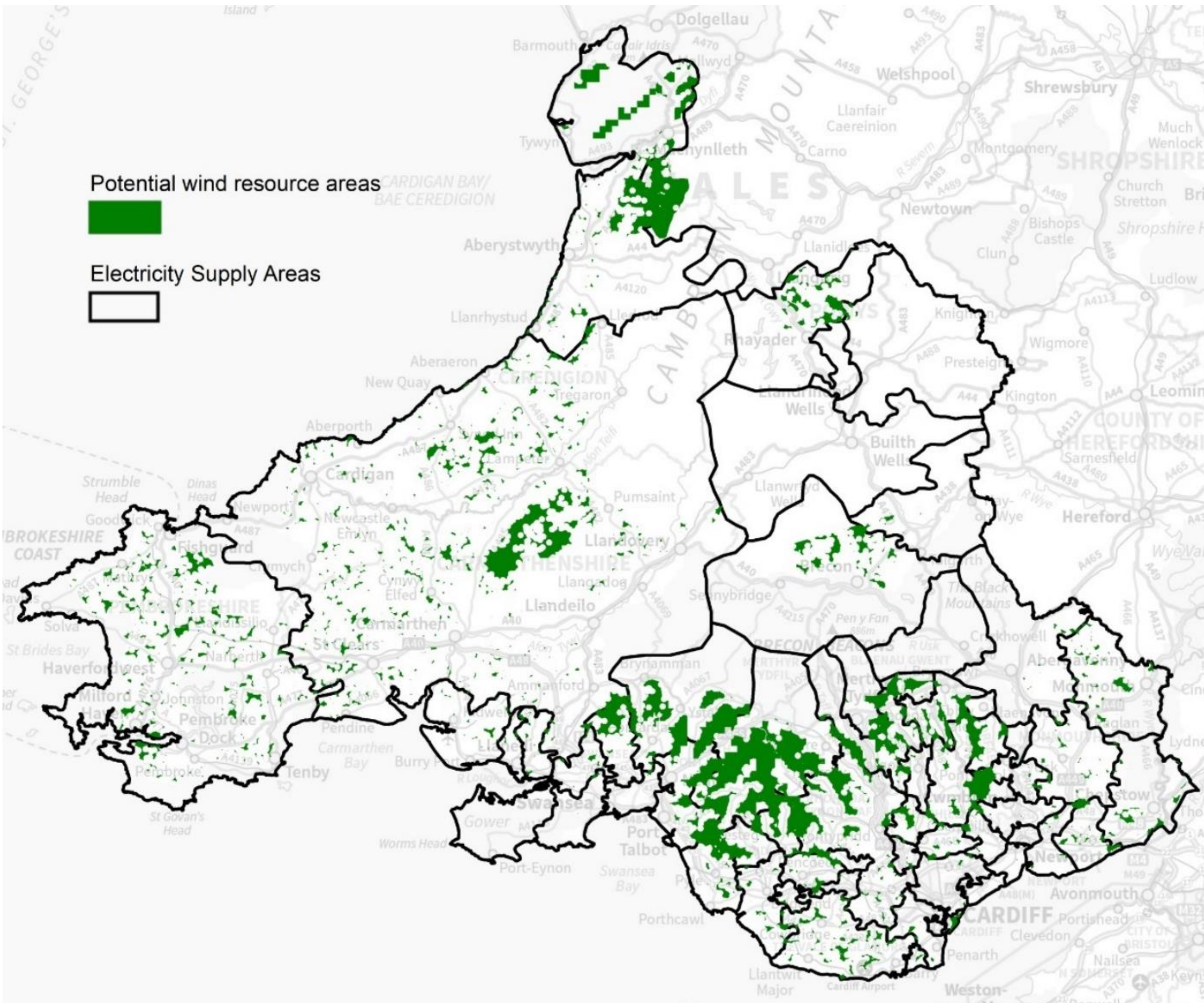
Baseline, pipeline and scenario capacity summary for distribution connected onshore wind

Scenario	2016 baseline (MW)	2020 pipeline (MW)	2020 to 2030 projection (MW)	Total (MW)
Gone green	413	310	580	1,303
Consumer power	413	211	197	821
Slow progression	413	268	217	898
No progression	413	67	50	530

4.2 Onshore wind – future energy potential

The GIS map below identifies potential onshore wind development areas by ESA based on the available resource and technical constraints to development.

Potential wind development areas within the WPD South Wales licence area



The analysis shows that there are hundreds of potential onshore wind development zones, shown as green areas on the map, all of different sizes with their own individual features. These range in size from small single site zones of hundreds of metres squared, to zones of over a hundred kilometres squared, which could accommodate larger wind farms or multiple smaller wind farms.

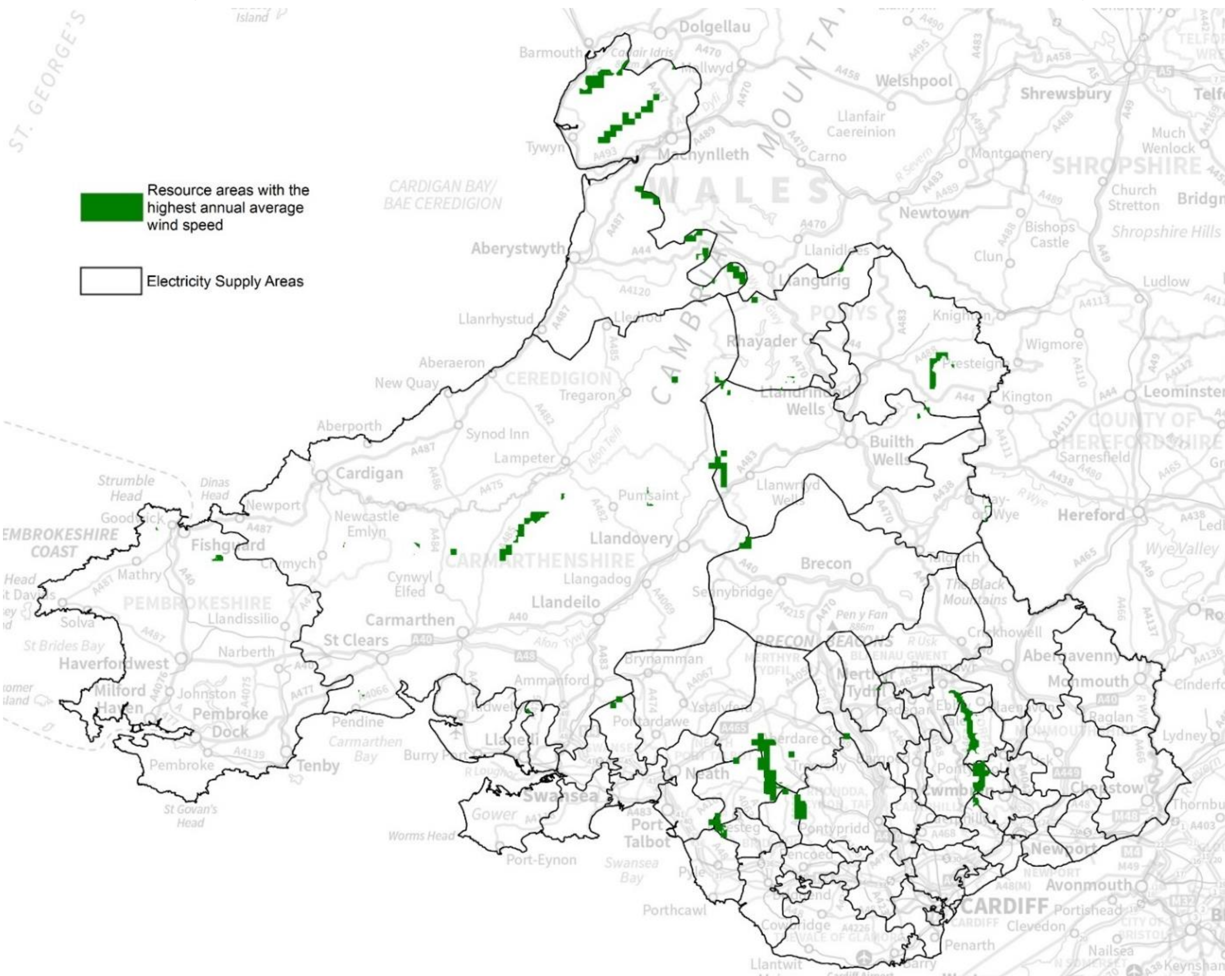
Given the constraints applied, the total developable area in the South Wales licence area is 1000 km², which represents 8 percent of the total land space.

If fully developed, the developable areas in the South Wales licence area could theoretically host an onshore capacity of eight to ten gigawatts. However, as the analysis in this chapter shows, under no future scenario is the South Wales licence area expected to reach this theoretical capacity.

Developable zones are highly concentrated in those ESAs that have a combination of high wind resource and access to the electricity network. For this analysis, the windiest areas have been identified as the most attractive areas to be developed, as identified on the map below.

The ten ESAs with the greatest wind resource account for 85 percent of the developable land space in South Wales. These areas are closely aligned to the Strategic Search Areas (SSAs) for wind energy identified in Technical Advice Notice 8 (TAN 8)[16], Planning for Renewable Energy (2005).

Most desirable potential resource areas in the South Wales licence area based on wind speed



---

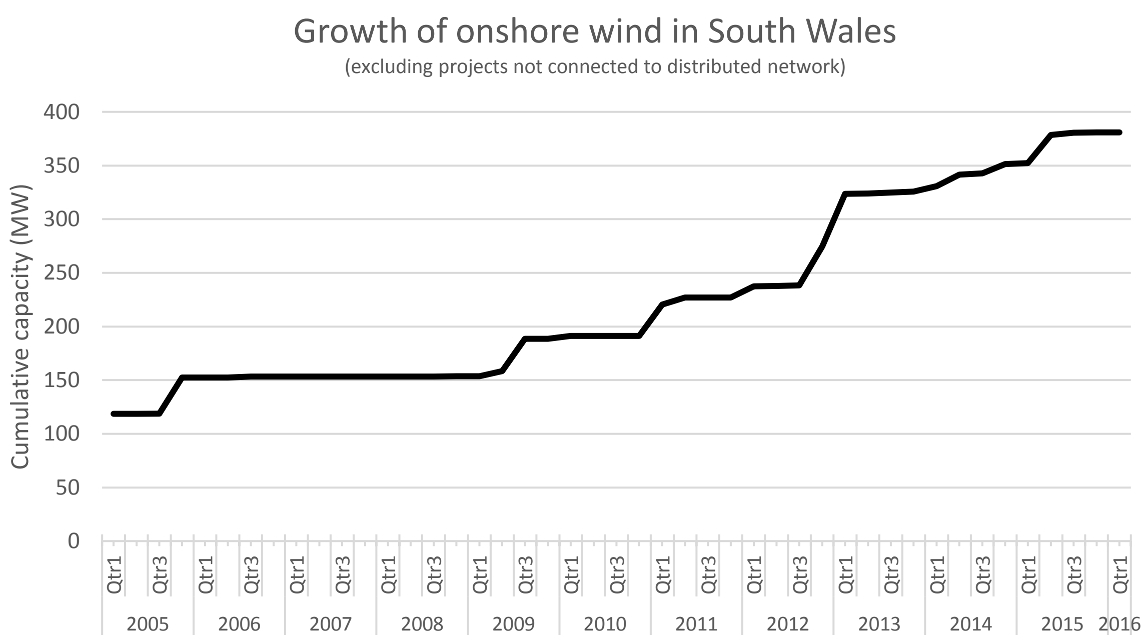
[16] http://gov.wales/topics/planning/policy/tans/tan8/?lang=en

4.3 Historic growth and baseline capacity

Despite being one of the few regions in the UK to host Strategic Search Areas for the development of commercial wind energy, the development of onshore wind in the South Wales licence area has been variable. The WPD South Wales study area currently has 410 MW of installed capacity, representing less than 15 percent of the England and Wales installed capacity. See table below.

UK comparison figures as of October 2015	Wind energy capacity including that connected directly to the National Grid
Total UK onshore wind installed capacity	Approximately 8.5 GW
England and Wales installed capacity	Approximately 2.9 GW
WPD South Wales area installed capacity	Approximately 410 MW

Trends in the growth of onshore wind in the South Wales licence area from 2005 - 2016

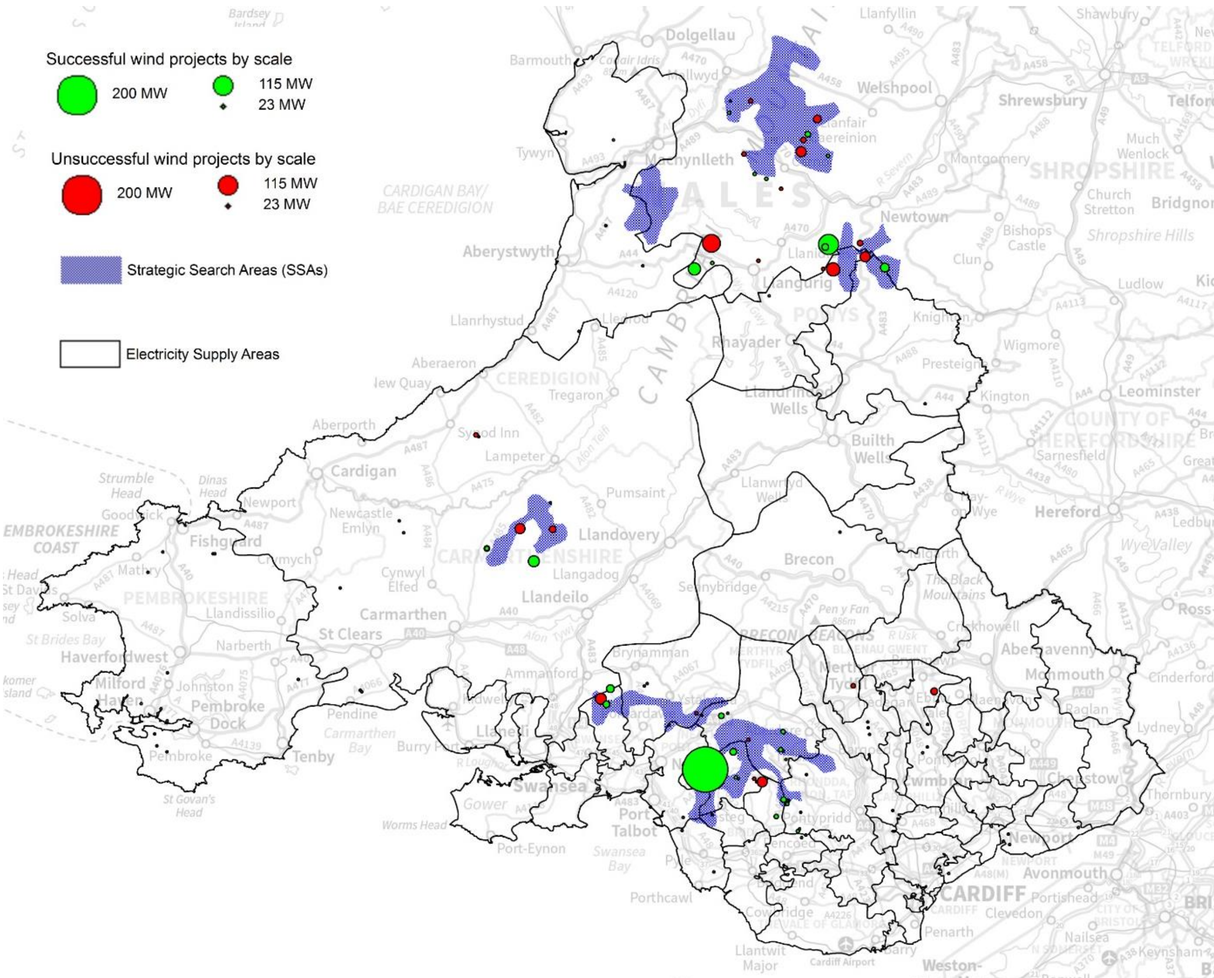


To create the baseline assessment, WPD project data was validated and cross referenced against DECC's Renewable Energy Planning Database, the Renewables Obligation database, the low carbon energy generation in Wales dataset that Regen produced for the Welsh Government, and through online research and stakeholder engagement; as projects in the datasets can be missing, incorrectly listed or listed with incorrect installed capacities. Many smaller wind projects were not in WPD's data sets, so these were added from DECC's Feed in Tariff database.

The map below shows the location of larger onshore wind projects that have been successfully built (green) and those that have been rejected or withdrawn in the planning process (red). The map demonstrates the policy led trend, where developers have concentrated on sites in Strategic Search

Areas within the region, where there is a good wind resource and a favourable policy environment provided by TAN 8[17]. This policy drive has created pressure on the distribution network, which is now inhibiting further development of these areas.

Successful and unsuccessful wind projects at planning in the South Wales licence area (May 2016)



Through TAN 8, the Welsh Assembly Government set a target of 4 TWh of renewable energy by 2010 and 7 TWh by 2020. The Welsh Assembly Government proposed in TAN 8 that 800 MW of this power requirement would come from onshore turbines in the form of strategic large-scale developments (over 25 MW).

[17] http://gov.wales/topics/planning/policy/tans/tan8/?lang=en

SSAs are characterised as displaying the following characteristics:

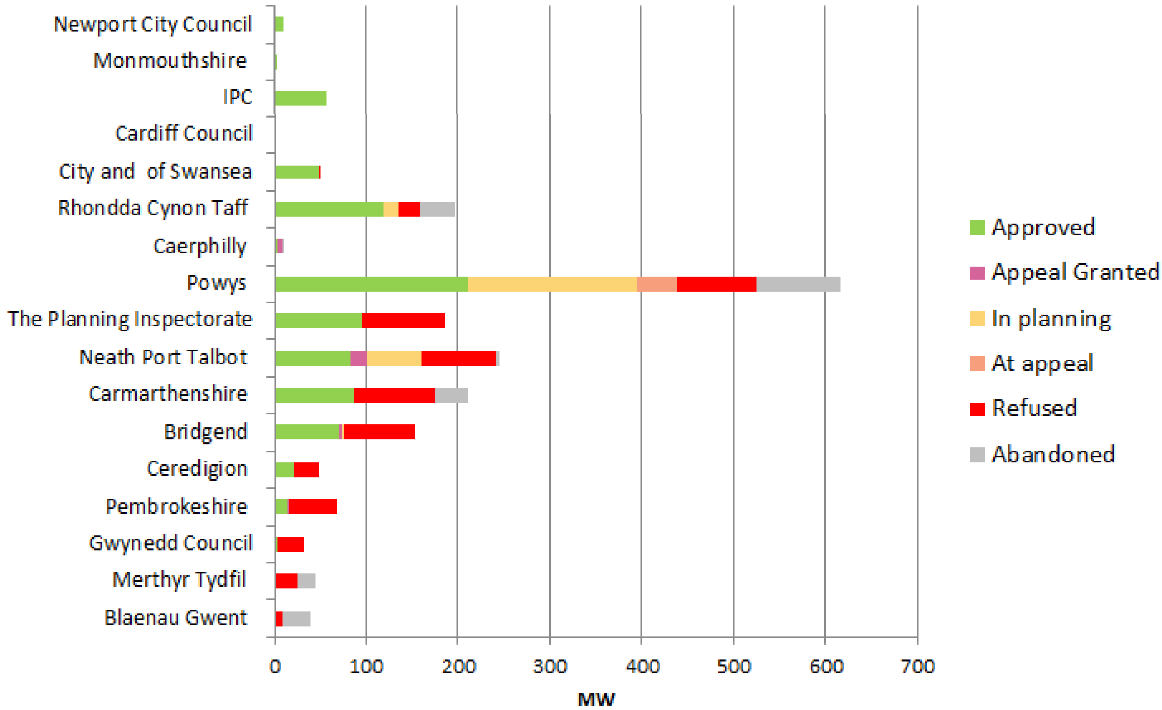
- extensive areas with a good wind resource (typically in excess of 7 m/s)
- upland areas (typically over 300 m above ordnance datum) which contain a dominant landform that is flat (plateau) rather than a series of ridges
- generally, a sparsely populated
- dominated by conifer plantation and/or improved/impoverished moorland
- has a general absence of nature conservation or historic landscape designations
- of sufficient area to accommodate developments over 25MW, to achieve at least 70MW installed capacity and to meet the target capacity
- largely unaffected by broadcast transmission, radar, MoD Mid Wales Tactical Training Area (TTA) and other constraints.

TAN 8[18] has created a unique planning policy environment for Wales, which clearly directs large wind developments to Strategic Search Areas, with C, D E, F, and G falling within the South Wales licence area. TAN 8 also serves to limit the proliferation of wind energy above 5MW outside these areas, creating an unfavourable policy environment for medium scale wind energy development outside SSAs in Wales. Please see the text box below for further details. In practice the majority of local authorities in the South Wales licence area have adopted this Welsh national planning policy quite literally; with policy encouragement for only small scale wind, under 5MW, with some limiting favour to community owned or direct wire projects.

TAN 8 states that most areas outside SSAs should remain free of large wind power schemes. It suggests that 'local planning authorities may wish to consider the cumulative impact of small schemes in areas outside of the SSAs and establish suitable criteria for separation distances from each other and from the perimeter of existing wind power schemes or the SSAs, stating in these areas, there is a balance to be struck between the desirability of renewable energy and landscape protection.' It goes on to state that 'whilst that balance should not result in severe restriction on the development of wind power capacity, there is a case for avoiding a situation where wind turbines are spread across the whole of a county. As a result, it states the Assembly Government would support local planning authorities in introducing local policies in their development plans that restrict almost all wind energy developments larger than 5MW, to within SSAs and urban/industrial brownfield sites. It is acceptable in such circumstances that planning permission for developments over 5MW outside SSAs and urban/industrial brownfield sites may be refused', although there is recognition that 'there may be further opportunities for the development of wind farm or other renewable energy schemes on urban/industrial brownfield sites up to 25MW within Wales' and these should be encouraged.

[18] http://gov.wales/topics/planning/policy/tans/tan8/?lang=en

Graphs showing the planning status of onshore wind farms in the South Wales licence area by MW and percentage in 2016



Pipeline projection to 2020

Based on an analysis of WPD's connection agreement data, the DECC RE planning database, the current market conditions in Wales and discussions with developers, it is expected that up to 310 MW of onshore wind could be added to WPD's network by 2020. The following developers have been contacted regarding their work in South Wales:

- RWE Innogy UK
- Pennant Walters
- RES
- Infinis
- REG
- Cenin Renewables
- Vattenfall
- Scottish Power
- Grid Connection Consulting
- Llynfi Afan Renewable Energy Park

As well as knowing which projects are likely to be built, an estimate as to when they will commission has also been included in the analysis. The build out of most pipeline projects is expected to take place before March 2017, when the grace period for schemes supported under the RO scheme expires.

