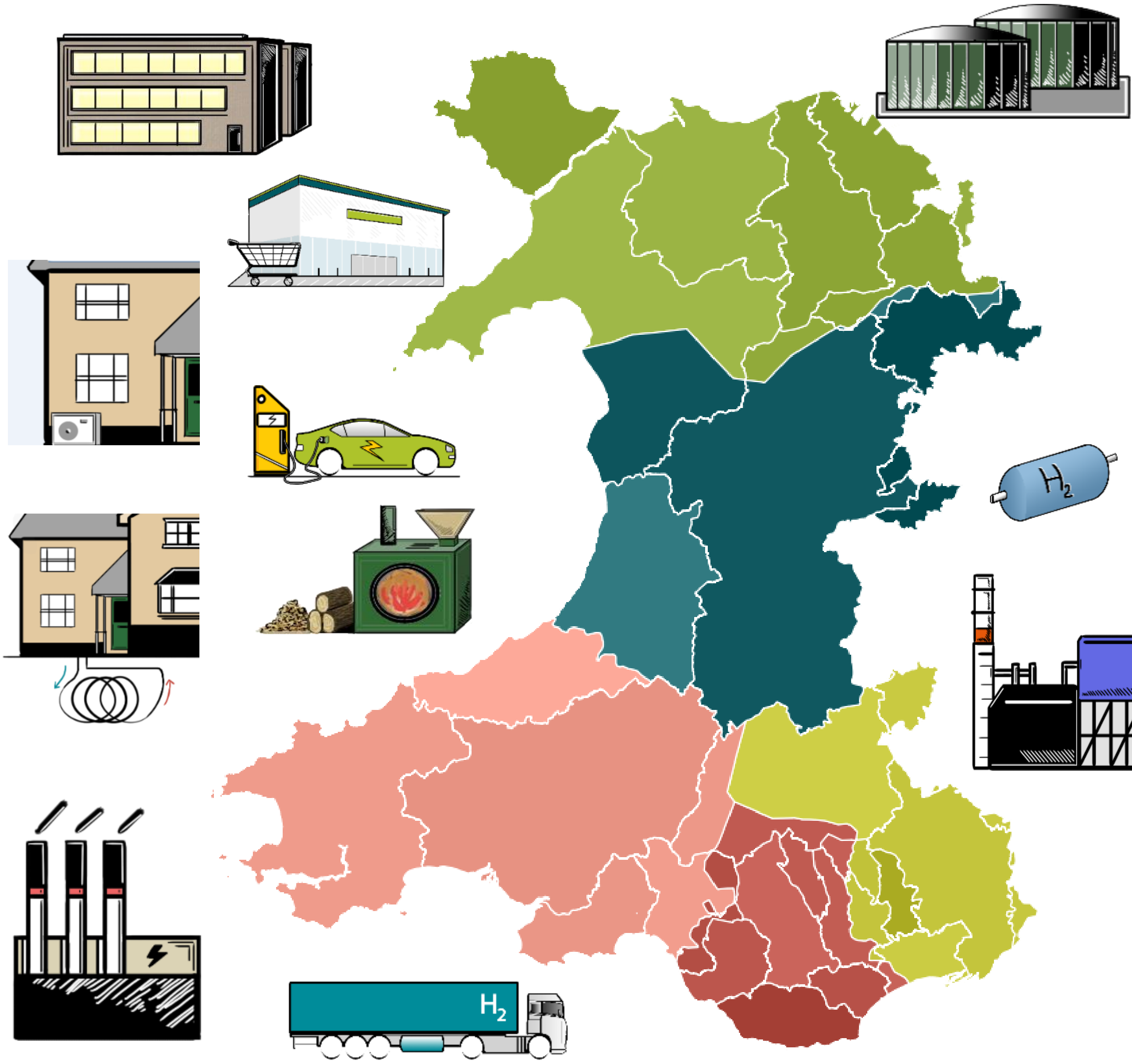
Network Innovation

Regional Growth Scenarios for Gas and Heat

Phase 3: Wales regional assessment

Technical report and summary results



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Contents

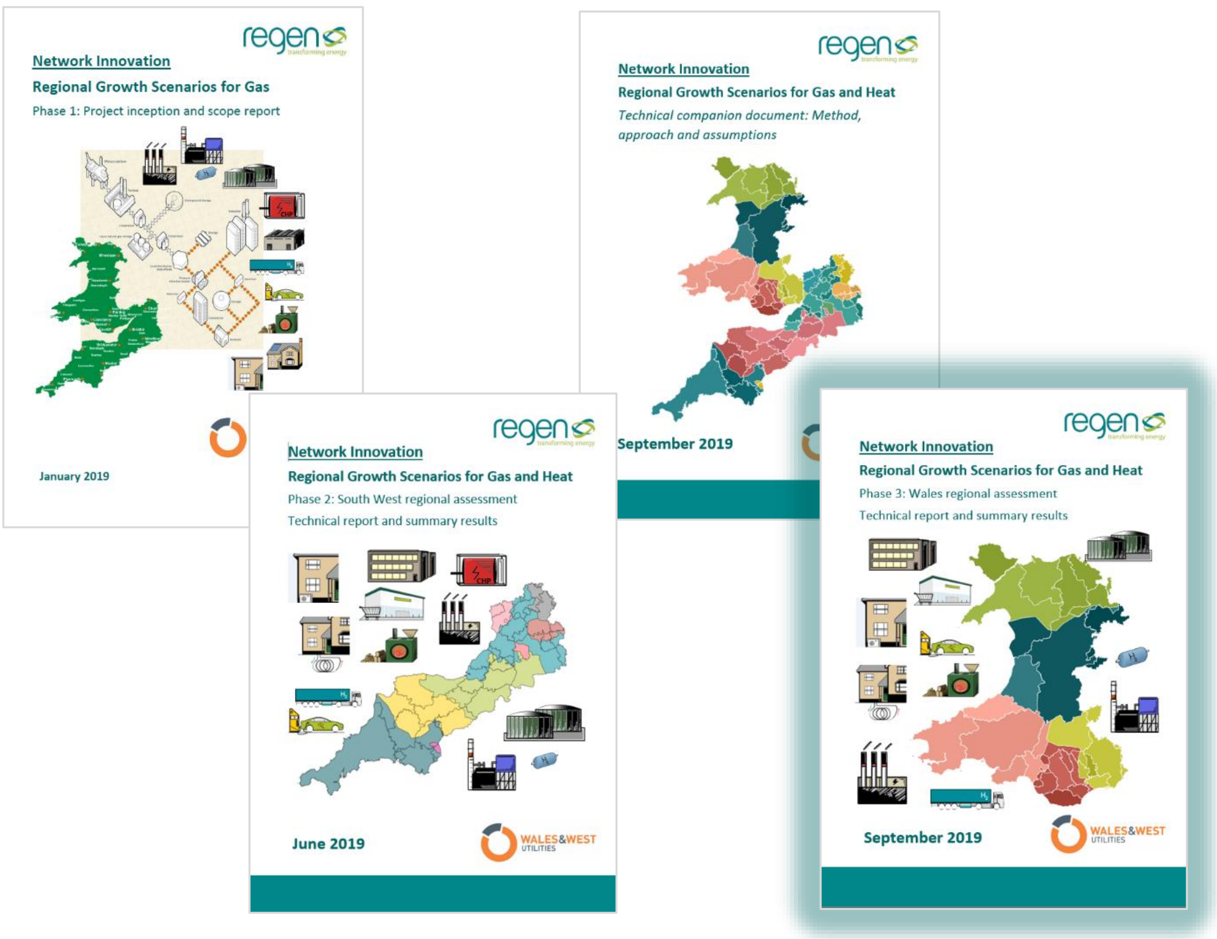
1 Regional Growth Scenarios for Gas and Heat – Report Series

Regional Growth Scenarios for Gas and Heat is an NIA funded project, managed by Wales & West Utilities and delivered by Regen, to develop and demonstrate a methodology to create a set of regional future energy scenarios for the gas distribution network in Wales and the South West of England.

This report, which details the results for the Wales gas Local Distribution Zones (LDZs), is part