A post-election assessment of the policy environment for wind energy in Wales has been undertaken. From a financial perspective, owing to the curtailment of ROs and the assumption that the UK Government will continue to heavily restrict access to Contracts for Difference (CfD) for onshore wind, we have assumed that there are unlikely to be any new projects built that do not already have an Accepted-not-yet-Connected network offer. The pipeline for wind energy to 2020 has been broken into scenarios because of the level of uncertainty regarding the ability of projects to reach commissioning.

Projects that are known to be connecting to the National Grid have been excluded from the pipeline.

The Gone Green pipeline totals 310 MW, and includes:

- all projects with an Accepted-not-yet-Connected offer, including those without a subsidy agreement in place, without planning and those at appeal, as this scenario assumes a favourable economic and policy environment.

The Consumer Power pipeline totals 211 MW, and includes:

- all projects that are Accepted-not-yet-Connected, except those without planning permission.
- This scenario only assumes a favourable economic environment

The Slow Progression pipeline totals 268 MW, and includes:

- wind farms that have planning permission and are awaiting network connection in SSAs or high resource areas

- schemes that are at planning appeal with network connection secured.
- This scenario assumes a favourable policy environment but a more challenging economic environment

The No Progression pipeline totals 67 MW, and includes only those wind farms that:

- are already under construction
- have both planning permission and network connection agreement, subsidy agreements and/or are discharging planning conditions, as this scenario assumes an unfavourable policy and economic environment.

4.4 Scenario growth analysis 2020-2030

4.4.1 Overall onshore wind distributed generation growth by scenario

Beyond the immediate pipeline, the potential for onshore wind development in South Wales looks much more promising than in some English regions, with large scale, subsidy-free wind energy a real possibility, which is reflected in the scenario analysis.

Based on the anticipated scenario factors described below, the overall distributed generation growth for onshore wind by scenario is shown in the table below.

Scenario	Baseline 2016	Pipeline 2016 to 2020			Scenario 2020 to 2030			Total 2030 capacity (MW)
		>25 (MW)	< 25 (MW)	Total (MW)	>25 (MW)	< 25 (MW)	Total (MW)	
Gone green	413	166	144	310	180	400	580	1,303
Consumer power	413	106	105	211	197	-	197	821
Slow progression	413	131	137	268	167	50	217	898
No progression	413	-	67	67	50	-	50	530

Across all scenarios, it is expected that onshore wind distributed generation growth will be strong in Wales compared to English regions due to the comparatively better policy environment.

The scenarios explore:

- Whether or not the strategic approach to development that has taken place to date through TAN 8 continues.
- How wind's cumulative impact on the network is managed.

- How further devolution may play out through a more plan led approach to planning under the Planning (Wales) Act 2015[19].
- The impact of potential City Deal investment[20].

The scenarios are described below:

- Gone Green is driven by an integrated, strategic Welsh Government policy on infrastructure, resulting in new strategic energy zones for development, backed by positive policies to support associated network infrastructure. Development would be focussed on over 25 MW and under 5 MW scales.
- In this scenario, it is assumed that a strategic infrastructure plan would be developed by the Welsh Government by 2019, taking an integrated approach and including energy, building on the previous TAN 8 policy. Strategic grid and network upgrades would be taken forward alongside planning applications for large scale wind development once the infrastructure plan was completed. Grid upgrades would take place by 2026 in new strategic energy zones allocated through this plan led approach, leading to large scale projects commissioning by 2028. Alongside this, it is assumed that there would be a significant amount of small scale wind energy outside the SSAs, driven by price parity and a positive economic climate for own use, local and community energy. Medium scale (5 to 25 MW) would continue to be restricted to brownfield sites, as access to the network for larger scale strategic projects is prioritised.
- Consumer Power is a market driven approach with policy direction devolved from the Welsh Government to local authorities. Development is therefore more dispersed and focused in the highest wind speed areas, at a scale where associated infrastructure investment is not prohibitive financially. There would be some deployment of 5 to 25 MW schemes and a high level of under 5 MW schemes.
- This scenario assumes no large scale wind development, as there would be no policy intervention to direct it and the associated infrastructure it would require. TAN 8 would be superseded and in its place, policies for small and medium scale wind energy would be devolved to local authorities to direct industry led applications. Through local policies, the devolved policy environment would, however, not be reinforced with any carrot or sticks to encourage approval of schemes. As such, only local authorities where a positive approach to planning for renewable energy has been demonstrated to date would see continued deployment, consisting of schemes around 25 MW in scale where the resources allow, as the TAN 8 requirement that restricts this scale of development would be removed. Small scale, on-site developments under 5MW would be more widespread, as private wire own use schemes would be economically viable and the policy environment would remain conducive to this type of development.

---

19 http://gov.wales/about/cabinet/cabinetstatements/2016-new/58437974/?lang=en

20 http://www.swanseabaycityregion.com/en/city-deal.htm

- Slow progression also sees policy direction devolution to local authorities, but backed by incentives and requirements to meet renewable energy targets. Development would be focussed on 5 – 25 MW schemes
- Under this scenario, responsibility for energy policy is still devolved to local authorities by the Welsh Government, but it is backed up by mandatory target setting and site allocations at a local level. However, there would be limited investment in infrastructure due to the economic climate. A positive planning environment would be upheld by the Welsh government, with TAN 8 being revised and the restriction on 5 to 25 MW schemes removed and replaced with progressive local policies. Local authorities would be required to allocate areas suitable for 5 to 25 MW wind energy projects and have a positive policy to support this. The Welsh Planning Inspectorate would be operating within a positive planning policy environment, so schemes would be approved at appeal if refused inappropriately locally. Parity would be achieved from 2019, as planning risk would be reduced in certain areas. Developments of up to 25 MW would already be at parity if planning were possible, as areas are accessible and technology costs have come down. Applications for 5 to 25 MW projects would go in from 2021 onwards, with developments commissioning from 2025. There would be little development over 25 MW in scale because there would be no strategic investment; however, a limited number of over 25 MW schemes would be enabled within the existing SSAs. There would be very little sub 5 MW due to a poor investment climate for this scale.
- No progression is a scenario where development remains constrained by the economic environment and is not supported by progressive local or government policies. There would be very little deployment at any scale.
- Under this scenario, a small amount of additional development is seen within the existing SSAs where it can be made economically viable. The current situation continues for medium scale wind energy, where there is no planning policy environment to support this scale of development, so there is a continuation of current deployment rates, plus a small uplift when they become economically viable in 2026. At the small scale, there continues to be no subsidy, but potentially the opportunity to use refurbished turbines would enable price parity to be achieved in some cases.

4.4.2 Scenario factors impacting future onshore wind growth in the South Wales licence area

FES Scenarios - Implications for onshore wind in the South Wales licence area	
Consumer Power • Medium growth scenario • No large scale development but a higher proportion of medium scale wind farms and single turbine projects – individual landowners, farmers and community groups • Wind cost parity in South Wales reached circa 2023-25 • Growth slightly higher than national FES growth scenario • Projects focused in high resources areas but relatively distributed across ESAs	**Gone Green** • Highest overall growth scenario • Both larger and small scale wind projects deployed • Strategic infrastructure led approach – new SSAs • Positive planning environment for distributed generation locally • Finance available • Wind cost parity reached imminently • High carbon price
No Progression • Lowest growth scenario • Poor planning and economic environment • Growth would be very slow with an increase post 2026 as costs reduce • Poor planning environment leads to long lead in times for any new projects to enter pipeline in the period to 2030, as majority of projects have to go through appeal process. • Growth would continue to be restricted by limited investment in infrastructure	**Slow Progression** • Medium growth scenario • Positive planning environment, devolved but with requirements locally • But poor economic and finance outlook, so strategic investment limited • Wind cost parity (South Wales) reached 2024/25 for best resource areas • Higher proportion of medium scale wind farms • Growth slightly less than UK FES • Projects focused in high resources areas in most attractive ESAs

4.5 Key growth drivers and constraints in the South Wales licence area to 2030

4.5.1 Planning constraints

The regime for obtaining planning consent for wind energy projects in Wales has recently undergone significant amendments through a variety of changes to legislation. It has now been devolved at almost all scales of development; significantly reducing the influence of Whitehall policy and politics.

Welsh local and national planning policy has yet to be updated to reflect these regulatory changes that came into force in March 2016. How this will play out is explored through the different scenarios.

Clause 79 of the UK Energy Bill 2016 changed the law to remove the need for the Secretary of State's consent for large onshore wind farms over 50 MW under the Electricity Act 1989. Instead, local authorities in England and Wales were made the primary decision-makers for planning applications for new onshore wind farms, including those with a capacity greater than 50 MW. This moved the consenting of new onshore wind farms under the Town and Country Planning Act 1990. Whilst in Wales, The Planning (Wales) Act 2015 makes provision to establish a new category of development called Developments of National Significance ("DNS"). This enables the planning applications for certain types of development to be made directly to the Welsh Ministers. The Regulations were laid on 3 December 2015 and came into force on 1 March 2016. The original regulations specified that energy generating projects which have an installed generating capacity of between 10 MW and 50 MW are to be captured as DNS, so an amendment was made following the implications under the Energy Bill 2016 to avoid the unusual situation whereby medium-large energy generation projects would be consented by the Welsh Ministers, while the smallest scale and the largest scale energy generation projects would be consented at the local level.

4.5.2 Financial and cost of energy environment

The UK government announced that it intends to end all subsidies for onshore wind. This will have an immediate impact on the project pipeline to 2020 unless the Welsh Government undertakes mitigation measures. However, it is not expected to have a significant impact beyond 2020, since the onshore wind industry is expected to reach price parity with other forms of low carbon energy and is expected to operate in a post subsidy environment. The future development of onshore wind is therefore most likely to be impacted by the timing in which parity is reached, electricity wholesale price and the underlying cost of carbon and operation of carbon pricing.

For large scale wind energy, the scenario analysis assumes:

- Gone Green and Consumer Power – price parity for large scale wind energy is achievable almost straight away, due to the potential scale of development which is achievable in Wales, and owing to reducing onshore wind costs, technical innovation, rising wholesale price driven by fossil fuels and/or the effective operation of a carbon price mechanism.

- Slow Progression – price parity is reached 2023/24 owing to falling onshore wind costs and operation of market carbon pricing mechanism.
- No Progression – price parity is barely reached by 2030 owing to low wholesale price due to lower economic growth, slow technology development and lower fossil fuel prices

4.6 Geographic distribution of onshore wind across ESAs

For the baseline analysis and pipeline forecast to 2020, the distribution of onshore wind distributed generation capacity by ESA has been achieved by mapping existing and planned projects. The onshore wind distributed generation growth scenarios datasets contain a breakdown of growth by ESA that represent a best estimate of the likely spread of onshore wind capacity; but the figures given are indicative only.

Under all scenarios, whether planning is centrally supported or devolved to local policy makers, development is expected to continue in areas with highest wind speeds and lowest population density, particularly in a post subsidy world. By contrast, ESAs with low wind resource and limited land space will continue to be difficult areas for windfarm development, although some private wire schemes and brownfield developments may come forward in suitable areas.

The factors that have been used to estimate the geographic spread of distributed generation growth by ESA include:

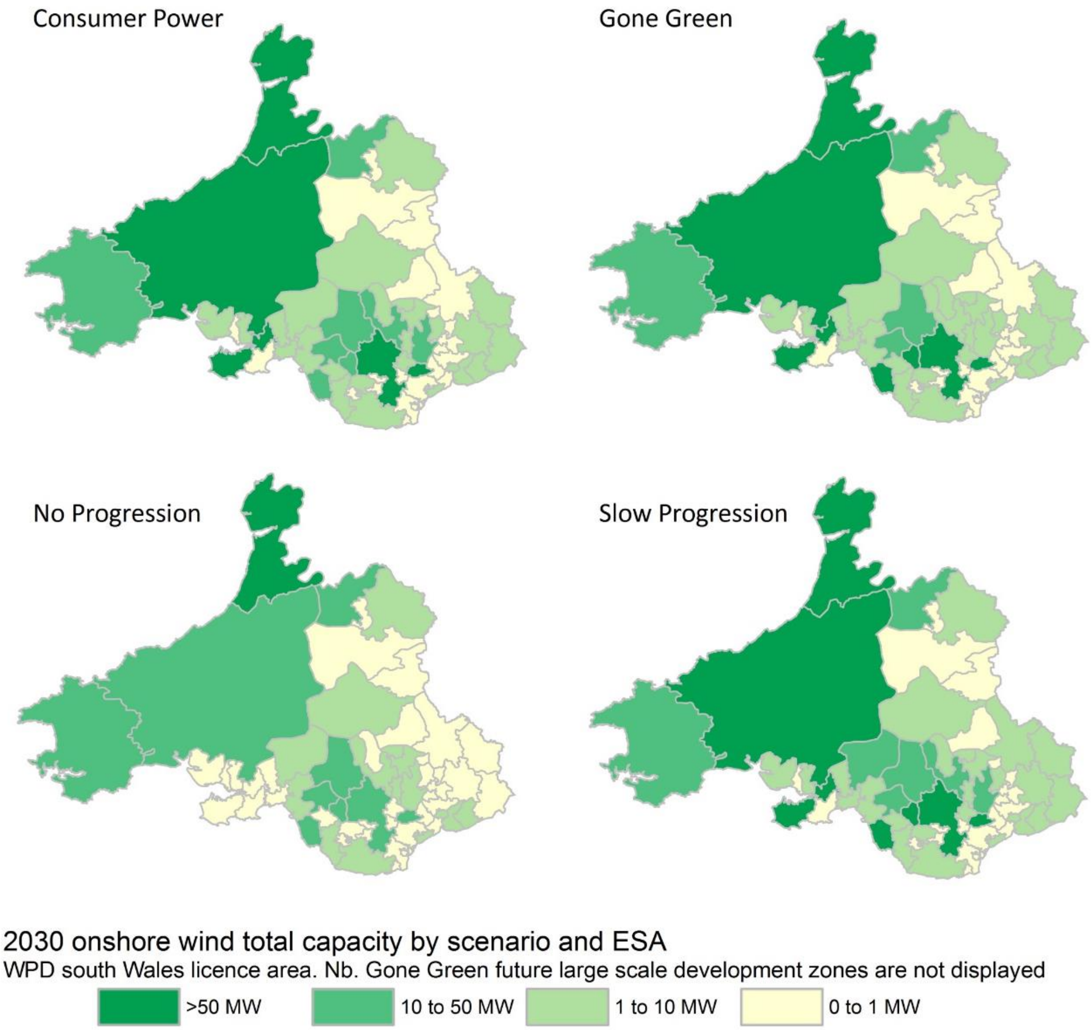
- Available developable land space, which includes factors such as wind resource, environmental designations and technical factors
- Historic wind deployment trends
- Cumulative impacts
- Planning environment
- A scenario based mix of larger scale v smaller scale wind

Key factors determining geographical distribution of wind development under each scenario:

- Under Gone Green, we have assumed that two new 200 MW onshore wind SSAs are created, centred on eastern Crumlin and in the northern area of the SP Manweb ESA. Deployment is focussed on these new SSAs, alongside build out in existing SSAs. Projects up to 5 MW are dispersed across the South Wales area, predominantly on the basis of wind resource. Planning policy is assumed to be positive across the area, so is not a determinant of development locations.
- Under Consumer Power, development of 5 to 25 MW projects is dispersed across the area, focussed on areas with high wind speeds and positive planning environments. There is also widespread deployment of sub-5 MW schemes, determined again by wind resource availability and the planning environment.
- Under Slow Progression, 5 to 25 MW projects would be dispersed across the area, determined predominantly by wind resource availability, due to a positive planning environment across the whole South Wales area.

- Under No Progression, low deployment is spread across the area, with a focus on areas with high wind speed and positive planning environments.

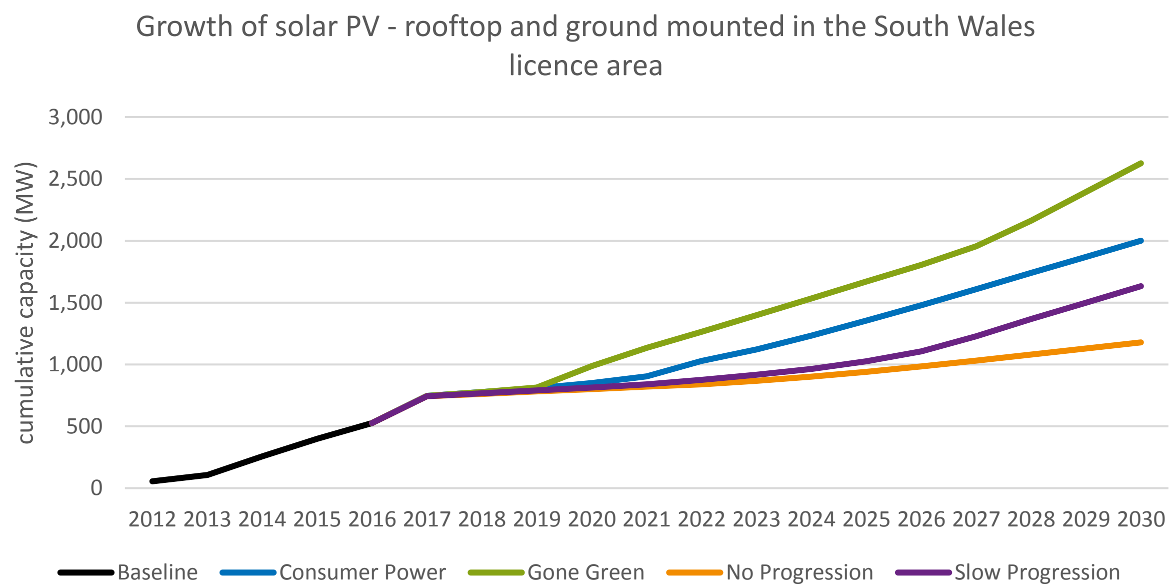
Geographic distribution of wind by ESA for each scenario



5 Analysis and results - solar PV technology growth scenarios

5.1 Summary distributed generation growth scenarios 2016-2030

This section of the report covers the future distributed generation scenarios for solar PV in the WPD South Wales licence area to 2030. Due to key differences in the technologies, the analysis for solar PV has been split into ground mounted PV and rooftop PV. A summary of the combined growth for solar PV can be seen below.



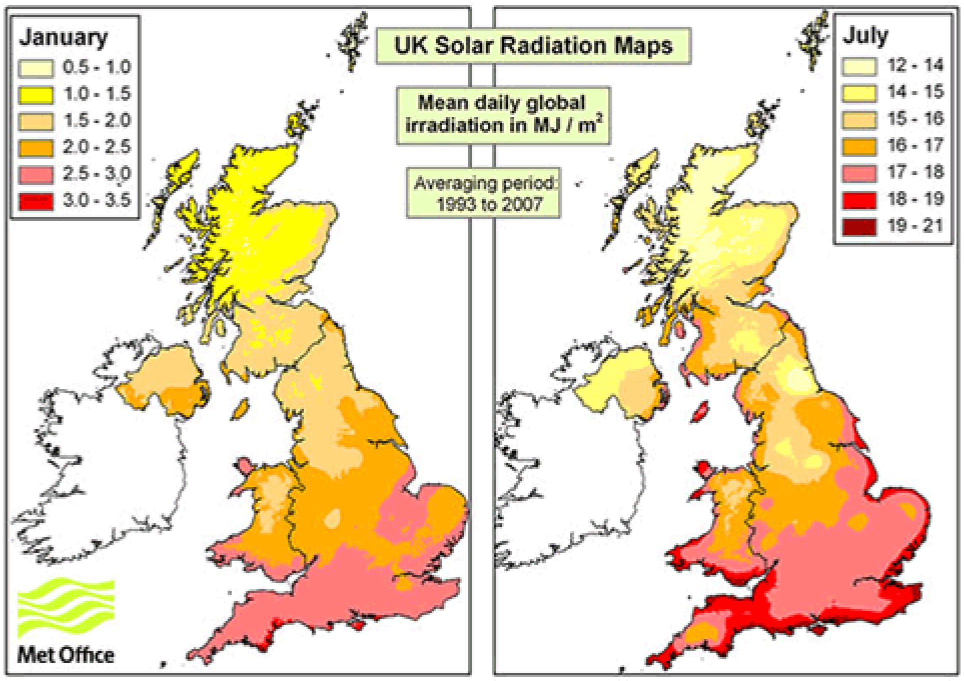
Baseline, pipeline and scenario capacity summary of ground-mounted and rooftop PV

Scenario	Baseline capacity 2016	Pipeline projection to 2017	Scenario forecast to 2030	Total (MW)
Gone green	526	219	1,881	2,626
Consumer power	526	219	1,255	2,000
Slow progression	520	216	890	1,633
No progression	520	216	436	1,178

5.2 Solar PV – future energy and growth potential

The solar irradiance map of the UK shows the coastline of South Wales as an attractive solar resource area of the UK. It is no surprise therefore that South Wales has seen significant deployment of both roof and ground mounted PV systems.

UK solar radiation map



This chapter contains an analysis of the South Wales license area by ESAs covering:

- The future energy potential of solar PV, both ground and roof mounted
- Historic growth and current (March 2016) baseline
- Pipeline projection of projects to 2017
- Scenario based growth forecasts to 2030

5.2.1 Developable ground mounted PV land space

Both ground mounted and roof mounted solar projects are technically viable across the South Wales licence area, but activity is predominantly south of the Brecon Beacons and to the far south west of the area due to higher irradiance, environmental considerations, and infrastructure availability. For ground mounted solar PV, the primary locational considerations are:

- Available land space – non-designated, brownfield or low grade agricultural land, flat/unshaded or south facing
- Access and proximity to the network at a reasonable connection cost

Additional considerations may include:

- Coastal areas and areas with higher average wind speeds, which have greater potential to cool the panels and therefore create slightly higher energy generation efficiency
- South facing land would be an advantage in terms of energy generation, however, from a visual impact consideration lower lying flat land, not shaded by trees but potentially 'nestled' into the landscape is more developable
- Ground mounted PV adjacent to major roads in rural areas is also attractive both from the perspective of vehicle access and also because these tend to correspond to lower grade agricultural areas, less sensitive landscapes and lower housing density. "A" roads for example, also tend to follow the major infrastructure/transport routes including the distribution network.
- Planning policy, guidance and local authority and community engagement

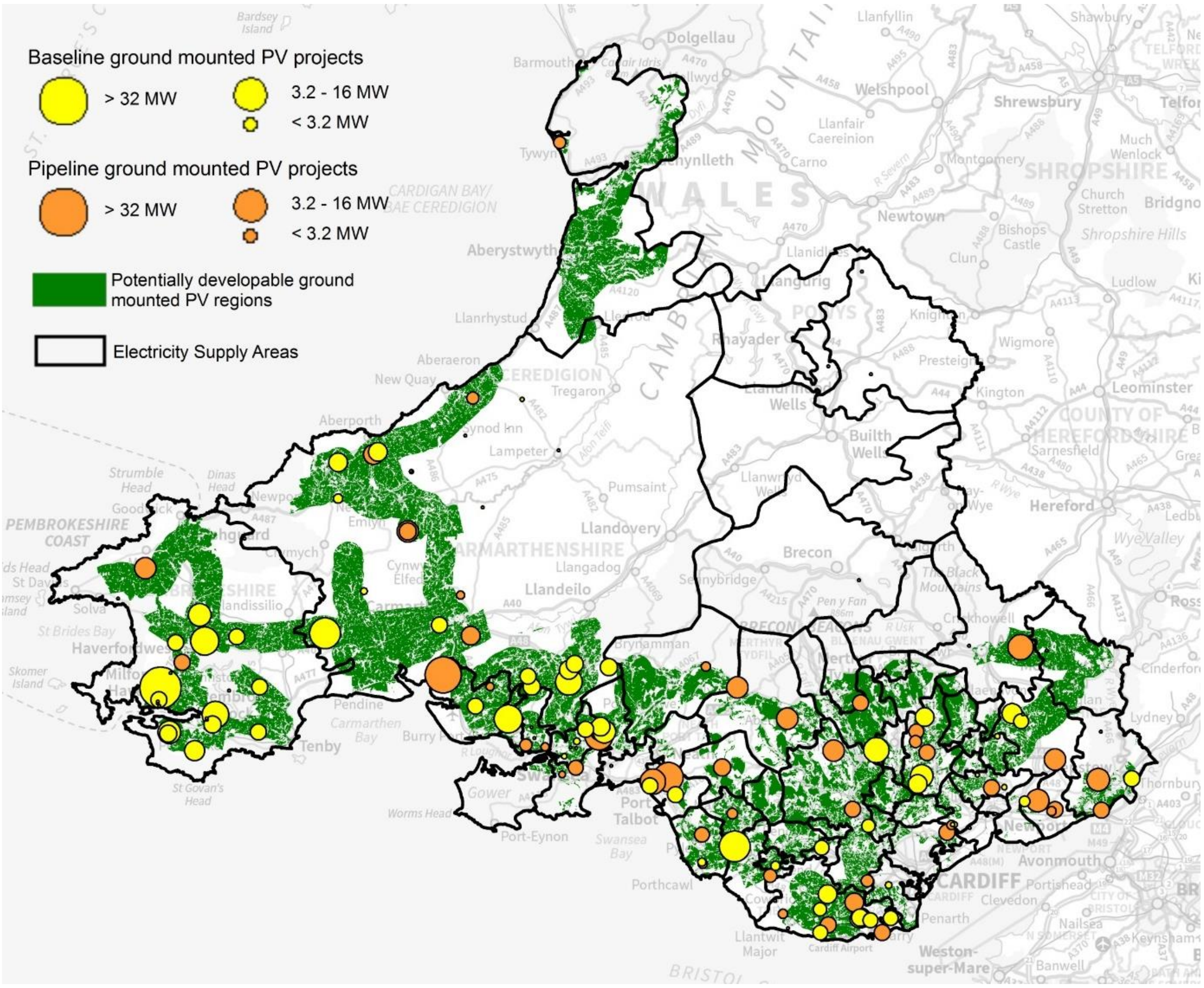
Given the widely available solar resource and the general availability of PV developable land space, the critical driver for the development of historic solar PV systems has been access to electricity network.

The importance of network availability is one reason why WPD has experienced a very high number of applications to connect to their network, as PV developers firstly try to secure an acceptable network connection before proceeding with a full planning application, raising finance and other project development activities.

The map showing "Ground mounted PV resource areas with baseline and pipeline projects" below shows an analysis of potential 'PV developable' resource areas based on excluding areas where solar PV is extremely unlikely to be built. The key constraints considered were:

- Designated land areas – National Parks, AONB, SAC, SPA, RAMSAR, SSSI, Heritage Coasts, local nature reserves, country parks, etc.
- Physical constraints – houses, roads, woodland, rivers, rural heathlands, water bodies, etc.
- Historic assets
- Agricultural land classification grade 3ba or above
- Within 25 m from residential properties
- Over 2.5 km distance from 33 kV (or higher) network as a proxy for network connection costs.

Ground mounted PV resource areas with baseline and pipeline projects



The occurrence of existing and proposed ground mounted PV farms, shown as yellow and orange dots, indicates a very strong correlation between the location of PV farms and the developable resource areas when a 2.5 km from 33 kV network proximity criteria is included. The PV farms that fall outside this network proximity criteria have typically found a sweet spot next to the 11 kV network.

The resource assessment above suggests that there could be over 600 km² of 'PV developable' land space within the WPD South Wales licence area, which could, in theory, host 25 to 30 GW of ground mounted solar. In reality, only 1.5 percent of the total developable resource area, has so far been developed. This is equivalent to less than 0.08 percent of the total land in the South Wales licence area.

5.2.2 Solar PV planning constraints

Unlike onshore wind, the deployment of solar PV has been less impacted by planning constraints. With planning lead times typically 6 months and a relatively high success rate (circa 84 per cent), developers have been able to bring forward PV schemes with some confidence of success where a network connection is viable.

Planning for renewables, including solar, under the Wales Act 2016-2017 is expected to become a devolved matter. However, TAN 8 remains the current national planning policy framework for all distributed renewable energy in Wales. With regards to solar, it states that other than in circumstances where visual impact is critically damaging to a listed building, ancient monument or a conservation area vista, proposals for appropriately designed solar thermal and PV systems should be supported.

Solar developments have been considered comparatively environmentally benign. However, cumulative impacts remain a particular concern. The Welsh Government, Practice Guidance: Planning implications of renewable and low carbon energy development, February 2011[21] set out how cumulative impacts should be considered. The guidance states that, proximity to the distribution network is a key factor affecting the economic viability of solar PV arrays. The need for sites to be located close to a suitable network connection means that proposals are likely to cluster around these network connection points. This makes it especially important that the sustainability effects of solar PV array proposals are considered not only in isolation, but also in terms of the potential cumulative effects, with similar proposals and other forms of development.

With the exception of one or two 'hot spots', the percentage of South Wales that has been given over to PV farms remains extremely low. Planning constraints to PV farms based on cumulative impacts are therefore likely to be localised and are unlikely to significantly affect the long term growth at an ESA or regional level.

We have experimented with two methods to assess which ESAs may need a reduction in their available resource due to cumulative impacts:

1. For each scenario, we have looked at the proportion of the area's land space that the scenario could see built out. We have capped deployment in areas where the scenarios create high concentrations of solar farms (over 3 percent), unless there is a good reason to support higher deployment in that area, e.g. co-location of solar and wind in an SSA, or high levels of existing capacity, or the land area is very small.
2. We have also limited the number of solar farms to around 2 or 3 PV farms within a 10 km² area

While these cumulative impact constraints do affect the siting of PV farms within a small geographic area, they do not constrain the overall growth of PV within the broader growth scenarios.

Concern has also been increasing regarding the use of potentially valuable agricultural land for solar development in Wales. To address this, only agricultural land classification grades 3b or below are considered as part of the resource assessment.

At a local level, some authorities have a history of not approving as many solar projects as others. Therefore, for some ESAs the future solar PV potential has been reduced by a scaling factor to reflect the area's planning history. This factor varies from 5 to 50 percent, reducing the total resource area, so

[21] http://gov.wales/topics/planning/policy/guidanceandleaflets/planningimplications/?lang=en

reducing both that ESA's future solar PV potential and the total future solar PV potential for South Wales.

This factor also takes into account past trends of solar in areas that appear to have resource and space for solar, but have had few applications. Carmarthenshire is an example of this and it is assumed that the network infrastructure there is not able to support the growth of further distributed generation due to existing thermal and voltage constraints in the short and medium term. Only later in the scenarios when these constraints could be mitigated is distributed generation growth expected to continue.

Given a widely available solar resource, large quantity of PV developable land space, low planning impact, short lead times, an established technology and a highly scalable supply chain; the future growth of solar PV in the South Wales licence area will be largely determined by:

- Project economics – whether, through subsidy or in the future price parity (rising wholesale, carbon price and/or falling PV costs), PV projects can generate a sufficient return on investment
- Availability of network – at a reasonable connection cost.

5.3 Historic growth and baseline capacity

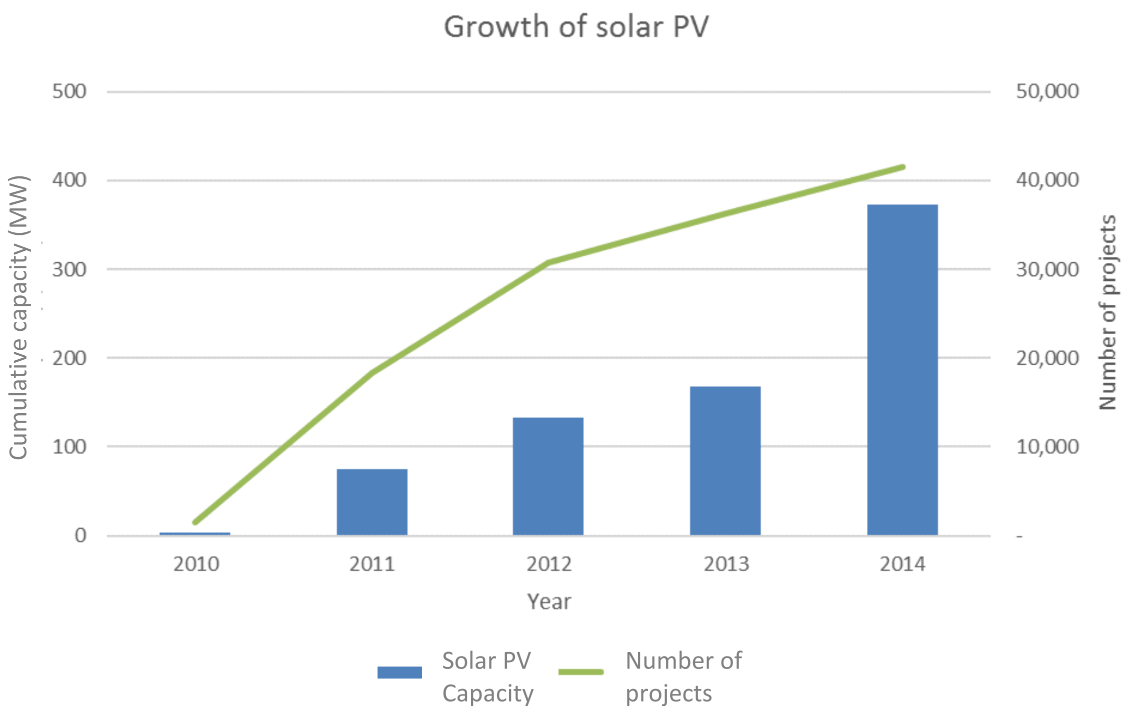
The rapid growth of PV across South Wales and the southern UK, has been one of the key features in the growth of renewable energy in the last 5 years. To assess the baseline capacity we used WPD connections data and validated the data with Renewables Obligation accreditations, BEIS Renewable Energy Planning Database and the Low Carbon Energy data that Regen produced for the Welsh government.

The overall growth in PV capacity across the South Wales licence area has been steady and looks, at first sight, to have been continuous.

In fact, there have been a number of distinct waves of PV growth:

- The first wave from 2010-2012 was the initial surge of smaller scale roof-top PV that was mainly domestic and driven by the initial high Feed-in Tariff (FiT) subsidy offered
- The second wave was larger ground mounted PV of >0.1 MW to 5 MW, again supported mainly by the FiT
- The third wave, which began to take off from 2014, was for very large PV farms of > 5 MW supported by the RO scheme.

Even within these waves, the PV market has been volatile and highly sensitive to the relative influences and interplay, of falling PV costs offset by falling levels of subsidy. Within the roof mounted PV market, for example, there was a significant spike in PV growth for domestic systems over the winter months of 2011/12 to beat the first major cut in the FiT.



5.3.1 Geographic spread of existing baseline projects by ESA

As discussed above, the geographic spread of ground mounted PV has tended to focus on those areas of PV developable resource that is close to the distribution network. The progression of solar farms has therefore to some extent been the result of developers encountering network constraints and higher reinforcement costs. The top 10 ESAs account for nearly 90 per cent of the total ground mounted capacity.

Notable areas without ground mounted PV farms, including Ceredigion and Carmarthenshire, are explained by the current unavailability of network connection and poorer access. Other areas have less ground mounted PV as a result of environmental factors.

Rooftop solar PV has followed a geographic distribution based on population, although there has been a more pronounced focus in areas to the south of the region in the urban areas of Swansea and Cardiff. Unlike in the south west of England, there is a weak correlation between the concentration of rooftop solar PV and affluence. In Wales, the impact of proactive investment by social landlords and community housing schemes has had a significant impact on distribution patterns.

5.4 Solar PV pipeline projection to 2017

Since the beginning of 2015, the PV industry has been impacted by a number of changes to subsidy levels and announcements related to energy policy at a UK level, as these remain reserved matters.

These measures include:

Closing of the RO to PV schemes affecting larger ground mounted schemes over 5MW from 1 April 2015

1) The RO was closed to new PV schemes above 5 MW in scale and to additional capacity added to existing accredited stations from that date, where the station is, or would become, above 5MW from 1 April 2015, except those that qualified for a 12 month grace period, which had until 31 March 2016 to commission.

Closure of the RO to small scale solar PV (less than 5 MW) from 1 April 2016

2) The closure applies to new generating stations with a total installed capacity less than or equal to 5 MW and any additional capacity added to existing stations whose new capacity does not exceed 5 MW.

3) There are grace periods until 31 March 2017 for projects that are:
    a. already pre-accredited; or
    b. which suffer from network connection delays; or
    c. that had made a 'significant financial commitment by 22 July 2015

4) In order to qualify for the grace period, projects:
    a. Needed to register under the Renewables Obligation on or before 31 March 2016
    b. Have to have submitted a planning application on or before 22 July 2015
    c. Have a network connection agreement by 22 July 2015
    d. Demonstrate confirmation of land rights

Reduction in the FiT – affecting schemes up to 5MW

5) Significant reduction in the available FiT for PV schemes meant that schemes which did not pre-accredit had to be built by 31 Dec 2015 to receive a higher FiT rate.

6) Schemes that did pre-accredit before 1 October 2015 qualified for a higher FiT but had to be built by:
    a. 1 April 2016 for domestic and commercial schemes
    b. 30 September 2016 for community based schemes

Whereas in the past, cuts to subsidy in one area have to an extent been offset by falling costs in other areas, these broad measures are expected to significantly impact the pipeline of PV projects coming forward for both rooftop and ground mounted schemes.

From now on, PV projects over 5 MW will have to be built without subsidy, however, as yet the majority of schemes are not yet achieving economic viability without subsidy. Ground mounted sub-5 MW projects that are not currently eligible for the RO grace period that runs to April 2017 will have to be viable with a very low FiT. Growth rates will depend on factors such as price parity under the future energy scenarios. For this reason, the pipeline analysis for PV runs to 31 March 2017 (not 2020).

5.4.1 Solar PV pipeline analysis

Project Scale	WPD Grid Connection		DECC Planning Database		2017 Pipeline Analysis	
	No. Projects	Capacity (MW)	No. projects	Capacity (MW)	No. projects	Capacity (MW)
'Ground' Projects < 1MW	171	749	56	390	51	224

To compile the pipeline, we used WPD Accepted-not-yet-Connected network data and DECC Renewable Energy Planning Database, to begin identifying projects.

Based on stakeholder engagement with the solar sector, we have the made the following assumptions:

- Sub-5 MW projects will only go ahead to March 2017 if they have a private wire connection or are eligible for the RO grace period. To be eligible for the RO grace period for sub-5 MW sites, projects have to have a network offer and a planning application in before 22 July 2015. We have therefore excluded projects without these in place. Where projects have planning in place, but it cannot be confirmed whether they do or do not have a network agreement in place, we have included them in the pipeline.
- Over 5 MW projects are generally not economically viable at present due to a lack of available subsidy. We have assumed that project developers with larger projects that have network and planning permission will reduce the scale of their sites to 5 MW to be eligible for the ROCs. They may then seek other ways to extend these larger sites post-March 2017, e.g. through private wire agreements or community projects. We have assumed that larger projects therefore are installed, but with a reduced capacity averaging 6 MW.
- We have also excluded projects that have had planning and a network connection for some time (over 4 years), but for a variety of reasons have not proceeded to construction.
- All pipeline projects will be built by 31 March 2017, after which we enter the scenarios.
- Some projects may still fall away as expected through the development process, but the pipeline shows upper expectations.

The WPD Connection Agreement database (April 2016) has 92 projects greater than 1 MW with a total capacity of just over 740 MW. This is significantly different to the DECC planning database, which holds 56 potential projects with a capacity of just 390 MW.

(Note: the initial analysis suggests that there are very few projects which have planning, or indeed have submitted a planning application, without having an accepted network connection offer in place. This supports the view that securing a network connection is a key priority for project developers and generally precedes a planning application.)

There are 51 projects in the pipeline, totalling 224 MW. Of these 201 MW have planning permission.

5.4.2 Rooftop – domestic and commercial scale pipeline

2016 had a number of milestones linked to FiT degression:

- 31 March 2016 for domestic and commercial pre-accredited schemes
- 30 Sept 2016 for community pre-accredited schemes

Installers across the UK have therefore been fitting the remainder of the pre-accredited schemes, after which the current pipeline comes to an end. We have seen deployment rates drop by 85 percent across the UK, and due to the current inability to accurately regionalise this data, we have assumed similar trends in South Wales; with the rooftop analysis going straight from baseline to scenarios from 2016.

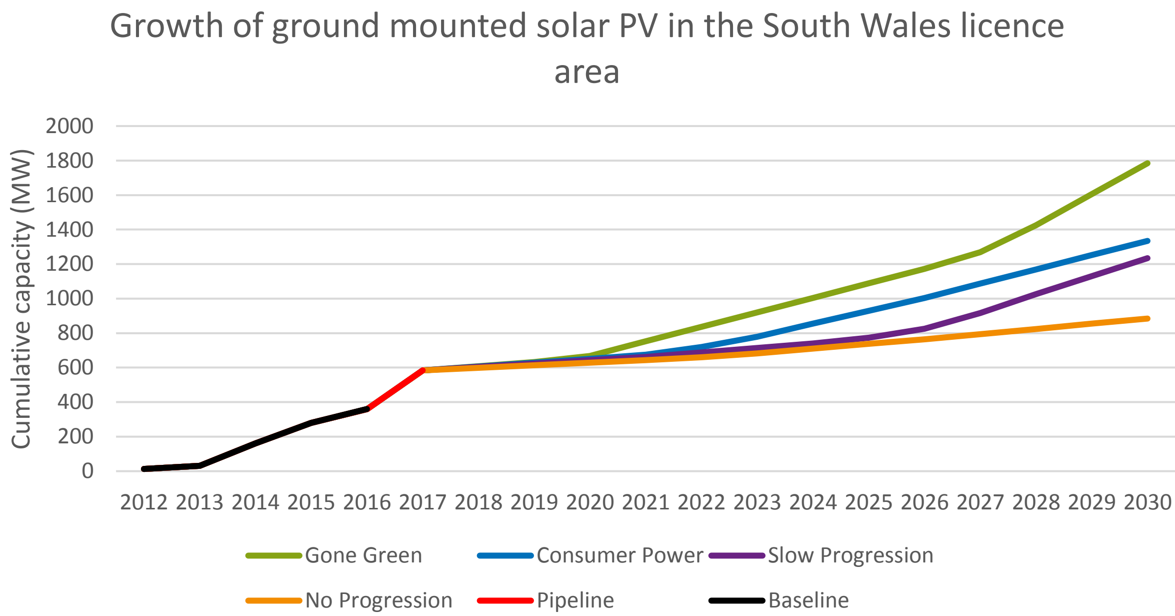
5.5 Solar PV scenario growth analysis 2017-2030

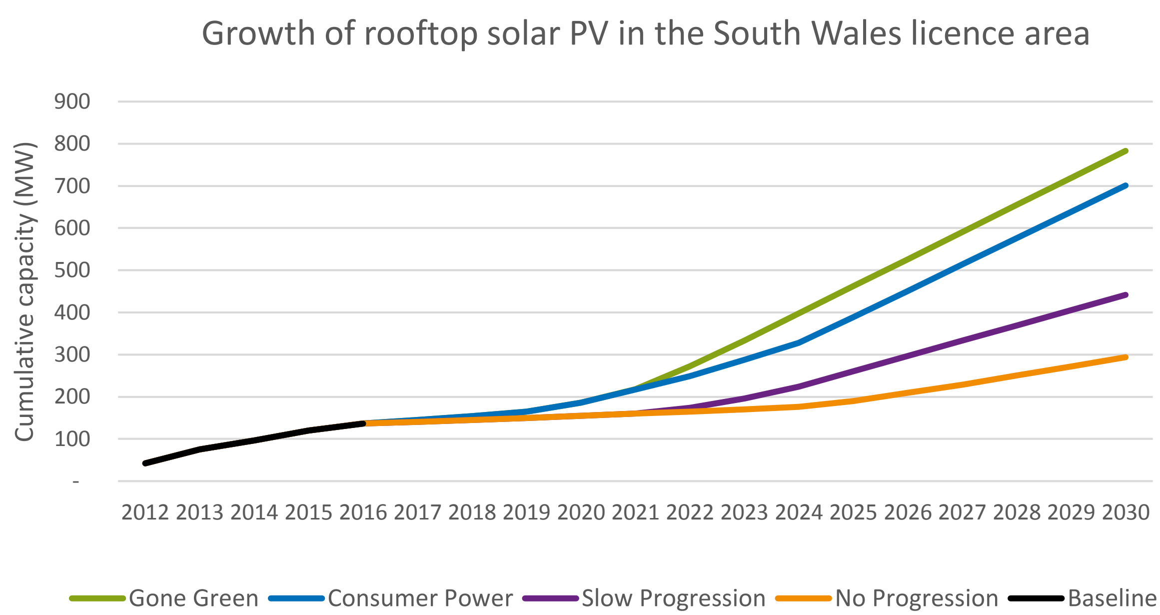
5.5.1 Overall solar PV distributed generation growth by scenario

As we have seen in the past five years, solar PV has the potential to be a disruptive technology, if the economic factors supporting projects are favourable. Post 2017, with potentially zero or very low subsides available, solar PV is entering a difficult period and it is expected that there will be a significant fall in installations under all scenarios initially. However, with relatively short lead times, and the potential for further falls in panel and inverter costs, solar PV could bounce back and grow rapidly in the next decade if grid 'price parity' is reached.

In the future, energy storage could also have a significant impact on PV project finances by allowing projects to better harness 'own use' energy, increase capacity utilisation and potentially exploit energy price markets. The potential impact and growth of energy storage is discussed in more detail in section 12. The timing of when price parity could be reached, and the impact of energy storage, is not yet clear and this is reflected in the future energy growth scenarios.

Growth of ground mounted and rooftop solar PV by scenario is shown in the graphs and tables below.


Growth of ground mounted solar PV in the South Wales licence area
Cumulative capacity (MW)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Gone Green
Consumer Power
Slow Progression
No Progression
Pipeline
Baseline


Growth of rooftop solar PV in the South Wales licence area
Cumulative capacity (MW)
900
800
700
600
500
400
300
200
100
-
2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Gone Green
Consumer Power
Slow Progression
No Progression
Baseline

Summary table of total PV installed by 2030 by scenario

	Baseline 2016 capacity			Pipeline 2016 to 2017 capacity			Scenario 2017 to 2030 capacity			2030 total capacity (MW)
	Total 2016 baseline (MW)	Ground mounted (MW)	Rooftop (MW)	Total 2017 pipeline (MW)	Ground mounted (MW)	Rooftop (MW)	Total scenario forecast (MW)	Ground mounted (MW)	Rooftop (MW)	
Gone green	526	378	149	219	212	7	1,881	1,352	529	2,626
Consumer power	526	378	149	219	212	7	1,255	799	456	2,000
Slow progression	526	378	149	216	212	4	890	650	240	1,633
No progression	526	378	149	213	212	4	436	300	136	1,178

Key points to note:

- Overall, it is anticipated that there will be slowdown in PV deployment growth post 2017, particularly for ground mounted solar PV. This would seem to be inevitable given the cut to available subsidies, plus the budget cap which has been placed on new schemes under the Levy Control Framework. These policies remain reserved matters and the UK Government has shown no inclination to step back from this position. Growth across the sector will therefore be predicated on PV achieving energy price parity (see below). Already developers and installation companies across the UK are preparing for a downturn in activity. The key uncertainty therefore is how quickly growth would recover under the four future energy scenarios. Of course it is within the gift of the Welsh Government to provide incentives for development they wish to see this accelerated, but we have not explicitly assumed that they would introduce a solar tariff, due to expectations that price parity could be reached in the near future.
- **Gone Green – Roof-mounted:** under this scenario it is anticipated that growth of roof mounted PV would significantly increase as the investment returns improve and a positive Government policy agenda helps to encourage deployment, with retrofit and new build deployment spreading across all levels of affluence. This is assumed to happen quite quickly, as the Welsh Government has the ability to drive this change through devolved policy making, including permitted development rights and building regulations. With a positive economic outlook, new build rates would be high.
- **Gone Green - Ground-mounted:** In the UK to date, some network capacity issues can be linked back to the proliferation of solar deployment. In this scenario, it is therefore anticipated that some network infrastructure investment financed by the public sector could come with the requirement to maximise the economic, social, environmental and cultural returns, as set out in the Wellbeing of Future Generations Act. This would potentially mean that as with wind, solar would be supported by strategic infrastructure planning; being permitted where positively planned for and/ or co-located with complimentary technologies such as wind energy, to create energy parks that maximise the value provided by network infrastructure assets. In this scenario deployment may not therefore be left entirely to the market.

- **Consumer Power** – in this scenario growth is slower than in Gone Green and price parity does not impact until 2021/2022. Ground mounted PV projects then continue to be developed through a market led approach, however, technology innovation and new 'own use' business models increasingly favour rooftop and building fabric PV installations for consumers, businesses and communities. Social perceptions of rooftop PV improve and align to see widespread deployment at all levels of society, due to improved returns on investment. New build installations are lower due to a lack of planning policies requiring carbon reductions.
- **Slow Progression** – growth in this scenario is slower and price parity does not impact until 2024/2025. The lower technological innovation favours larger scale ground mounted solar and the government policy backing means that deployment returns to the historic peak levels seen before, facilitated by small but strategic improvements in network infrastructure. Co-location would remain a theme in this scenario to maximise returns from any network availability, but this would be entirely market led. Slow Progression and Consumer Power result in a similar total capacity of ground-mounted deployed, but Slow Progression has substantially less roof-mounted than Consumer Power. Building regulation changes come into force affecting new build capacity from 2022, but fewer homes are actually built than in Gone Green.
- **No progression** – due to limited investment in network infrastructure, deployment rates are low at all scales through to 2030, focussed on private wire and links to own use storage opportunities. Rooftop solar PV continues to see low deployment levels due to lower prosperity and less green ambition.

5.5.2 Scenario factors impacting future solar PV growth in the South Wales licence area

FES Scenarios - Implications for solar PV in the South Wales	
Consumer Power	**Gone Green**

• High growth scenario
• Technological innovation
• New business models and storage support 'own use'
• Rooftop and building fabric schemes, but lower new build deployment due to a lack of low carbon buildings requirements
• Price parity reached circa 2021/22 for larger rooftop and own use schemes
• Higher proportion of rooftop projects
• Very large ground projects focused in high resources areas
	• High growth scenario
	• Strategic infrastructure investment facilitating plan led ground mounted solar
	• Improved regulations supporting roof top PV
	• Price parity – first projects 2018/19
	    o Falling PV costs
	    o Co-location and energy parks
	    o Technology innovation
	    o High carbon price
	• Growth rates approach peak seen during 2011-15
	• New business models including energy storage

No Progression	Slow Progression
• Lowest growth scenario • Poor planning and economic environment • Growth would be very slow 2020-25 with a slight increase post 2025 as price parity met for some business models • Limited growth would be more weighted to economically viable projects – very large or 'own use'. • Some municipal and community schemes	• Medium growth scenario • Positive planning environment • But poor economic and finance outlook meaning a lack of investment capital available • Less domestic rooftop projects due to lower prosperity • Price parity reached and impacting 2024/25 • Projects focused in high resources areas but relatively distributed across ESAs

5.6 Key growth drivers and constraints in the South Wales licence area to 2030

5.6.1 Grid price parity

In a post subsidy environment, the growth of solar PV will be primarily driven by its ability to compete with other energy generation technologies. There is some discussion about what price parity means in practice, but for the purposes of this paper it is the point where solar PV projects can be built without a direct revenue subsidy or grant.

In this regard, PV has already seen a significant fall in costs and is now approaching the point where very large ground mounted schemes (>10 MW), without significant network reinforcement costs, could become viable without subsidies by 2020.

Roof mounted schemes have traditionally been more expensive but a combination of new technology – especially for new build – plus energy storage enabling 'own use' business models could enable larger roof mounted schemes to be viable without subsidy.

Factors which could contribute to solar PV achieving price parity are listed in the table below:

Potential factor enabling PV price parity	Likely scenario			
	GG	CP	SP	NP
Falling international PV panel and inverter costs – potentially due to reduction in import duties and also manufacturing innovation and economies of scale	X	X	X	X
Falling installation costs – potentially due to increased supply chain competition in a falling market		X	X	X
Rising electricity wholesale price – potentially driven by economic growth, increased demand and/or falling supply	X	X		
Technological innovation – especially for rooftop and building fabric PV technologies	X	X		

New business models – ‘own use’ enabled by energy storage	X	X	X	
New business models – ‘capacity utilisation’ enabled by energy storage	X		X	
New business models – ‘energy market’ enabled by energy storage	X			
Lower network reinforcement costs – enabled by pre-emptive investment	X		X	
Lower network reinforcement costs – enabled by ‘smart’ solutions, active network management and demand response solutions etc.	X	X		
Impact of an effective carbon price	X		X	
Residual subsidy – potentially a minimum price ‘guarantee’ mechanism	X		X	
Innovative integrated systems – PV linked to electric vehicle charging for example	X	X		

5.6.2 Solar PV with energy storage

The development and growth of energy storage solutions is discussed in Section 12.

For solar PV especially, given its relatively low capacity factor, energy storage solutions supported by new business models could open up a range of new commercial opportunities for new and existing PV plant.

Exactly how and how quickly energy storage technologies will impact the energy market is unclear, but a number of technologies and models are already being considered.

The rapid growth of own use energy storage solutions is a real possibility and evidence from the US and Germany suggests that storage solutions will increasingly be offered as part of a standard PV or small scale wind package. Evidence from the German Solar Trade Association suggest that 70 percent of solar installers are now offering energy storage solutions as part of a standard PV package and that the proportion of new domestic PV storage systems will grow by 50 percent with one in three installations now taking storage options. In part, the high growth in Germany has been driven by very high electricity prices; however, with falling costs, energy storage solutions could equally grow here in the UK.

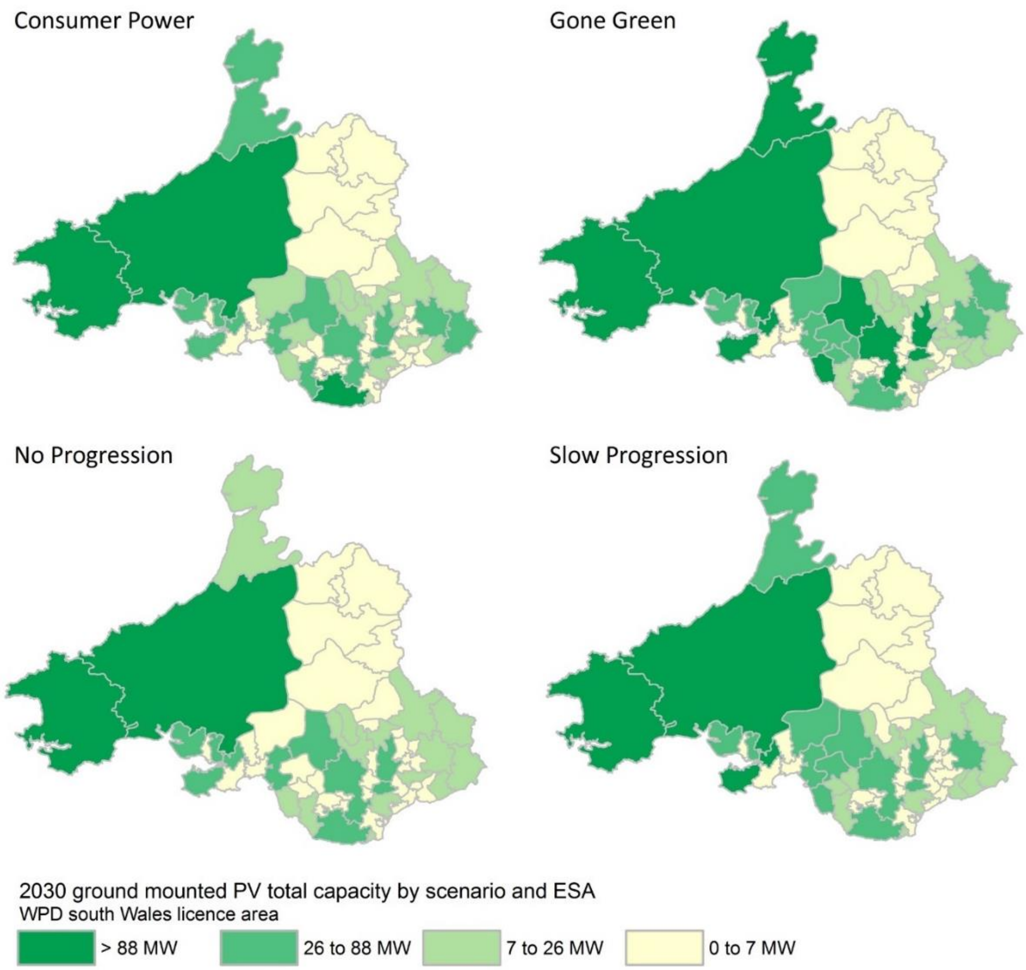
5.7 Geographic distribution of solar PV distributed generation 2030

The maps below show, the potential geographic distribution of both ground and rooftop solar PV under different development scenarios.

As discussed above, the distribution of solar PV is less constrained by planning than onshore wind and therefore there is less obvious concentration of projects within specific geographic areas.

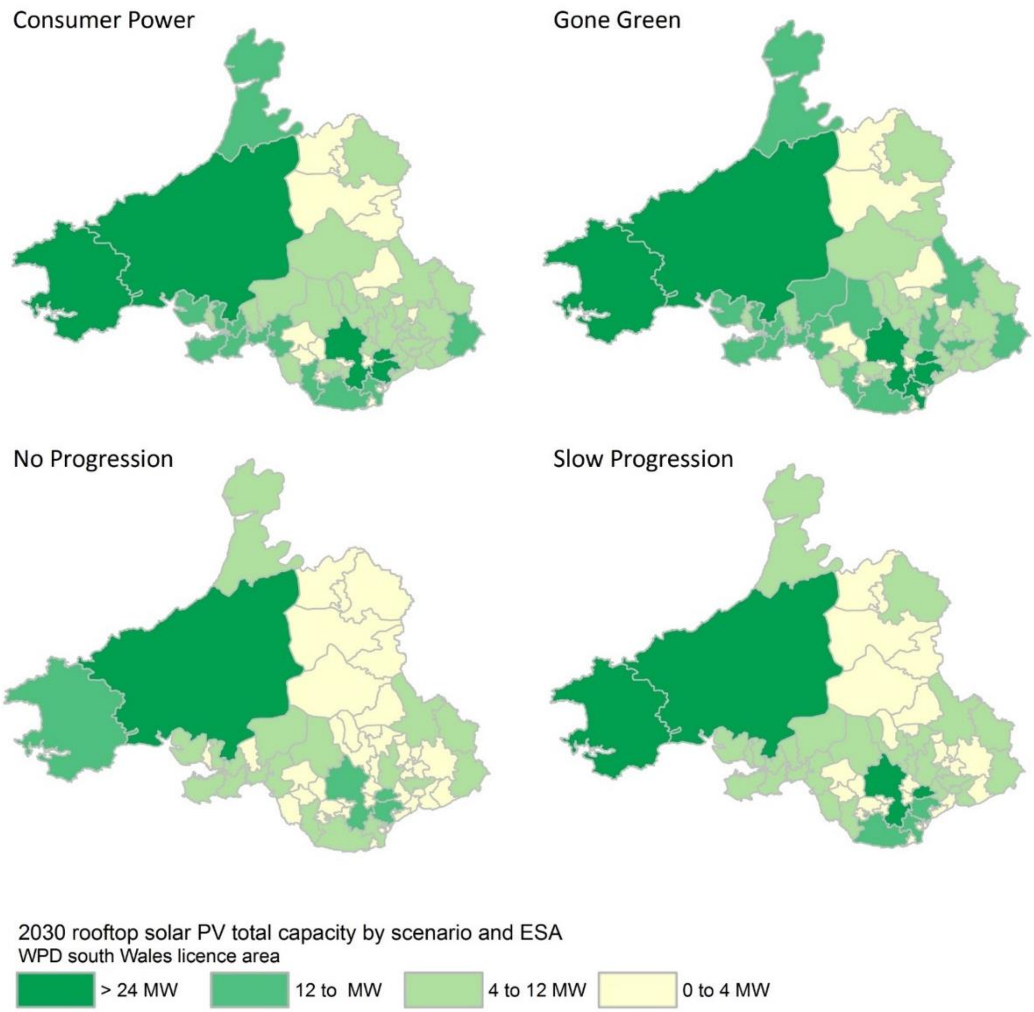
Ground mounted distribution

The distribution of the forecast capacity by ESA is based on resource potential, including proximity to the network, which was found to be the most important factor for siting a large ground mounted project. In addition, in the Gone Green and Slow Progression scenarios, the co-location of solar, particularly with onshore wind in the new and existing SSAs, has an impact on its distribution. Under Consumer Power and No Progression, the distribution of ground-mounted PV is more dispersed, as development is less concentrated on strategic co-location. Planning has been found to be a minor factor in the current climate and so has not been deemed to be a factor holding back the development of solar in any ESA.



Roof-mounted PV distribution by ESA

The projection for roof-mounted PV is allocated to ESA based on the number of buildings within the ESA, both existing and projected new build homes. Since domestic projects account for the overwhelming majority of total capacity (over 85 percent), it was considered appropriate to allocate deployment by the number of dwellings, without factoring in commercial buildings. In addition, areas with more homes tend to have more commercial buildings.



6 Analysis and results - offshore energy technology growth scenarios

6.1 Offshore energy scope and context

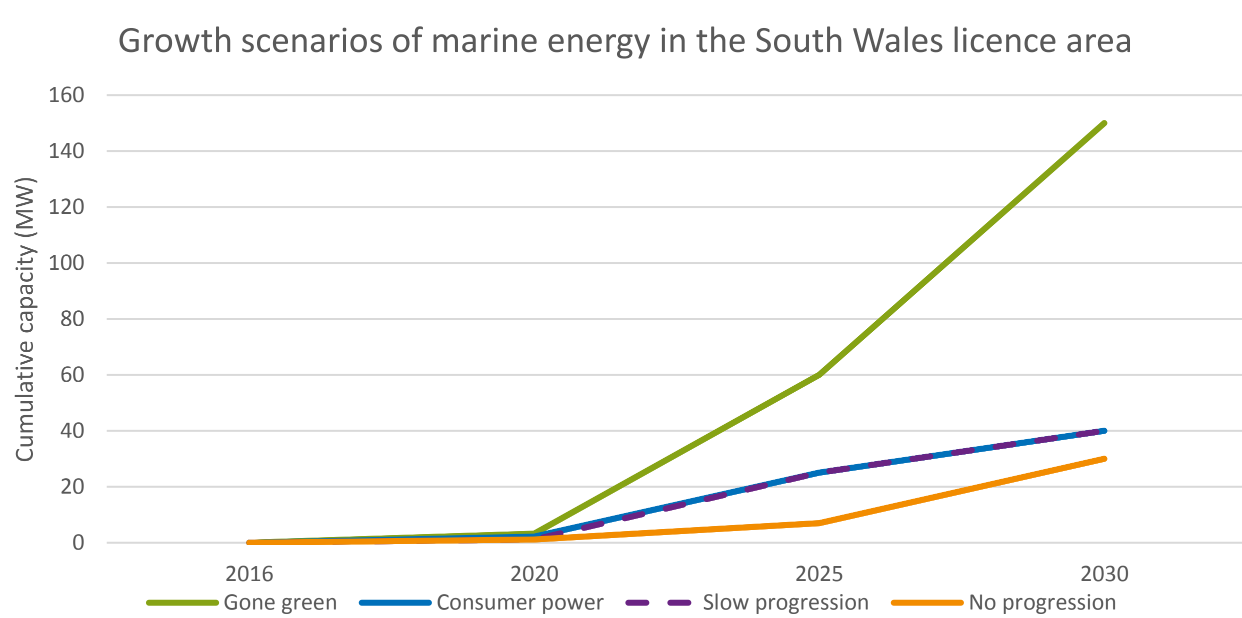
This section of the report covers the future distributed energy generation scenarios for offshore renewable energy in the WPD South Wales licence area to 2030. These technologies include:

- Wave energy
- Tidal stream energy

For the purpose of this analysis, it is assumed that if any large scale tidal range project is constructed in the period to 2030, such as the planned Swansea Bay Tidal lagoon, it will connect directly to the National Grid Transmission network and so would not be considered as distributed generation.

There are no planned offshore wind farms in the South Wales area and if projects were to develop in the Bristol Channel, these would likely connect directly to the National Grid, so these have also not been included. If technology development progresses in floating offshore wind, there may be projects developed in the Bristol Channel, though these are likely to fall outside the timeframe being considered and again may connect straight into National Grid.

Summary of offshore energy generation growth scenario 2016-2030



The analysis presented below draws heavily on a number of existing reports, including:

- The Economic Impact of the Development of Marine Energy in Wales (Regeneris Consulting Ltd, July 2013)
- Wales Marine Energy Site Selection (PMSS, Welsh Development Agency, March 2006)
- Marine Renewable Energy Strategic Framework (Welsh Assembly Government, 2011)

6.2 Offshore energy – future energy potential

The development of offshore energy, with particular focus on the emerging technologies of wave energy and tidal stream is a strategic priority for South Wales. To support the development of the sector in Wales, significant investment has been provided.

Investment has included £1 million from Welsh Government into the Marine Renewable Energy Strategic Framework to understand the resource potential, plus funding from the European Union, supporting individual technology developers, such as Tidal Energy Limited, who received over €10 million of funding to develop their device, which was successfully deployed in 2015. In addition to this, the Welsh European Funding Office (WEFO) has provided over €100 million of EU structural funding to support development across Wales. This investment will support both individual technology developers and the Pembrokeshire Demonstration Zone (€20 million ring-fenced for development at the wave energy site). A further €300 million of funding was allocated under "Priority Axis 1: Research and Innovation" in the EU Structural Fund Framework for Wales (2014-2020) which, although not specifically marine energy focussed, is expected to fund work into low carbon energy and the environment, plus renewable energy technology more broadly.

In 2006, PMSS carried out a high level study of marine resource in Wales, which provides an estimate of the available resource surrounding the South Wales coastline.

The breakdown of potential capacity by technology type was given at:

- 5.6 GW wave energy
- 910 MW shallow water tidal stream resource
- 640 MW deeper water tidal stream resource

However, while the energy potential of offshore renewables in South Wales is huge, the build out of very large offshore projects in the region is unlikely to happen until after 2030. This is because tidal stream and wave energy technologies are still in a period of technology development and demonstration and so, while there are a number of projects currently in the pipeline, these are likely to be of a relatively small scale. Initially, it is likely that projects will be demonstration scale projects, at the Pembrokeshire Demonstration Zone (wave) and Ramsey Sound/St David's Head, as Tidal Energy Limited continue to build out their projects. Following these smaller scale projects, it is expected that the Demonstration Zone will continue to be utilised to its full potential.

Likely build out of wave and tidal stream projects to 2030

Deployment period	Type of project	Scale of projects
2015-2020	Demonstration and pilot project	1 MW-3 MW demonstration 1-10 MW pilot arrays
2020-2025	First commercial projects	10-30 MW
2025 onwards	Full commercial projects	30-100 MW plus

This build out approach does, however, means that many early projects will most likely connect to the distribution network, at key coastal substations. Since these early projects are critical to supporting future industry growth and the economic stimulus the sector requires, access to the network will be of critical importance for project success and delivery.

6.3 Offshore energy scenario baseline, pipeline and growth analysis 2016-2030

6.3.1 Offshore energy baseline and pipeline

The baseline of deployed projects consists of 400kW of tidal stream in Ramsey Sound. We have analysed the pipeline through the scenario process, incorporating appropriate assumptions around existing lease and network connections and plans for demonstration zones.

6.3.2 Overall offshore renewable energy distributed generation growth by scenario

The overall distributed generation growth for offshore renewable energy technologies by scenario is shown in the table below.

	2023			2025			2030		
	Wave Energy (MW)	Tidal Stream (MW)	Total (MW)	Wave Energy (MW)	Tidal Stream (MW)	Total (MW)	Wave Energy (MW)	Tidal Stream (MW)	Total (MW)
Gone green	20	10	30	30	30	60	100	50	150
Consumer power	10	10	20	15	10	25	30	10	40
Slow progression	5	3	8	15	10	25	30	10	40
No progression	3	1	4	5	2	7	20	10	30

Key points to note:

- Capacity estimates are for distribution network connected projects and exclude very large scale tidal range projects, which would most likely connect to the National Grid.

- Offshore renewables require both significant investment in technology R & D as well as the political drive to progress the development zones off the coast of South Wales. Due to this interdependence, the Consumer Power and Slow Growth scenarios result in significantly lower deployment than Gone Green.
- All scenarios include the proposed projects at the Pembrokeshire Demonstration Zone, Ramsey Sound and St David's Head. In relation to tidal stream, it is assumed that Tidal Energy Limited successfully build out their planned portfolio; increasing their 400kW site in Ramsey Sound to 1.2 MW, followed by deploying a 10 MW array at St David's Head, with timings varying by scenario.

6.3.3 Scenario factors impacting future deployment of offshore energy in South Wales

FES Scenarios - Implications for offshore energy in South Wales	
Consumer Power • Lower growth scenario • Marine energy continues to innovate and develop new technology but there is a lack of government support so the sector fails to reach commercial scale by 2030 • Pilot and demonstration projects are deployed at the Pembrokeshire Demonstration Zone. • Innovation export and specialist research sustains specialist companies	**Gone Green** • Highest overall growth scenario • UK exploits its position as leading centre for global marine energy • Investment support enables wave and tidal stream to achieve commercial potential • South Wales becomes a leading centre for marine energy • Pilot projects at the Pembrokeshire Demo Zone lead to first commercial wave energy arrays by 2025 • Tidal stream also successfully achieves commercial scale deployment • Export opportunities sustain investment and economic growth
No Progression • Very low growth scenario • Marine energy and innovative renewable energy technologies struggle to raise finance or gain funding support • Initial pilot projects do not progress to commercial scale • Innovation and economic opportunities are lost – development activity moves overseas	**Slow Progression** • Lower growth scenario • Poor economic and finance outlook means that marine energy struggles to gain financial support despite policy drivers • Pilot and demonstration projects are deployed • UK regions fail to exploit their global leadership position

6.4 Key growth drivers and constraints in South Wales to 2030

6.4.1 UK and South Wales growth opportunity

The anticipated growth of marine energy in South Wales depends on a number of factors. These have been documented in a number of papers, including the Wales Marine Energy Site Selection report, The Economic Impact of the Development of Marine Energy in Wales Marine Renewable Energy Strategic Framework. In summary, the key growth factors identified are:

- Technology development – proving the reliability and performance of new technology
- Success of a series of pilot and demonstration projects
- Access to resources including the planning and consenting process
- Access to finance – which will initially require collaboration between public and private sector investment
- Policy and political support for the sector – at Welsh, UK and European level.

As discussed above, under the St David's Day devolution process there will be devolved powers to Wales which could, in time, support the further development and growth of the marine energy sector, through greater consenting powers. These would need to complement a marine plan that strongly favours marine energy development, however, it is unlikely that Wales would have its own Levy Control Framework to provide long term funding for marine energy projects and therefore it is expected that issues surrounding subsidies will be the same in Wales as the rest of the UK.

Under the Gone Green scenario, it is assumed that the growth factors are optimal. The industry is therefore able to progress from pilot and demonstration projects, to the first commercial arrays by 2025. As already documented, it is very likely that the first wave energy projects will be built at the Pembrokeshire Demonstration Zone, which was designated by The Crown Estate and has the potential to support wave arrays up to 30 MW per project. Tidal stream projects are likely to be built out at the St David's Head site, leased by Tidal Energy Limited.

Under the Consumer Power and Slow Progression scenarios, the potential for large scale marine energy projects is limited. The industry may continue to deploy pilot and demonstration projects into the 2020s.

Under a No Progression scenario, with poor financial and political support, there is very limited opportunity for marine energy or any other innovative renewable energy technology to be developed. This would also imply that the UK loses its leadership position in the sector and the opportunity to export technology and capability to the global market.

Investment in marine energy, and the research and development capability that supports it, has become a critical part of the wider growth of marine industries in South Wales. By supporting other strategic investments across the area, marine energy is helping to create high value engineering jobs and increase Welsh national productivity. The growth and development of marine energy has also supported existing facilities, including both the Port of Milford Haven and Pembroke Port and has supported traditional industries such as shipbuilding, for example, Mustang Marine (now Mainstay Marine Solutions) who fabricated and assembled the Tidal Energy Limited DeltaStream turbine.

6.4.2 Importance of the distribution network for sector development

While anticipated capacity likely to be deployed for marine energy is comparatively low as compared to solar PV and onshore wind, the availability of a network connection in specific coastal locations, such as Pembroke, will be critical for the strategic development of the marine energy sector.

This is partly because the choice of offshore location for marine energy is extremely constrained by the available resource, plus factors such as, but not limited to, water depth, seabed conditions, shipping routes, environmental designations, Ministry of Defence uses, commercial fishing, leisure activities, proximity to ports etc.

For these reasons, it is highly likely that marine energy projects in South Wales will focus on a small number of viable network connection points. Of significant immediate importance is the network connection point at Pembroke and Texaco ESA due to the Demonstration Zone for wave energy and the 10 MW network connection agreement at St David's Head held by Tidal Energy Limited.

6.5 Geographic distribution of offshore energy distributed generation

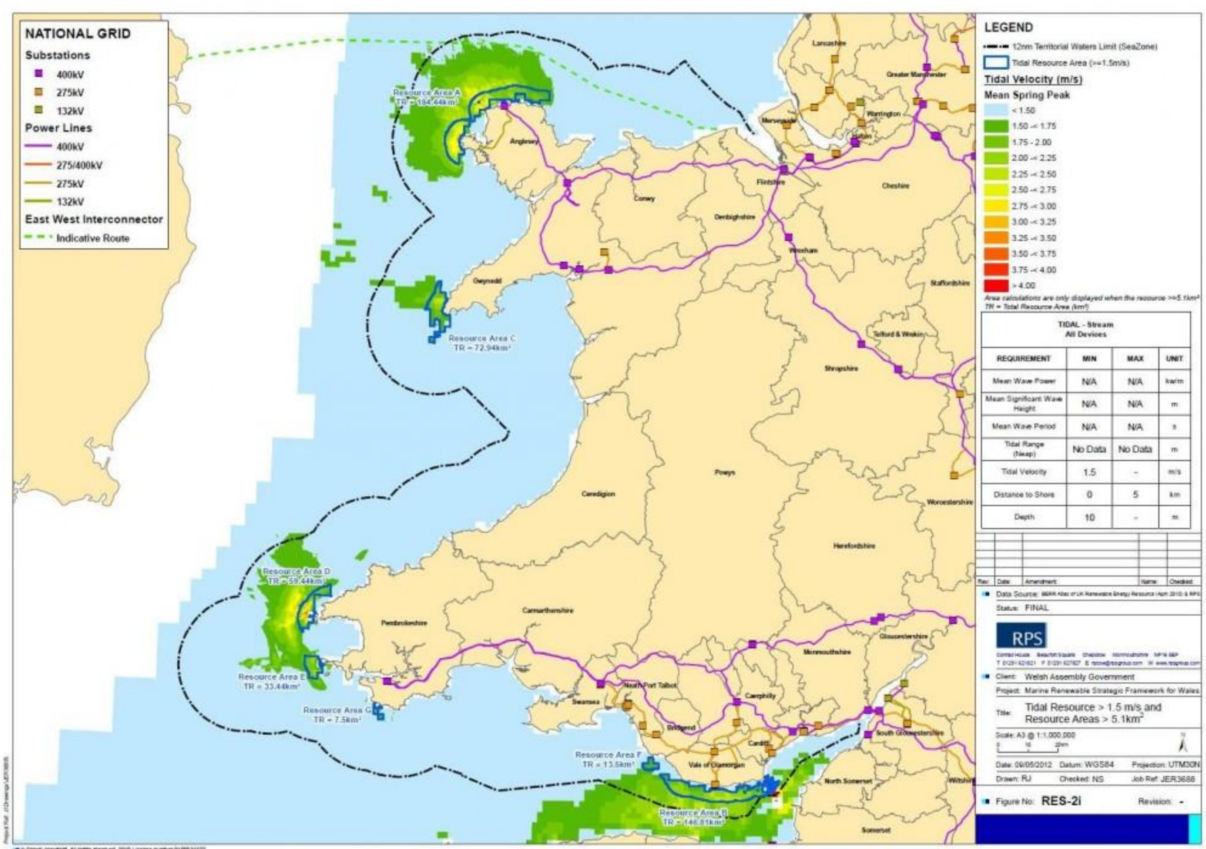
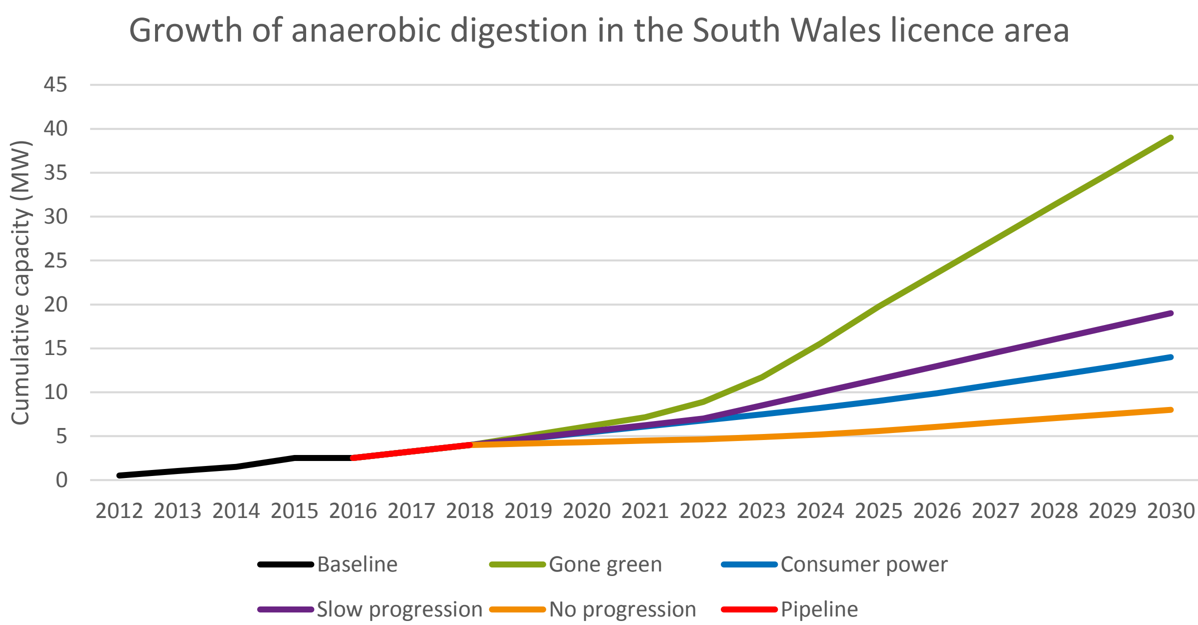


Image courtesy of: http://www.marineenergypembrokeshire.co.uk/wp-content/uploads/2010/04/Tidal-resource-for-Wales-MRESF-1024x718.jpg

The graphic above gives an overview of the available marine energy resource in South Wales. Tidal stream energy is concentrated in a small number of areas which are predominantly inshore areas and around headlands; off St David's Head and in Ramsey Sound. Wave energy is almost exclusively focussed around Pembrokeshire, which has been recognised through designation by The Crown Estate.

7 Analysis and results - anaerobic digestion technology growth scenarios



Scenario	Baseline capacity 2016 (MW)	Pipeline projection to 2017 (MW)	Total scenario forecast to 2030 (MW)	Total (MW)
Gone green	3	1.5	35	39
Consumer power	3	1.5	10	14
Slow progression	3	1.5	15	19
No progression	3	1.5	4	8

Technology	Key growth drivers	Basis of forecasted ESA distribution
Anaerobic digestion	• Government support • Grid availability • Waste policy	• Agricultural land distribution • Large population centres

7.1 Baseline

Anaerobic Digestion (AD) in South Wales has been slow to take off. There are only 6 AD projects in the South Wales licence area with a combined capacity of 2.5 MW that have been identified. The baseline was constructed using the Low Carbon Generation data that Regen produced for the Welsh Government.

7.2 Pipeline

There are 7.7 MW of AD plants at the Accepted-not-yet-Connected stage in South Wales. Based on consultation with industry, we have assumed that only 20 per cent of that capacity will be built due to current issues affecting the deployment in South Wales (see below).

7.3 Future growth potential

Given the right conditions, there is good potential for the development of AD in the area. South Wales has an abundance of potential AD sites and a plentiful waste resource for the development of both on farm and larger scale AD. If the market were to take off, there would be the opportunity for a South Wales AD industry to develop, bringing economic benefits to the area. The current challenge is that AD is a long way from price parity and with existing subsidy levels it is difficult to make projects economic.

However, as well as having increasingly variable and diverse fuel sources, AD is suitable for a variety of different uses at different scales. AD can offer benefits to many different stakeholders, including farmers, industry, communities and local authorities. Fully utilising the different combinations of heat, power, and gas generation at different scales, will help AD to become increasingly viable. It will also make the technology more efficient and cost effective.

Larger scale AD projects are increasingly concentrating on the emerging market of gas to grid, over electricity export. There are now a number of these projects in the UK, outside of South Wales. It is currently only viable for larger AD projects to buy the equipment required to export gas. Projects exporting gas to the gas network generally only generate electricity to meet the parasitic load, as more can be earned exporting the gas, than burning it for electricity generation.

7.4 Scenarios

Despite significant potential resource and benefits from AD, deployment in South Wales is expected to remain at a low level across all scenarios until 2022, due to a number of factors that are affecting current and future deployment:

- Current deployment has been lower than in other areas: Because AD is less geographically limited than other renewable energy technologies, developers are able to focus on the most economically viable sites. South Wales' expensive network connection costs, coupled with marginal economics mean that AD installers are focussing their efforts on other regions of the UK and interest from local farmers has been limited.

- The current low return on investment that is available is only sufficient to attract project owners with available capital i.e. it is not high enough to allow for the cost of borrowing, reducing the pool of potential farmers able to develop schemes.
- Technology cost reductions are likely to be limited until post 2030. Similarly, installation costs are likely to remain high, given the small size of the current market. Price parity is unlikely to be achieved until after 2030.
- Lower UK FiT levels were introduced in February 2016, which include quarterly deployment caps and a more severe degression system. The first round of applications for AD reached the 5.8 MW first quarterly cap in 20 minutes. Projects entering the queue to receive the FiT currently have to wait through three quarterly degressions before reaching the top of the queue and being assigned a FiT rate. Deployment caps and degressions are severely limiting small-scale deployment (up to 500 kWe) across the UK.
- The UK government is current considering responses they received to a consultation[22] that proposed cutting all subsidy for projects over 500 kW, reducing small scale tariffs and introducing sustainability requirements, including a limit on the use of energy crops as a feedstock. If these policies are implemented, this will reduce the economic viability of schemes even further. In particular, large scale schemes would be dependent on income streams from processing food waste, which are dependent on local waste policies being supportive.
- The Levy Control Framework means that the available budget through the FiT is limited and at the current rate of deployment the budget for AD will have been exhausted by 2018 and no further FiT will be available, meaning that few schemes will be economically viable post-2018.
- Uncertainty over the future of the RHI (the government has introduced an overall budget cap that could close the RHI to new projects) is muting the deployment of projects with useable heat or for bio-methane injection.

Under the Gone Green and Slow Progression scenarios, government subsidy is made available post-2022 for farm scale projects, either by the Welsh Government or by increasing the FiT, resulting in an uplift after that date. Complimentary local waste policies would also be established through policy incentives. Due to a good level of subsidy and strong economy, we estimate that up to 30 MW of AD could be deployed in South Wales under the Gone Green scenario, a significant increase against current installed capacity (2.5 MW). The majority of this would be farm scale with a limited number of food waste fuelled projects, aimed at managing the waste resource. Under Slow Progression, a lower subsidy and poorer economic situation would reduce deployment to 15 MW.

Under Consumer Power, deployment would be lower, as increased government subsidies would not be available. Growth would be relatively linear as the market develops over time, with falling installation

22 https://www.gov.uk/government/consultations/review-of-support-for-anaerobic-digestion-and-micro-combined-heat-and-power-under-the-feed-in-tariffs-scheme

costs and as the technology develops. Again the majority of deployment would be farm scale, driven by farmers with capital available to invest. A limited number of food waste sites would develop to manage the food waste produced by a consumerist society.

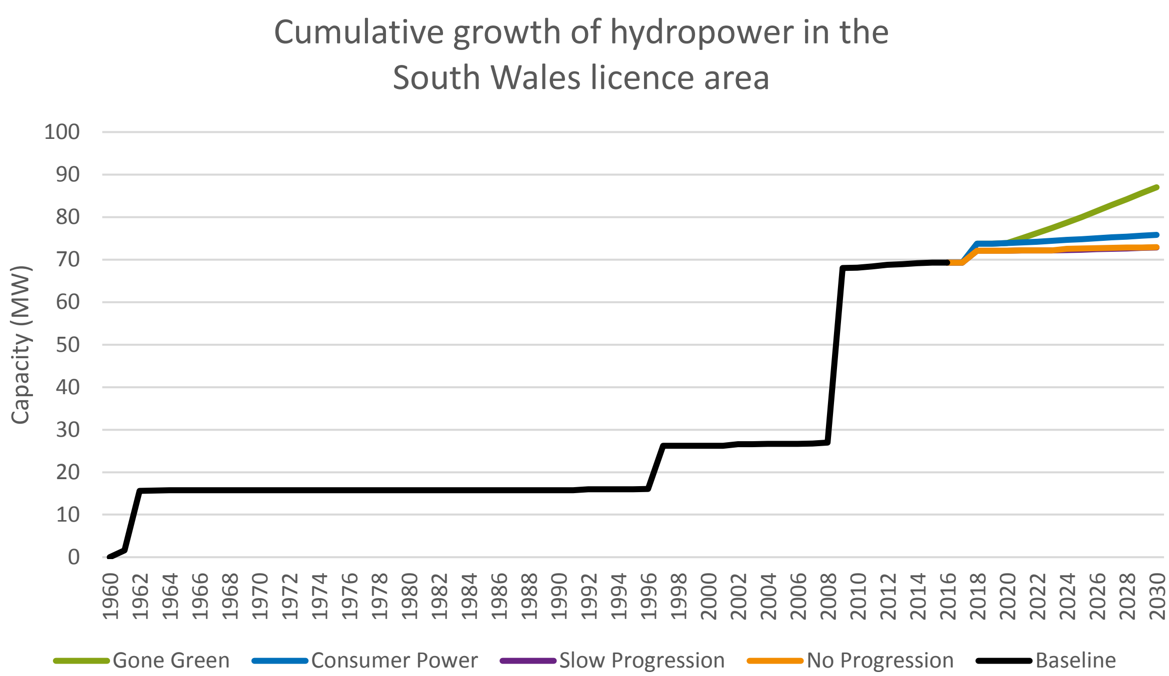
Under No Progression, deployment would be at a very low rate (4 MW), with a lack of subsidy or market-driven cost reductions and a lack of investment capital available.

FES Scenarios - Implications for anaerobic digestion in South Wales	
Consumer Power • Low deployment • No increase to subsidies • Sites are developed by ambitious landowners that produce electricity or heat for onsite demand, driven by farmer and landowner demand for investment projects for their available capital • Limited food waste projects driven by need to process waste • Technology costs reduce and performance improves as a result of R & D investment	**Gone Green** • Deployment continues at a low rate until 2022, with only own-use sites developed by ambitious landowners • Post-2022 UK FiT is increased or a Welsh incentive for small scale AD is introduced and growth begins to gather pace, making use of the abundant resource • Mainly farm scale projects are built, with some food waste projects to process waste • Technology costs reduce and performance improves as a result of R & D investment
No Progression • Very low deployment • No increase to subsidies • The only projects installed are on farm waste management projects with very low export capabilities. • A lack of available investment in R & D means that high technology costs and performance issues remain prohibitive to widespread roll-out, and to large scale projects.	**Slow Progression** • Deployment continues at a low rate until 2022, with only own-use sites developed by ambitious landowners • Post-2022 a subsidy is available but lower than under Gone Green, aimed at incentivising farm waste projects. • A lack of available investment in R & D means that high technology costs and performance issues remain prohibitive to widespread roll-out and to large scale projects.

7.4.1 Distribution by ESA

In the scenarios analysis, new projects are distributed across the region based on the availability of agricultural land within the ESA. Current baseline deployment shows a strong correlation to the available area of agricultural land within an ESA. Food waste projects would be close to urban centres.

8 Analysis and results - hydropower technology growth scenarios



Scenario	Baseline capacity 2016 (MW)	Pipeline projection to 2018 (MW)	Total scenario forecast to 2030 (MW)	Total (MW)
Gone green	69	4	13	87
Consumer power	69	4	2	76
Slow progression	69	3	1	73
No progression	69	3	1	73

Technology	Key growth drivers	Basis of forecasted ESA distribution
Hydro	• Environmental constraints • Grid availability • Subsidy availability • Ease of permitting • Availability of investment capital	• Historic trends • Hydropower resource assessment - an analysis of all obstacles on a river, including available head and flow rate from Environment Agency resource data

8.1 Baseline

There is 69 MW of hydropower installed in the South Wales licence area in 105 projects. The baseline includes kW scale hydro (usually 20-300 kW projects) and six MW scale hydro projects, including the 41 MW Rheidol Power Station.

The baseline was constructed based predominantly on WPD's connections data, which was verified with our own data on hydro projects from publicly available reports. Many small scale projects from the FiT register were added to WPD's data.

Hydropower growth has been slow, with 0.2 MW annual growth since 2008. We have excluded the 41 MW project, Rheidol Power Station, which commissioned in 2009 from the annual average, as an anomaly that is unlikely to be repeated.

8.2 Pipeline

The pipeline is based on WPD's connections data, verified using planning data. It runs until February 2018 as this is the date by which sites that are pre-accredited under the FiT need to be built out to qualify for the higher tariff. There are two large MW scale projects in the pipeline and numerous smaller kW scale projects.

We have assumed that under the Gone Green and Consumer Power scenarios, both large scale pipeline projects are built, as the investment capital remains available to finance them. Under the No Progression and Slow Progression scenarios, one of the large scale projects is built and the other is not due to lack of available investment capital.

8.3 Future growth potential

Hydropower is particularly appealing to community energy groups and landowners who are attracted to generating energy from this very visible resource in their area. Hydropower is a well-developed technology, with an established supply chain and high public approval. It is a predictable and reliable renewable energy resource and is expected to play a role, albeit relatively small in terms of generation capacity, across all the future growth scenarios.

According to the Environment Agency resource assessment, there remain a very large number of potential sites in South Wales that could be developed. However, there are a number of obstacles to current and future development, which mean that growth is limited under all scenarios. Issues affecting deployment include:

- The closure of the RO and severe reductions to the UK FiT in February 2016 mean that beyond the current pre-accredited pipeline, few new sites are expected to be developed as the subsidy available is not sufficient for the majority of sites to be economically viable. The focus will be on the higher head sites found in North Wales and Scotland; sites with onsite usage; and the refurbishment or improvement of existing sites.

- Hydropower is a relatively expensive technology to deploy, given the need for detailed technical feasibility studies, permitting requirements and high upfront capital costs. The technology is relatively mature, with limited market scale and so unlikely to see the type of cost reductions that other renewable technologies are expected to achieve. In addition, civil engineering costs make up a large proportion of installation costs and, if anything have increased since the introduction of the FiT, as regulators' expectations of good practice have been raised. Civils costs are site specific and cost reductions are therefore unlikely.
- It seems that Natural Resources Wales (NRW) is taking a more pre-cautionary approach to abstraction licensing than permitting bodies in other regions. Although other factors have limited current deployment rates, overall this means that fewer projects will be possible within a catchment area.
- In March 2016, the UK Government proposed new legislation to change fish passage powers, requiring the removal of river obstructions or the building of fish passes to provide a route around or through these hurdles. Proposed new legislation will make taking action to improve fish passage a legal requirement for owners of some critical obstructions. This legislation has been proposed previously, without success. If enacted, this would pose a new regulatory driver that may affect some new hydro projects, although many projects already include the necessary infrastructure, in order to meet existing permitting and/or good practice requirements.
- Eel regulations were introduced in 2009 and since then NRW practice has been evolving. The current interpretation of screening requirements can cause difficulties for some low head schemes.
- Business rates for renewable energy installations are due to be re-evaluated in April 2017, with the potential for large increases. The impact would reduce the economic viability of schemes further.
- There are a number of site conditions that need to be right to make a scheme viable and sites with optimal conditions tend to have already been developed. Unlike wind and solar, third party development models are more unusual, outside of the community sector, and as a result, good site conditions have to be aligned with an owner who is keen to develop a hydro project and who has the necessary finances.

8.4 Scenarios

The installation rate is highest under Gone Green, but even under this most optimistic scenario, only an annual average of just over 3 MW of hydropower would be installed.

FES Scenarios - Implications for hydro in South Wales	
Consumer Power • Current low rate of deployment is maintained • No increase to subsidies • Sites are developed that produce electricity for onsite demand, driven by farmer and landowner demand for investment projects for their available capital	**Gone Green** • Highest deployment rate but only slightly higher than current rate, with an average of 0.4 MW per annum plus one large scale project per year • NRW implements strategies and offers some economic incentives to facilitate the co-deployment of hydropower projects alongside fish passage upgrade programmes. • UK FiT is increased or a Welsh incentive for hydropower is introduced
No Progression • Very low deployment • No increase to subsidies • Permitting and ecological requirements are increased, increasing development costs	**Slow Progression** • Installation rate drops marginally below current rate focussed on sites with onsite demand, although the availability of investment capital amongst landowners is limited. • NRW implements strategies to encourage the co-deployment of hydropower projects alongside fish passage upgrade programmes, but is unable to offer additional financial incentives • No increase to UK FiT or other subsidies

In the scenarios analysis, new projects are distributed across the region based on past trends and the available hydropower resource within an ESA. The hydropower resource assessment is based on Environment Agency data, which details the location of all obstacles such as weirs, rapids and waterfalls, with the corresponding flow rates and available head.

9 Analysis and results - energy from waste technology growth scenarios

	Baseline (MW)	Pipeline (MW)	Scenarios (MW)
Gone Green	31	19	20
Consumer Power	31	19	15
Slow Progression	31	19	20
No Progression	31	19	0

9.1 Baseline

There is only one Energy from Waste (EfW) project in South Wales, the 31 MW Trident Park project in Cardiff which was commissioned in March 2015. The facility treats residual household waste from five Councils: Cardiff, Newport, Monmouthshire, Vale of Glamorgan and Caerphilly.

9.2 Pipeline

There are no incineration projects in the pipeline, with no projects in planning or with an Accepted-not-yet-Connected network application. There is, however, an advanced thermal treatment of waste site under construction in Hirwaun, near Swansea, which will process around 10 percent of the waste that arises in South East Wales. Under No Progression, we estimate the delivery of this plant will be delayed to 2020.

9.3 Future growth potential

There has been a move towards energy from waste as the landfill tax has made landfill prohibitively expensive. Landfill sites in South Wales have an estimated 10 years of spare capacity to take more waste[23]. However, the maximum waste resource is a finite amount, unless South Wales were to become a major importer of waste. The resource is also potentially a shrinking resource, as the emphasis on recycling, reusing and reducing waste increases.

New advanced thermal treatment technologies (gasification and pyrolysis) remain in their infancy in the UK and we do not expect to see the market developing sufficiently to make a sizable contribution to the mix by 2030.

[23] https://naturalresources.wales/media/2805/wales-waste-information-eng.pdf

9.4 Scenarios

We have therefore assumed that no more than one new energy from waste plant would be built in South Wales; we have not specified the technology in the scenario, but given current UK and global trends it is likely to be incineration. Cardiff's Trident Park processes 95 percent of the residual waste for the local authorities it serves, so only waste from the western areas remain available for new EfW plants. Under Gone Green and Slow Progression a larger plant is built by 2023, with a smaller plant under Consumer Power by 2026, and no new capacity under No Progression.

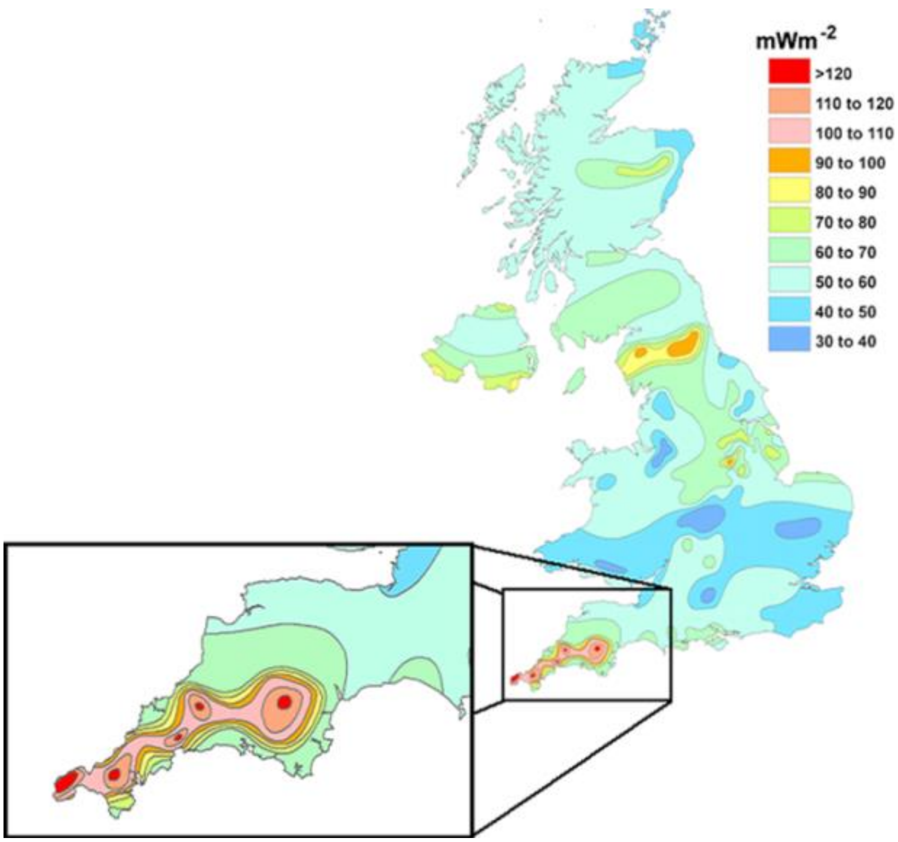
FES Scenarios - Implications for energy from waste in South Wales	
Consumer Power • Lower green ambition would lead to a smaller 15 MW plant being built by 2026 when landfill sites are due to be at capacity. • Excess waste would be incinerated without energy recovery or exported.	**Gone Green** • One new 20 MW plant would be built by 2023 to take waste from Swansea and the western areas of South Wales. • Although waste quantities would decrease due to green ambition, there would be increased emphasis on diverting from landfill and producing useable energy so waste would be processed from a wider area, justifying a 20 MW plant
No Progression • No new plants would be built. • Due to lack of investment capital and lack of green ambition, waste would continue to be landfilled until sites are at capacity (expected around 2026). Post-2026 waste would be exported or incinerated without energy recovery.	**Slow Progression** • One new 20 MW plant would be built by 2024 to take waste from Swansea and the western areas of South Wales, a year later than under Gone Green due to a slower economy. • Although waste quantities would decrease due to green ambition, there would be increased emphasis on diverting from landfill and producing useable energy so waste would be processed from a wider area, justifying a 20 MW plant.

10 Analysis and results - deep geothermal

Deep geothermal uses high temperature rocks (> 150 ^{o}C) at a depth of approximately four to five kilometres to produce surface heating, cooling, and steam generated power. This is achieved by injecting water down one well, and then abstracting it by another once it has been superheated by the rock. Deep geothermal projects can provide energy for up to 50 years.

The South Wales licence area does not have the right geology to accommodate deep geothermal plants.

Deep geothermal resource map



11 Analysis and results - energy storage technology growth scenarios

11.1 Technology overview and future growth potential

The potential development of energy storage has been the subject of significant market interest in the last year. In part this interest has been driven by falling technology costs and the recognition that, as the UK electricity system develops to meet the challenge of decarbonisation while maintaining energy security, the value of flexibility is set to greatly increase in the medium to long term. The National Infrastructure Commission report on Smart Power (2015)[24] has estimated the value of flexibility, compared with a strategy to only invest in infrastructure and capacity, could be worth over £8 billion a year to the UK energy system.

Energy storage is one of a number of new market areas which could grow to harness this value. Other market areas include demand side response, inter-connectors and other system balancing technologies.

The Committee on Climate Change Power Sector Scenarios for the Fifth Carbon Budget report[25] estimates that there are around 200 MW capacity of demonstration and pilot storage projects across the UK. The report scenario assumes growth of up to 10 GW of distributed storage across the UK by 2030, providing both reserve and frequency response, in addition to the current 2.7 GW of pumped storage. The report however highlights that such growth is contingent upon successful trials, further cost reduction and the 'regulatory and legal' clarification of energy storage technology.

The National Grid 2016 Future Energy Scenarios also recognises the potential of energy storage to grow in the coming decade. Their scenario analysis presents a large range of Energy Storage outcomes and capacities.

Scenario	Baseline capacity 2016 (MW)	Pipeline projection to 2017 (MW)	Total scenario forecast to 2030 (MW)	Total (MW)
Gone green	3	1.5	35	39
Consumer power	3	1.5	10	14
Slow progression	3	1.5	15	19
No progression	3	1.5	4	8

[24] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/505218/IC_Energy_Report_web.pdf

[25] CCC 5th Carbon Budget Report Nov 2015

Technology	Key growth drivers	Basis of forecasted ESA distribution
AD	• Government support • Grid availability • Waste policy	• Agricultural land distribution • Large population centres

National Grid Future Energy Scenario 2016 – Electricity Storage 2040

Scenario	Transmission Connected (GW)	Distribution Connected (GW)	Sub 1 MW (GW)	Total Electricity Storage (GW)
Gone green	5.9	3.8	1.7	11.4
Consumer power	4.1	13.2	1.0	18.3
Slow progression	3.9	2.3	0.2	6.4
No progression	3	0.5	0.1	3.6

The large range of potential FES capacity growth outcomes is in part a reflection of the rapidly changing landscape for energy storage, including the anticipated development of new technologies and falling technology costs. It also reflects the very wide range of potential energy storage applications, from very small domestic and vehicle systems (which could be aggregated), to larger commercial and utility scale storage systems.

The very high levels of energy storage achieved under the Consumer Power scenario outcome is attributed to the higher levels of distributed generation and the opportunities for local network system balancing to peak shave variable generation and demand.

11.1.1 Emerging business models

Part of the attraction of energy storage is that it can provide a number of different functions within the future energy system. A key challenge for the industry is to create viable (long term) business models which are attractive to investors and ultimately bankable. The good news is that given energy storage's intrinsic value to provide an energy reserve, rapid response and the time/price shift of energy demand or supply, there are plenty of value streams to tap into. The difficulty is to combine revenue streams in a way which is compatible within the technical, regulatory and commercial constraints of the current market.

Growth factors in the short term will be the rate of cost reductions, the firmness of combined revenue streams, the clarification of regulation and improvements in how National Grid and DNOs procure services.

Energy Storage Functionality and value Streams	
Energy Reserve	"The ability to store and discharge energy when it is needed" Potential uses include capacity reserve (large scale), short term operating reserve (STOR) and local network balancing services. The Dinorwig pumped storage facility is used to provide STOR services.
Response Services	"The ability to respond quickly (milliseconds – minutes) to grid, frequency and/or price signals" Potential applications include the provision of ancillary network services such as frequency response and voltage support.
Time and price shift	"The ability to shift energy from lower to higher price/cost periods" Potential applications include price arbitrage, transmission and distribution cost avoidance and peak generation shaving.

A key challenge and opportunity for energy storage technologies is to develop and adapt new business models that will allow storage solutions to generate revenue and/or enhance services. The consensus in industry and amongst analysts is that combining several revenue streams, utilising the full value proposition and functionality of energy storage, new projects will be financially viable. The challenge however is to combine revenue streams which are compatible (technically and commercially) and to overcome some of the regulatory and market barriers.

Energy Storage – Emerging Revenue Streams		
Storage Function	**Revenue stream**	**Description/characteristics**
Reserve	**Capacity market**	The Capacity Market is part of the Electricity Market Reform programme to ensure the future security of our electricity supply. The Capacity Market offers all capacity providers (new and existing power stations, electricity storage and capacity provided by voluntary demand reduction) a steady, predictable revenue stream on which they can base their future investments. In return for Capacity Payments revenue, providers must deliver energy at times of system stress, or face penalties.
	Backup Power	Back-up generation for high and critical energy users in response to grid transmission shutdowns.

	STOR (Short Term Operating Reserve)	Short Term Operating Reserve (STOR) is a service for the provision of additional active power from generation and/or demand reduction. Required to offer a minimum of 3MW or more of generation or steady demand reduction. STOR is a service for the provision of additional active power within 240 minutes or less from receiving instructions from National Grid. Provide full MW for at least 2 hours when instructed.
	Fast Reserve	Fast Reserve is used, in addition to other energy balancing services, to control frequency changes that might arise from sudden, and sometimes unpredictable, changes in generation or demand. Active power delivery must start within 2 minutes of the despatch instruction at a delivery rate in excess of 25MW/minute, and the reserve energy should be sustainable for a minimum of 15 minutes. Must be able to deliver minimum of 50MW.
Response	**Mandatory Frequency Response**	Mandatory Frequency Response is an automatic change in active power output in response to a frequency change and is a Grid Code requirement. Primary Response - provision of additional active power (or a decrease in demand) within 10 seconds after an event and can be sustained for a further 20 seconds. Secondary Response - provision of additional active power (or decrease in active power demand) within 30 seconds after an event and can be sustained for a further 30 minutes. High Frequency Response - the reduction in active power within 10 seconds after an event and can be sustained indefinitely.
	Firm Frequency Response (FFR)	Firm Frequency Response (FFR) is the firm provision of Dynamic or Non-Dynamic Response to changes in Frequency. Unlike Mandatory Frequency response, FFR is open to BMU and non-BMU providers, existing Mandatory Frequency Response providers and new providers alike. Must be able to deliver a minimum of 10 MW response power.
	Enhanced Frequency Response (EFR)	A new service aimed predominantly at storage assets to provide frequency response in 1 second or less. Enhanced frequency response is defined by National Grid Electricity Transmission as being frequency that achieves 100% active power output at 1 second (or less) of registering a frequency deviation. This is in contrast with existing frequency response services of Primary and High which have timescales of 10 seconds, and Secondary which has timescales of 30 seconds.

Time and price shift	**Triad avoidance**	Triads are the three half-hour settlement periods with highest system demand and are used by National Grid to determine charges for demand customers with half-hour metering and payments to licence exempt distributed generation. They can occur in any half-hour on any day between November to February inclusive but are separated from each other by at least ten full days.
	Transmission Network (TNuOS) charge avoidance	Transmission Network Use of System (TNUoS) charges recover the cost of installing and maintaining the transmission system in England, Wales, Scotland and offshore. Transmission customers pay a charge based on which geographical zone they are in, whether they are generation or supply and the size of that generation or supply.
	Distribution Use of System DUoS	Reducing distribution network demand in order to avoid times pf peak distribution network charges - "red zones"
	Load levelling	Load levelling usually involves storing power during periods of light loading on the system and delivering it during periods of high demand. During these periods of high demand, the energy storage system supplies power, reducing the load on less economical peak-generating facilities. Load levelling allows for the postponement of investments in network upgrades or in new generating capacity.
	Peak Shaving	Peak shaving is similar to load levelling, but may be for the purpose of reducing peak demand rather than for economy of operation. The goal is to avoid the installation of capacity to supply the peaks of a highly variable load. More used for industrial and commercial customers who want to avoid peak prices on energy bills, i.e. on half hourly metering energy bills are made up of actual usage and peak demand. Peak shaving reduces peak demand and hence makes energy bill cheaper.
	Own use arbitrage	by enabling domestic and industrial energy users to utilise own energy generation e.g. PV, Wind and CHP
	Price Arbitrage	purchasing (storing) energy when electricity prices are low, and selling (discharging) energy when electricity prices are high

11.1.2 Technology development and falling costs

While hydro and pumped storage has been around for some time, the industry focus for new storage projects has been on the potential of battery storage. Underlying factors include the rapid fall of battery costs and growth of variable generation, while the demand for flexibility increases. National Grid's 200 MW Enhanced Frequency Response tender at the beginning of 2016 led to 1.8 GW of applications, 88 percent of which were from battery storage providers.

Main energy storage types and example technologies

Storage type	Example technologies
Primary storage	Super-conductors magnetic ES Capacitors
Mechanical storage	Pumped hydropower, flywheels, compressed air
Electrochemical energy storage (batteries)	Classic solid state batteries Lead/acid, Lithium-Ion, Lithium-S, Lithium-Polymer, metal air Sodium-Ion, Sodium-Sulphur, Nickel-Cadmium and many others Flow batteries Vanadium rodox, Zinc – bromine
Chemical energy storage	Hydrogen, synthetic natural gas
Thermal energy storage	Heat – water, heat packed bed, molten salts and others

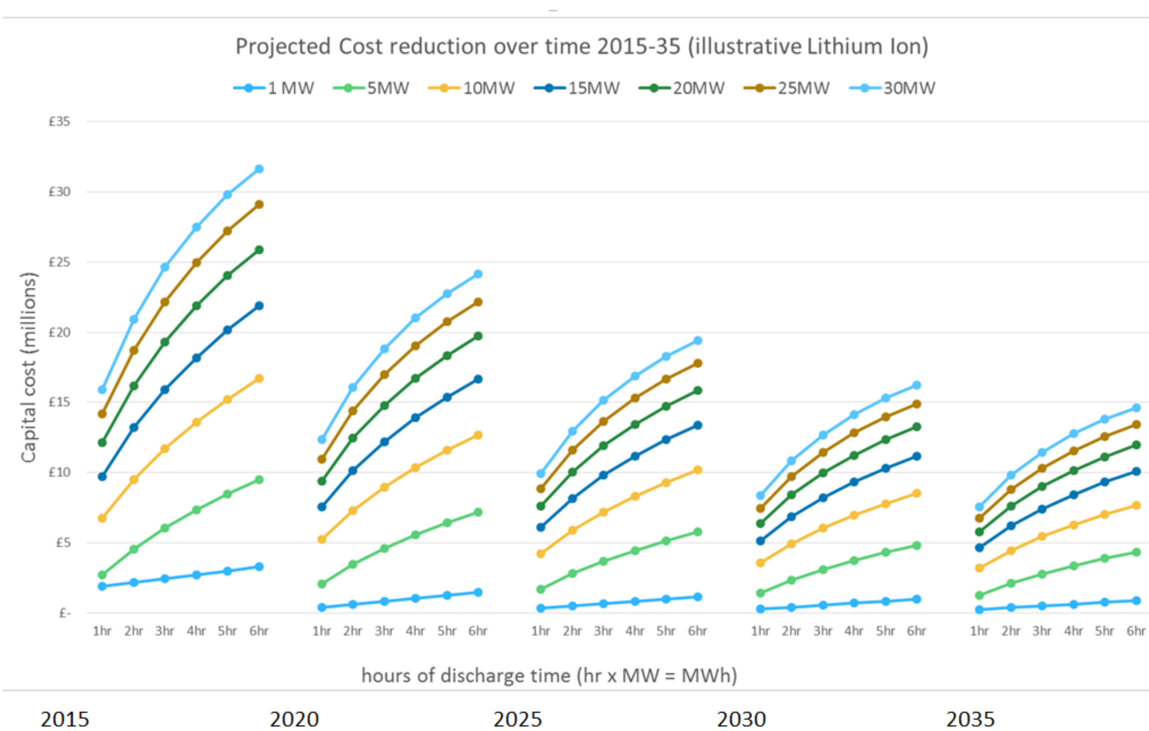
Energy storage costs have fallen significantly and are set to continue to fall into the next decade. Domestic batteries for home-use energy storage are still expensive and without subsidy. Domestic systems currently quoted at £2-3k allowing a potential payback period of 10-14 years depending on their application. At a larger scale, there are now a number of container sized[26] battery solutions with a storage rating of 1-2 MWh, with the potential to be stacked, that could be used to provide larger commercial energy storage "farms".

Lithium based batteries are currently dominant in the UK energy storage market, but several other battery technologies are being developed and may prove both cheaper and more environmentally friendly in the longer term. Sodium based batteries, for example, are being used extensively in other European markets and could provide a solution for larger storage over longer discharge periods.

Example: Electrovaya MWh scale storage solution

[26] http://www.pv-magazine.com/fileadmin/PDFs/pv-magazine_Storage_Special_Jul_2015.pdf

Regen's analysis suggests that energy storage costs will fall rapidly due to both economies of scale for larger systems and technology/market development over time. As a general rule energy storage systems are expected to increase in both power and storage capacity over time. While economies of scale and the requirements of rapid response to provide frequency response services will tend to focus storage systems towards relatively high energy output (MW), falling battery costs and access to wider reserve and Time/Price Shift revenue streams will see a shift towards high storage capacity (MWh) systems.



11.2 Current Welsh energy storage baseline and pipeline applications

Energy storage is not new to Wales and in fact the 1.8 GW Dinorwig power station in Snowdonia, which was commissioned in 1984, is the largest pumped hydro storage scheme in the UK and one of the largest in Europe. Newer examples of pumped storage include the Quarry Battery in Glyn Rhonwy. According to the latest Committee on Climate Change report, there is circa 2.7 GW of pumped storage capacity in the UK able to store around 30GWh of electricity.

Domestic and small scale battery storage has begun to make an impact and a number of PV related battery solutions are now available to buy. Unfortunately, domestic energy storage systems are not registered through an accreditation system and therefore it is difficult to estimate numbers installed, except by speaking to suppliers and installers. Having spoken with a number of suppliers Regen has estimated that the numbers deployed are relatively small, numbering in the tens to low hundreds across the UK. We have therefore assumed a baseline of zero installed capacity within the South Wales licence area.

There are a number of larger scale commercial battery storage projects across the UK. An example demonstration project just outside the South Wales licence area is the WPD SoLa Bristol project, which is a consumer based 'own use scheme'.

There are a larger number of demonstration and pilot projects across the UK. The majority of projects are aimed at renewables capacity firming applications, voltage support and energy time shift[27]. Examples include:

- Network support service schemes e.g. WPD Falcon, SSE Shetland NINES 1MW battery, SSE Orkney Energy Storage Park, Smarter Network Storage Bedfordshire,
- Consumer support 'own use' for domestic and commercial customers e.g. WPD SoLa Bristol, Moixa, SSE Zero Carbon Homes.

To date, there are no larger scale battery storage projects installed within the South Wales licence area.

11.2.1 Grid connection application pipeline

While the number of installed and operational energy storage projects is extremely small, the number of new projects coming through the pipeline has jumped significantly in the past twelve months. This has affected all DNO licence areas. Requests to connect storage to the distribution network are rapidly increasing, with Western Power Distribution and UK Power Networks alone receiving over 11 GW of applications in England and Wales.

Many of these applications have been made on the back of the recent tender for Enhanced Frequency Response, however, it is also the case that energy storage project developers are looking at a number of potential revenue streams and applications.

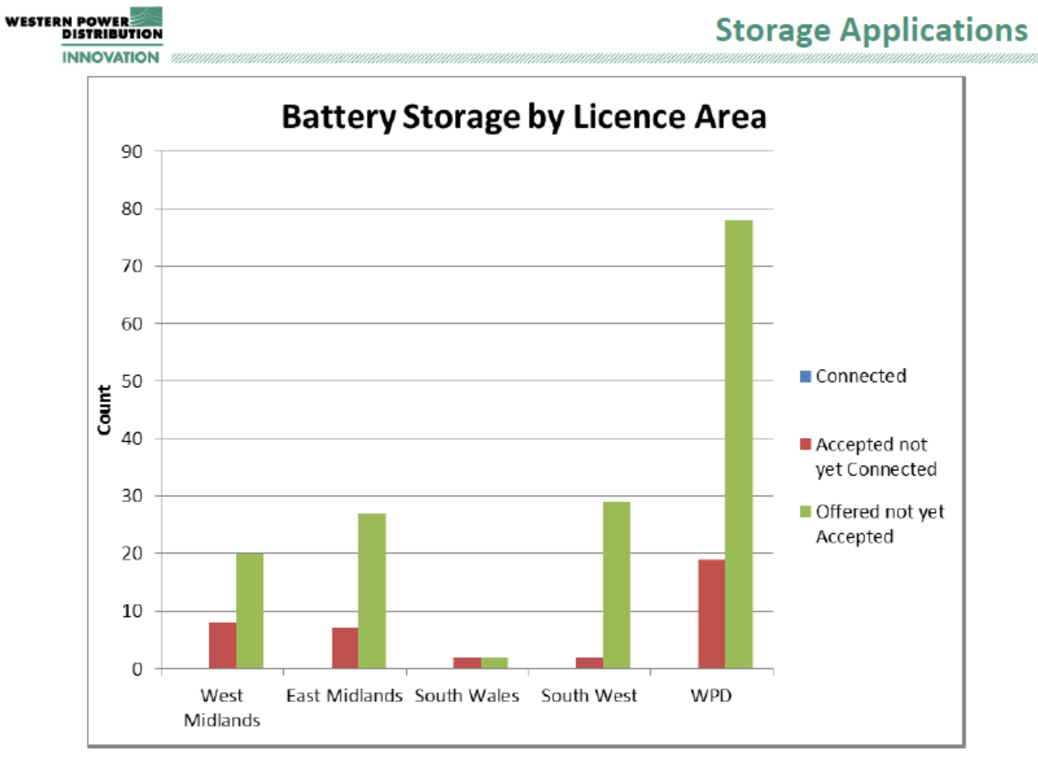
Given that the first wave of energy storage projects has been focused on the provision of ancillary services to the network, including Enhanced and Firm Frequency Response, it is unsurprising that project developers have tended to make and accept network connection offers in geographic areas where there is ready access to the distribution network and transmission grid.

For this reason, the bulk of applications have been made in central licence areas in the midlands rather than in the periphery areas such as South Wales and the further South West peninsula. The network constraints already present in South Wales and the requirement to submit a Statement of Works to National Grid has been a key factor dissuading the first wave of battery storage developers from South Wales.

As of June 2016, there are two battery storage projects in the South Wales licence area with an Accepted-not-yet-Connected network connection agreement in place, totalling 30MW of export capacity.

---

[27] Top Markets for Energy Storage in Europe 2015 Update



11.3 Energy storage growth in South Wales by scenario analysis to 2030

From the analysis above it is clear that energy storage is starting from a very low base in the South Wales licence area. There are a handful of domestic energy storage installations and potentially two larger battery storage projects in the connection pipeline, with a combined capacity of 30 MW.

Against this low baseline, it is recognised that energy storage could grow to become a significant technology within the UK's energy system. The overall Future Energy Scenario analysis for the UK shows a potential deployment up to 18.3 GW under the Consumer Power scenario.

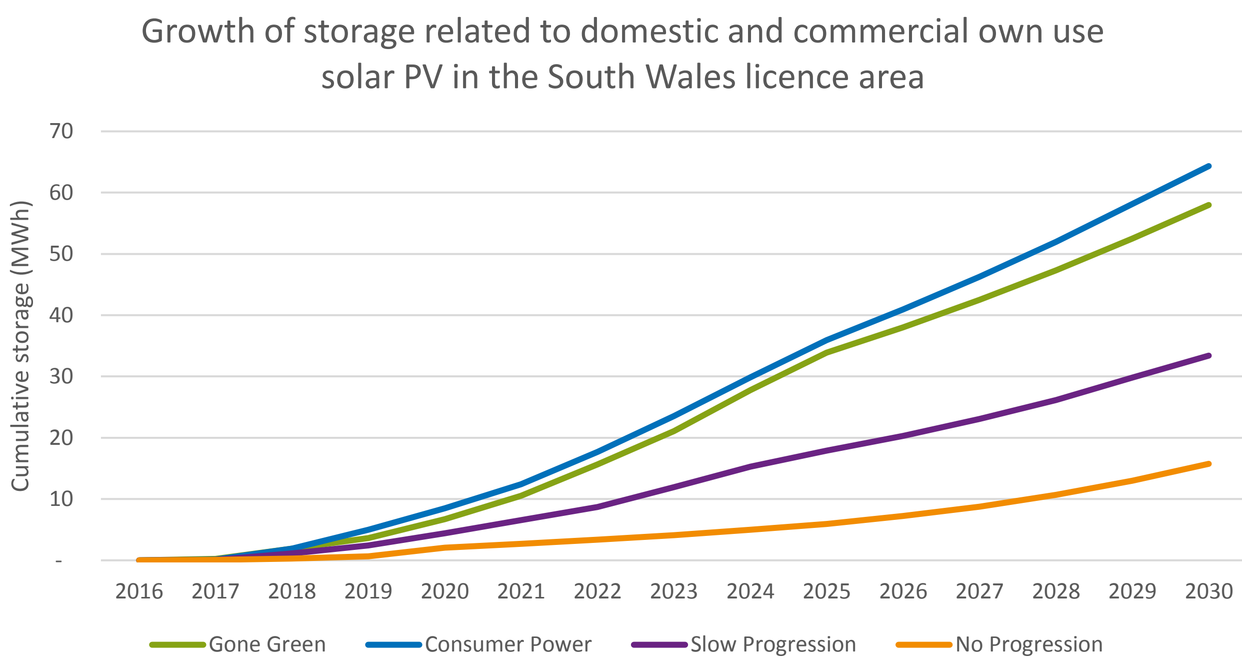
It is anticipated that energy storage deployment is likely to come in a number of "waves".

11.3.1 Projection of domestic and small scale energy storage in South Wales to 2030

In the medium term, the growth of domestic and small scale energy storage is likely to be linked to the growth of new PV installations and a degree of retrofit to existing PV installations.

Domestic and small scale energy storage – High growth scenarios Consumer Power and Gone Green

Time frame/wave	Market growth drivers	South Wales deployment scenarios for Consumer Power and Gone Green
Wave 1 Early adopters 2016-2020	Given high costs and the absence of subsidy support - long payback periods (10-14 years) inhibits domestic energy storage installation.	Tens to potentially hundreds of energy storage installations mainly associated with new and existing PV installations. But numbers remain low. Adoption by social housing providers could be a key growth driver.
Wave 2 Integrated systems 2020-25	Falling battery costs and the easy availability of integrated systems means that domestic energy storage becomes a common option alongside domestic and commercial rooftop PV assuming some regulatory changes. Time of use settlement and half hourly billing – enabled by smart meter technology roll out are key enablers.	An increasing proportion of new PV installations include energy storage as an integrated option. 40-50% of new PV installations include energy storage. 10-20% of existing PV installations retrofits energy storage.
Wave 3 Fitted as standard 2025-30	Falling costs and the ability to aggregate energy storage solutions to access additional revenue streams means that energy storage is now fitted as standard alongside PV installations.	Under Consumer Power a very high proportion (70%) of new PV installations include energy storage. Potentially reaching 4-5% of South Wales' households by 2030. The proportion of energy storage installed with new PV under Slow and No Progression is less and with a lower install base the growth of energy storage is limited.
Wave 4 Ubiquitous energy storage 2030 onwards	Under Consumer Power (and to a lesser extent Gone Green) energy storage becomes a ubiquitous technology linked to smart systems, domestic appliances and electric vehicles. Aggregators – enabled by ICT integration – are able to exploit additional revenue streams.	South Wales would benefit from the smart power revolution with widespread use of energy storage across a range of applications.



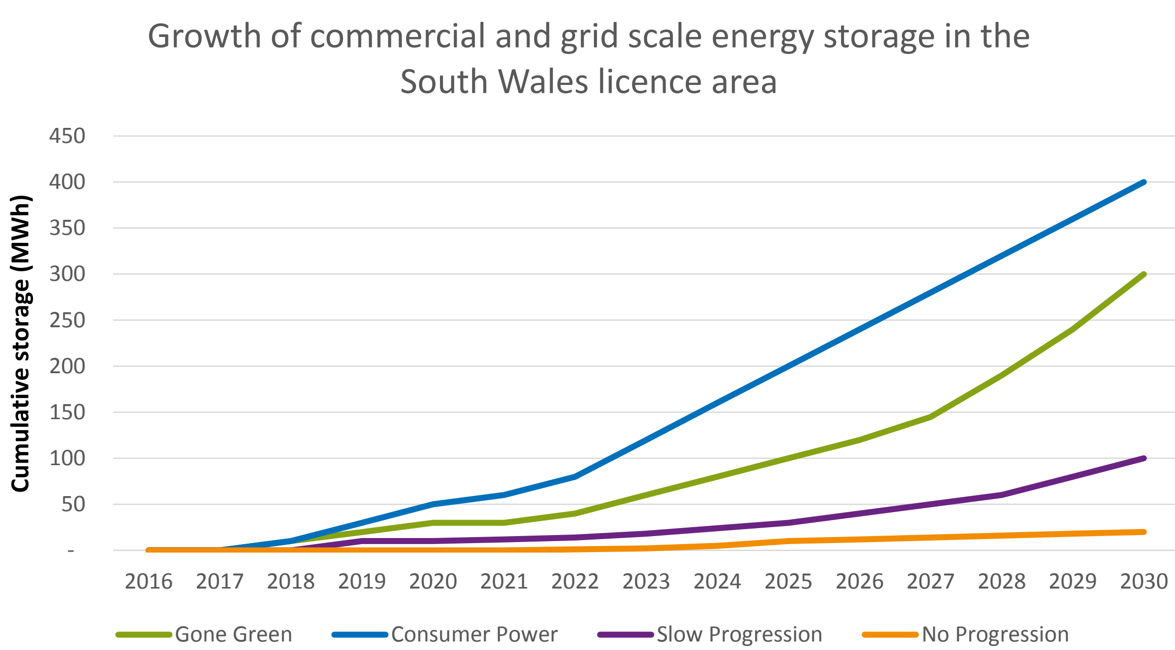
	Baseline 2016			2020 (cumulative)			2025 (cumulative)			2030 (cumulative)		
	Retrofit MWh	New projects MWh	Total 2016 baseline MWh	Retrofit MWh	New projects MWh	Total 2020 MWh	Retrofit MWh	New projects MWh	Total 2025 MWh	Retrofit MWh	New projects MWh	Total 2030 MWh
Gone Green	0	0	0	3	2	5	16	18	34	18	40	58
Consumer Power	0	0	0	4	2	7	16	20	36	18	46	64
Slow Progression	0	0	0	2	2	3	8	10	18	10	24	33
No Progression	0	0	0	1	1	2	1	5	6	2	14	16

11.3.2 Projection of commercial and distribution network scale energy storage in South Wales to 2030

Commercial and network scale energy storage –High growth scenarios Consumer Power and Gone Green

Time frame wave	Market growth drivers	South Wales connected to distribution network for Consumer Power and Gone Green
Wave 1 Ancillary Services 2016-2019	Focus on higher value services such as Enhanced and Firm Frequency response but potentially including secondary revenue streams e.g. Triad avoidance. High value services but a limited market size. System focus is on high MW output delivered within a very rapid response time.	Limited projects in South Wales owing to existing network constraints. **Typical Project scale** Power Output 10 MW Discharge Cap. 10-20 MWh **Installed capacities:** 30-50 MW 30-60 MWh
Wave 2 “Own Use” 2018-25	Falling costs begin to make behind the meter applications more viable to take advantage of “own use” electricity generation and avoid transmission and distribution charges. Focus on higher energy users with time of use tariffs and half hourly billing.	Growth of commercial projects co-located with energy generators and high energy users. **Typical Project scale** Power Output 1-5 MW Discharge Cap. 2-10 MWh **Installed capacities:** 100-200 MW 200-400 MWh
Wave 3 Price Time Shift 2022-30	Under Consumer Power and Gone Green scenarios - generation support and price arbitrage supports broader peak shaving and local network system balancing as energy storage reaches its full potential providing greater system flexibility. Energy storage displaces existing STOR service providers, as well as providing local network balancing to DSO’s.	Rapid growth of storage projects as energy users and generators take advantage of price arbitrage opportunities. **Typical Project scale** Power Output 20-50 MW Discharge Cap. 50-150 MWh **Installed capacities:** 300-400 MW 800-1400 MWh

	System focus moves to higher capacity discharge (MWhs) as battery storage costs fall rapidly.	
Wave 4 Multi-vector System and network balancing By 2040	Widespread use of energy storage for local network balancing. Energy storage applications linked to transport infrastructure.	Installed capacities under Gone Green and Consumer Power: **Typical Project scale** Power Output 20-50+ MW Discharge Cap. 50-150 MWh **Installed capacities:** 700-1000 MW 1500-2400 MWh



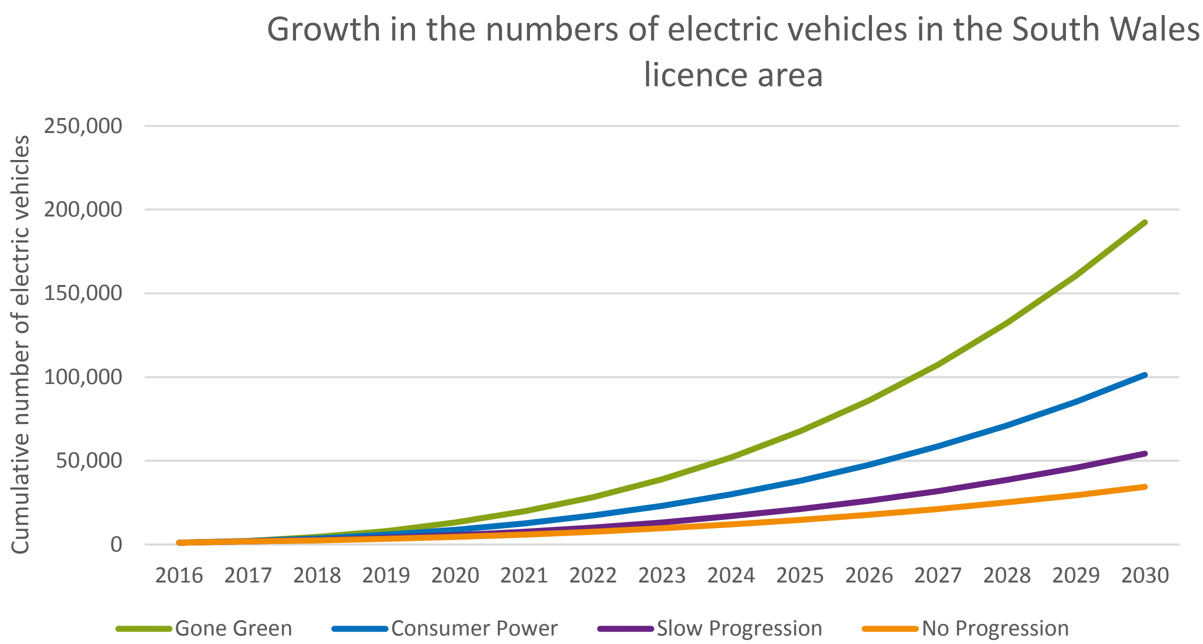
11.3.3 Geographic distribution of 'own use' energy storage to 2030

The distribution of domestic energy storage is correlated with the deployment of domestic and other rooftop PV installations.

The distribution of commercial scale energy storage is expected to be concentrated in ESAs with:

- High energy users
- Commercial and industrial "brownfield" sites
- Easy access to the distribution and transmission network.

12 Analysis and results - electric vehicles technology growth scenarios



Technology	Key growth drivers	Basis of forecasted ESA distribution
Electric cars	• Public awareness • Cost reductions • Electric car infrastructure • Technology innovation • Discount/ grant • Economic prosperity	• Total number of households • Historic PV trends

12.1 Baseline

The baseline has been constructed using data from the Department for Transport's plug-in vehicles grants scheme, which is available on a local authority basis. This data allows us to look at how many electric vehicles are being bought in South Wales each year, how many in each local authority and what percentage those are of the total vehicles purchased.

The number of electric vehicles on the UK's roads doubled over the last year, fuelled by falling costs and government grants. There are now over 60,000 electric vehicles on the roads in the UK.

The UK government has committed to make nearly every vehicle in the country zero-emission by 2050 and has developed a multi-stranded funding programme to enable the shift:

- The plug-in vehicle grant opened in 2011, with the aim of supporting the purchase of 50,000 electric vehicles by February 2016. Having achieved that aim, the government announced a £400 million extension to the scheme to fund a further 100,000 vehicles up to March 2018.
- A grant for 75 percent of home charge point costs is currently available.
- Nottingham, Bristol, London and Milton Keynes have been awarded shares of £40 million to improve their electric vehicle infrastructure. Further rounds of funding may be available for other cities under this programme.

Meanwhile, costs have fallen and continue to fall considerably, while vehicle performance and infrastructure improves. As a result, the rate at which new electric vehicles are purchased has tended to grow each quarter since the plug-in grants scheme started.

In South Wales, 1,058 electric vehicles have been purchased to date through the plug-in grants scheme. Electric vehicle purchases are lower than the national average in South Wales, although the location of sales across the UK is skewed towards localities where there is a major leasing firm, such as Lex Autolease in Birmingham.

12.2 Future growth potential and scenarios

There is no pipeline for electric vehicle purchases. It is assumed growth will remain steady for the next few years under all scenarios supported by the UK government plug-in grants until March 2018, with uptake then taking off more significantly in the 2020s.

We have considered both the number of new vehicles that would be purchased under each scenario and the proportion of those that would be electric. As a result, with more cars bought each year in Gone Green, and a higher percentage of them being EVs, there are many more EVs than in No Progression in which both fewer cars are bought and a lower percentage of them are EVs.

The 2016 FES predicts the number of electric vehicles in Great Britain will grow to between approximately 1,163,000 (No Progression) and 5,814,000 (Gone Green) in 2030. We have estimated that a Gone Green scenario in South Wales would result in higher levels of EV purchases than the FES estimates for the UK. We feel that the FES estimates for the UK under Gone Green are lower than could occur. Also, in South Wales, the Welsh government has the potential to invest in the supporting infrastructure and incentives to support deployment to achieve a higher level than the UK average.

We have not been able to include the concept of driverless cars in our projections as it is too early to predict the effect this innovation will have on the vehicle market.

	Growth in number of electric vehicles			
	Baseline	2020	2025	2030
Gone Green	1,069	13,051	67,564	192,419
Consumer Power	1,069	8,770	38,050	101,263
Slow Progression	1,069	5,485	21,177	54,254
No Progression	1,069	4,483	14,631	34,423

In order to have this many electric vehicles on the road, between 7 to 40 percent of all vehicles sold will be electric by 2030, up from 0.6 percent today. The table below summarises the numbers of cars and the percentage of total car sales the EVs represents for each scenario, for the South Wales licence area.

There is significant growth potential for electric vehicles, which will result in increasing demand on the electrical network. Therefore, as well as numbers of vehicles, we have modelled the peak energy demand for the South Wales license area based on FES peak energy demand data.

Summary of peak demand by scenario for the South Wales licence area

	Peak electric demand from electric vehicles (MW)			
	Baseline	2020	2025	2030
Gone Green	1	9	40	117
Consumer Power	1	7	30	81
Slow Progression	1	4	15	37
No Progression	1	4	12	30

FES Scenarios - Implications for electric vehicles in South Wales

Consumer Power

- Medium numbers of EVs sold
- Current UK incentive programme continues but is not replaced post-March 2018.
- Electric vehicles are perceived as a desirable purchase, driving a market led by consumers who have the available capital to invest in new vehicles
- R & D investment improves the performance and reduces the cost of EVs
- Lack of public sector investment in infrastructure limits purchases to those with off-road parking, restricting the overall market size.

Gone Green

- High numbers of EVs sold – above FES prediction
- Public sector invests in supporting infrastructure, such as on road charge points in residential areas, which enables householders without off-road parking to invest.
- UK government or Welsh government continues a programme to incentivise consumers to purchase new vehicles.
- Thriving economy and green ambition enables and encourages consumers to invest
- R & D investment improves the performance and reduces the cost of EVs

No Progression

- Low numbers of EVs sold
- Current purchasing rate continues, below UK national average.
- Current UK incentive programme continues but is not replaced post-March 2018.
- Due to a weak economy, fewer consumers have the available capital to invest in new cars and consumers take longer to discard older vehicles.
- Slow uptake continues post-March 2018 as battery and EV prices are reduced gradually by the global market

Slow Progression

- Lower numbers of EVs sold
- Public sector led invests in supporting infrastructure, such as on road charge points in residential areas, which enables householders without off-road parking to invest.
- UK government or Welsh government continues a programme to incentivise consumers to purchase new vehicles.
- Due to a weak economy, fewer consumers have the available capital to invest in new cars and consumers take longer to discard older vehicles.
- Battery and EV prices are reduced gradually by the global market

12.2.1 Modelling growth to ESA

Growth under the scenarios has been allocated spatially. Analysis of existing purchases found a strong correlation between EV purchases and the number of homes in an area and the historic rate of PV purchases. The strongest correlation for historic EV purchases was found when ESAs were weighted 60:40 for number of homes and historic PV installations. As a broad demographic, those with solar panels are more likely to be early adopters of electric vehicles, due to both their willingness to invest and interest in green technologies.

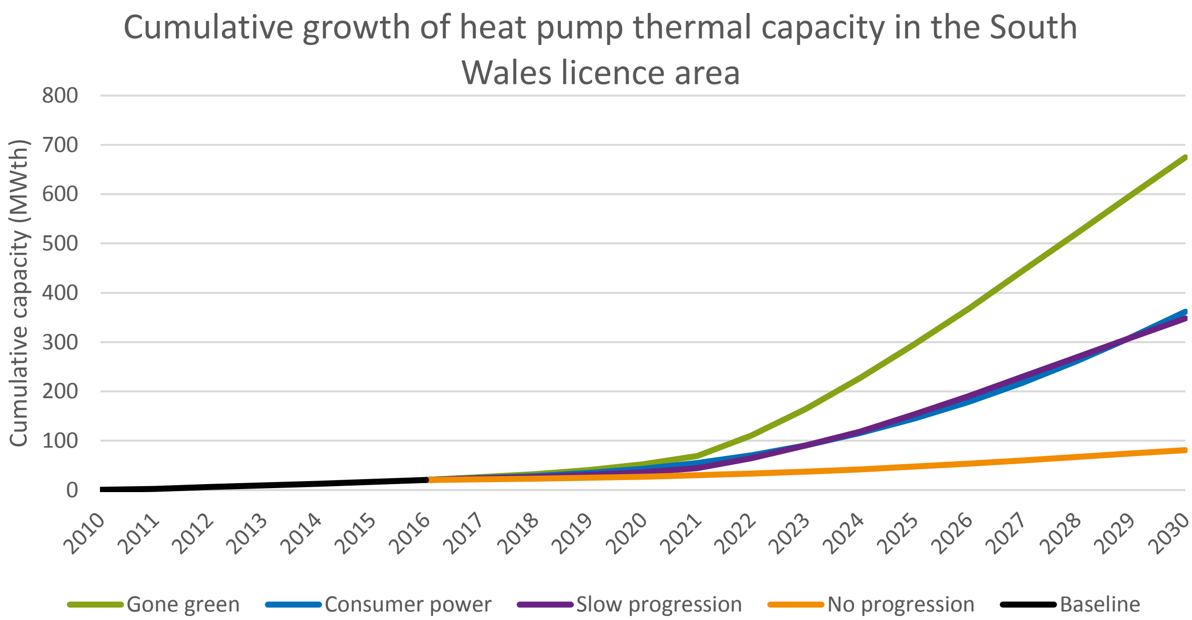
For the projections to 2030, different scenarios are weighted differently for number of homes and historic PV installations, with affluence introduced as another influence. In the Consumer Power scenario, the number of purchases is driven by a consumer-led market and a lack of investment in on-road charging infrastructure means purchases are limited amongst those without off-road parking. Therefore, under the Consumer Power scenario, we have weighted the spatial distribution more heavily towards areas with higher levels of affluence. In the Gone Green scenario, government investment in both on-road charging infrastructure and in incentivising purchases means that both affluence and the ability to purchase a PV system is less of an indicator of a household's ability to purchase an electric vehicle. So for the spatial distribution of growth under this scenario, the ratio is weighted slightly more towards number of homes.

12.2.2 Peak electric vehicle demand

Peak electric vehicle demand was modelled on the FES 2016 analysis of the relationship between the number of vehicles and the peak demand. This changes by scenario, and also changes between 2016 and 2030.

13 Analysis and results - heat pumps technology growth scenarios

13.1 Summary distributed generation growth scenarios 2016-2030



Baseline and scenario thermal capacity summary

	Baseline (MWth)	Baseline percentage of houses with heat pumps		2030 scenarios percentage of retrofit houses with heat pumps		2030 retrofit installations (MWth)		Total 2030 retrofit (MWth)	Total 2030 new build capacity (MWth)
		Off gas houses	On gas houses	Off gas houses	On gas houses	Off gas houses	On gas houses		
Gone Green	20.4	0.23 %	0.04 %	6.5 %	1.8 %	118	167	285	390
Consumer Power	20.4	0.23 %	0.04 %	5.2 %	1.2 %	94	111	206	156
Slow Progression	20.4	0.2 3%	0.04 %	3.5 %	0.8 %	64	74	138	211
No Progression	20.4	0.23 %	0.04 %	1.5 %	0.4 %	27	37	64	17

Technology	Key growth drivers	Basis of forecasted ESA distribution
Heat pumps	• Government support • Technology performance • Price parity • Public awareness • Building regulations	• Distribution of off gas houses • Distribution of on gas houses • Historic trends • Number of houses • New build house location

13.2 Heat pumps – future energy potential

Heat pumps (ground source and air source) are at present a small but growing part of the UK energy market. If deployed in significant numbers heat pumps could potentially place a significant additional demand on the network, especially at peak times, when electricity is used to augment the heat energy extracted from ground and air sources.

A number of studies commissioned by the UK Government and other bodies have predicted that heat pumps could become a key technology to enable the decarbonisation of heat energy generation in the UK. For example; in the 'The Future of Heating: Meeting the Challenge' (2013), the Department of Energy and Climate Change (DECC) predict that heat pumps will be the main heat source for off-gas rural and suburban areas in the future. In addition, UK government policy has combined with improving technology, so that we now have heat pumps directly competing for the on-gas market through the development of hybrid air source heat pumps (ASHP). Hybrid systems enable customers to use the ASHP at times when electricity is cheaper than gas. Heat pumps may also be used to supply heat networks, with a pilot in construction at EON's Cranbrook network, near Exeter, Devon. Across the UK, from 14,000 units in 2012, BSRIA[28] expected 26,000 ASHP systems to be sold in 2015, reaching 50,000 by 2017 – all largely driven by the owner/occupier market[29]. The Committee on Climate Change's Fifth Carbon Budget has decreased its target for the number of heat pumps in homes by 2030 from 4 million to 2.3 million. This is the 'minimum that could keep deep decarbonisation of heat in buildings in play for 2050'[30].

Despite this potential, the number of heat pump installations across the UK to date has fallen well below these estimates, reflecting that there are still a number of significant challenges to growth. In summary these challenges include:

- A natural inertia against domestic and commercial customers replacing heating systems
- Higher upfront capital costs – which has not been overcome by grant and Renewable Heat Incentive schemes
- Practical constraints – e.g. land space and bore holes for ground source heat pumps.
- The need for well insulated homes and ideally underfloor heating solutions - heat pumps work best providing low-grade heating that requires relatively air-tight, well insulated properties to achieve cost effectiveness
- Public awareness of heat pumps remains low. DECC's Public Attitudes Tracker found in 2015 that 33 percent of those surveyed were aware of air source heat pumps and 40 percent were aware of ground source heat pumps, with less than 5 percent feeling that they knew a lot about the technologies[31].

[28] Building Services Research and Information Association
[29] http://www.phamnews.co.uk/the-right-conditions-for-market-growth/
[30] https://d2kjx2p8nxa8ft.cloudfront.net/wp-content/uploads/2015/11/Sectoral-scenarios-for-the-fifth-carbon-budget-Committee-on-Climate-Change.pdf

[31] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/474170/Wave_15_Summary_of_Key_Findings.pdf

- Doubts and concerns about heat pump performance – partly driven by some poor installations but also some critical studies – and their reliance on electricity as the main backup and augmentation energy source.

13.3 South Wales historic growth and baseline capacity to 2016

The baseline data for heat pumps in the South Wales licence area is based on our analysis of the Welsh Government's Low Carbon Generation in Wales data. We were able to calculate the numbers and capacity of heat pumps in each ESA, analyse the growth over time and investigate the driving factors of heat pump deployment within the licence area.

The South Wales licence area has seen small increases year on year in the growth of heat pumps installations, but figures remain below the UK national average and insufficient to meet the UK government's objectives in relation to the electrification of heat.

Our data shows that there is 20 MW of installed thermal heat pump capacity in the South Wales licence area.

The geographic spread is heavily influenced by the number of off-gas network properties and it is estimated that as many as 80% of all heat pump installations are associated with off gas properties (0.23% of off-gas homes having heat pumps and 0.04% of on gas). Nearly half of all heat pumps in the South Wales licence area are in the ESAs covering Pembrokeshire, Carmarthenshire, Ceredigion and Powys, despite these ESAs accounting for only a fifth of houses in South Wales. These areas are the main off-gas ESAs, with one ESA, Ammanford, Carmarthen, Rhos, Lampeter & Llanarth, having over 65 percent of the properties off the gas network. There is therefore a strong correlation between the number of heat pumps within an ESA, and the number of off gas properties, with urban on gas areas showing much lower levels of deployment. This general trend is expected to continue, where off gas properties lead the heat pump market until costs fall further to make it more economically viable for on gas properties to install heat pumps.

No correlation between higher levels of installations and housing association programmes was found, unlike in other areas of the UK.

There is no specific pipeline for heat pumps identified in this study. Instead, from 2017 onwards the scenarios have been applied. This is because without a planning timeline or network connections data there is no pipeline as such. Instead, the scenarios allow us to predict what could happen based on a variety of factors.

13.4 Scenario growth analysis 2017-2030

Future scenarios analysis has been undertaken on the basis of retrofit deployment levels and the proportion of new build homes that would include heat pumps. The number of new homes built each year varies under the different scenarios. The Gone Green and Consumer Power scenarios are assumed to have more new homes than the other two, due to a better economic environment. New homes have been allocated spatially based on known development plans and current numbers of homes in each area.

We have assumed under all the scenarios that alternative solutions to decarbonising heat, such as hydrogen and bio-methane do not become economically or technologically viable on a widespread basis until after 2030.

From 2017, the initial growth rate across all the scenarios is expected to be slow, due to the current low deployment rate, with growth picking up in the early to mid-2020s.

Public policy to increase building standards that could have driven heat pump demand has been weakened at the UK level. Brexit means that new homes in the UK will no longer have to meet the EU Nearly Zero-Energy Homes Directive[32]by 2020, which would have driven heat pump installations. What happens with zero carbon building policy across the UK now depends on the UK government analysis of the most cost-optimal solutions, and given past UK government policy decisions on this area, the UK is now unlikely to see strong carbon reduction requirements for new buildings by 2020[33]. However, the Welsh Government have the authority to adopt their own building standards, and it is assumed that they implement stricter carbon reduction requirements from 2020 under the Gone Green and Slow Progression scenarios; these Welsh building regulations would begin to have an impact on new developments built from 2022 onwards.

Public perception of heat pumps may also improve from 2017 with the publishing of a UK Government report into the performance of heat pumps funded through the Renewable Heat Premium Payment Scheme. This will build on trials conducted by the Energy Saving Trust, which had mixed results and was not wholly welcomed by industry but did show high customer satisfaction with systems[34].

It is forecast that the total thermal capacity for heat pumps in the South Wales licence area could reach approximately 675 MW by 2030 in the Gone Green scenario.

FES Scenarios - Implications for heat pumps in South Wales	
Consumer Power • High growth scenario • Demand is from private consumers rather than public sector • Deployment reaches a tipping point and market awareness increases rapidly	**Gone Green** • Highest overall growth scenario • Positive planning environment with Welsh government introducing zero carbon homes regulations and enforced renovation of old buildings • Government incentives to install heat pumps stimulate demand

[32] http://www.epbd-ca.eu/themes/nearly-zero-energy
[33] http://www.eib.org/epec/ee/documents/comparative-methodology-epbd.pdf
[34] http://www.energysavingtrust.org.uk/sites/default/files/reports/TheHeatisOnweb(1).pdf

• Rate of new build increases dramatically and consumers increasingly want efficient, low carbon buildings • Demand for cooling requires reversible systems • Demand for network stabilisation technologies enables development of consumer market • Rapidly decreasing prices for PV systems resulting in more integrated systems • Some take up in on-gas areas due to investment • Self-build market grows strongly • No zero carbon homes policy • Costs fall as R & D is invested in improving the technology and reducing the price	• Dynamic network developed with payment systems for those able to take energy off the network and store • Cost of energy increases resulting in increasing viability of applications (heat networks, waste heat capture) • Substantial take up in on-gas areas due to investment • Heat network market develops • Housing associations and public sector roll out investment programmes, alongside higher private demand • Costs fall as R & D is invested in improving the technology and reducing the price
No Progression • Lowest growth scenario with lower than current deployment • No zero carbon homes policy and fewer new build properties are built • Retrofit growth keeps in the 'able to pay' sector, with fewer consumers having the available capital • Cost of key components increases, stifling technology development • Heat network development focuses on gas and biomass combined heat and power systems only • RHI continues until 2018 but is then cut or stopped.	**Slow Progression** • Medium growth scenario • Positive planning environment with Welsh government introducing zero carbon homes regulations – but fewer new homes are built - and enforced renovation of old buildings • Social housing cuts result in reduced demand from this sector • Energy prices stay low • Government incentive made available but less uptake as fewer consumers can afford the investment • Retrofit growth keeps in the 'able to pay' sector, with fewer consumers having the available capital • Cost of key components increases, stifling technology development

13.5 Heat pump distribution by ESA

Distribution by ESA of the projected heat pump numbers was calculated by a combination of these factors:

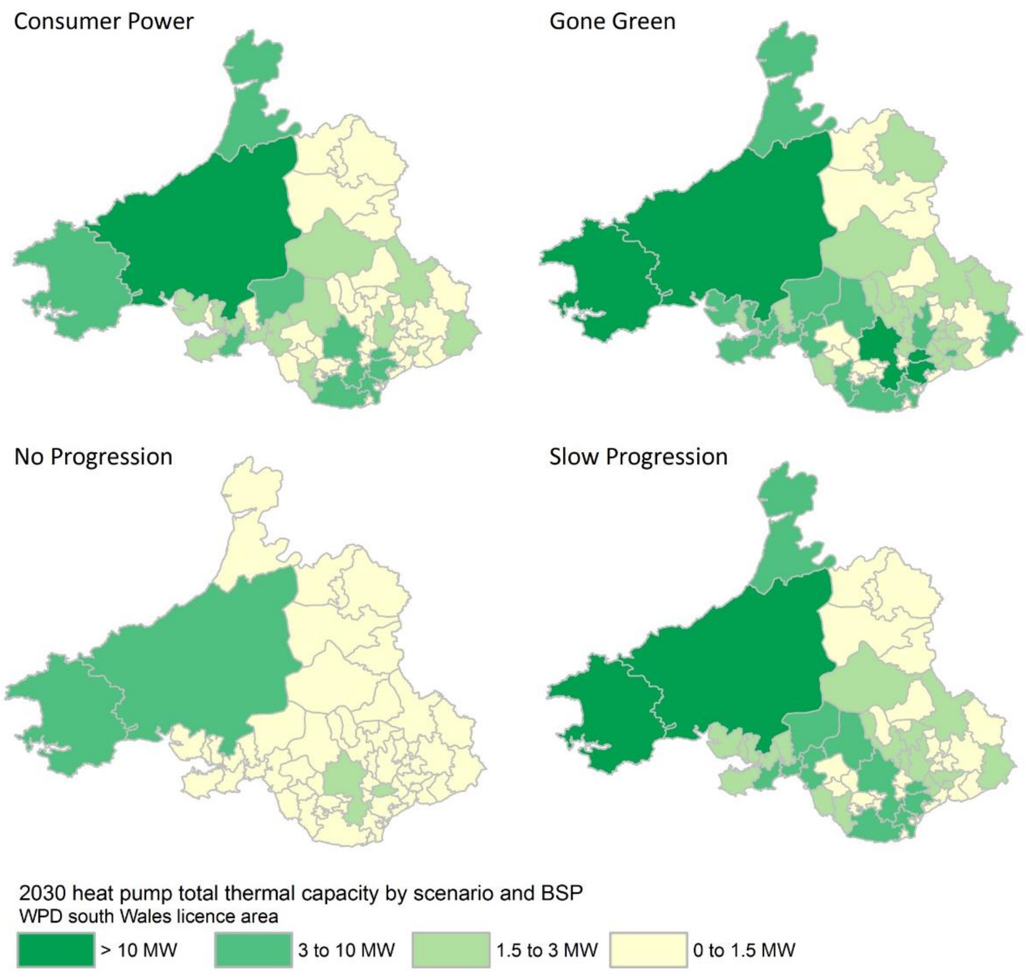
- The distribution of off gas houses

- The distribution of on gas households
- Past trends

The number of new build houses in each ESA was determined based on known development plans and the availability of land space. Environmentally protected land was taken into consideration, as well as environmental and technical factors such as flood plains and agricultural land designations.

Under each scenario, a different proportion of off and on gas homes were predicted to install heat pumps, based on the features of the scenario. This weighting has then affected the geographical spread of heat pumps by ESA, depending on the degree to which each ESA is off or on gas.

Geographical distribution of heat pump capacity in the Gone Green scenario



13.6 Heat pump capacity impact on electricity demand

Heat pump installations are rated by thermal capacity, as they provide heat to buildings. Baseline data on installed thermal capacity was collated using MCS data from the Low Carbon Generation in Wales report and used to develop the pipeline and the scenarios.

Equivalent data for electrical demand is not available through the MCS database. However, this study needed to estimate the impact of heat pumps on electricity demand in the region and so a conversion from installed thermal capacity to electrical demand was needed.

In order to calculate the electricity demand, a suitable Coefficient of Performance (COP) was researched. It was determined that an appropriate average for all heat pumps was a COP of 2.5. Ground source heat pumps can regularly be found to have a COP of 4; however, the majority of heat pumps are air source heat pumps, for which a COP of over 3 is unusual.

The COP of 2.5 is used for the Baseline of all scenarios; however, different COP values are used up to 2030 in the different scenarios. In the Gone Green and Consumer Power scenarios, the COP is projected to rise to 3.4 and 3.3 by 2030 respectively. This is because more new, well-insulated homes are projected to install heat pumps, resulting in a higher COP. In addition, technology developments will lead to an increase in the average COP in these scenarios.

In the Slow Progression scenario, there are slighter fewer new homes with heat pumps installed than Gone Green. There is still investment and technology development in the Slow Progression scenario and so an average COP of 2.9 is projected to be reached by 2030.

In the No Progression scenario, heat pump improvements are hindered by poorly insulated homes and little technology development. Therefore, the COP is not expected to increase and will remain at 2.5.

The projected number of heat pumps was estimated based on the total projected installed thermal capacity, using the assumption that the average heat pump thermal capacity reduces from 10.6 kW in 2016 to 9 kW by 2030. This 10.6 kW value is based on historical trends, which show that the average thermal capacity of all heat pumps in the region has remained at 10.6 kW in recent years. However, this is considered reasonably high as an average, and so as technology improvements are made, and more domestic retrofit smaller scale heat pumps are installed, the average size is projected to decrease to 9 kW.

14 Conclusion

As with any scenario based forecast, the analysis is based on a large number of assumptions and uncertain factors that could impact on the future growth of both distributed generation and new electricity demand. However, this work has been able to provide much greater clarity and visibility of the baseline situation. It has also been able to offer a more robust analysis of the pipeline; as after a period of high growth seen previously, the rate of distributed generation deployed slows as the market resets following changes to UK government policy and subsidies.

With a new Welsh administration bedding in, how it responds to the opportunities presented by the new legislative framework it is operating within will have a fundamental impact on the speed of change and shift between alternative scenarios. Despite the current downturn in renewable energy growth, there is an underlying presumption that, provided that future UK governments are committed to decarbonise energy and make good the climate change commitments made in COP Paris, then the growth of decentralised generation will recover in the next decade, meaning that even under a Slow Progression or Consumer Power scenario decentralised generation growth is significant[35]. The opportunity for Wales to position itself on a more comfortable trajectory to achieving our long term carbon commitments compared to English regions, however, demonstrates how the regionalisation of the scenarios is so important, and decisions made over the coming months and years will set the tone for how Wales will contribute to the UK energy challenge and global clean energy revolution going forward.

A key uncertainty is the speed with which the growth of decentralised generation can recover from the expected downturn. That will depend on both government policy and on the market's ability to reach price parity for different technologies. This in turn will depend on the rate of cost reduction and technology innovation as well as the adoption of new business models.

As the section on energy storage shows, the introduction of new business models will be critical. Sometimes these will be market driven – price variability, for example, allowing generators and consumers to capture additional market value by avoiding peak price periods or selling energy into them. In other areas, new business models based on network optimisation and network support will in part be driven by the requirement to manage more variable generation and a more decentralised generation network.

The adoption of new technologies – smart technologies, energy storage, electrification of heat and electric vehicles – could all radically change the demand/supply balance and the operation of the

[35] Only if a future UK energy strategy was based almost exclusively on very cheap nuclear reactors would the growth of decentralised generation be curtailed. This would imply a reversion to big generation technologies, nuclear, large scale offshore wind and large gas generation, coupled with carbon capture and storage. This could potentially be a decarbonisation scenario outcome but is less likely in the period to 2030.

network. This work has explored these, but clearly there is uncertainty about how quickly new technology will be deployed.

Whatever the outcome, the role of the distribution network and of DNOs will be critical. The analysis above will therefore provide an input for the next phase of the WPD Strategic Grid Investment Options Study. As that broader study progresses, it is clearly not a straight forward decision to commit to invest in new capacity. The alternatives of Active Network Management, energy storage and demand side response are also important pieces of the puzzle. Timing of investments and the impact of demand changes will also have to be modelled. The Welsh Government and other stakeholders will have an important role in aligning national and regional economic strategies and plans with any business case for strategic investment in infrastructure, to create commercial opportunities and employment in Wales.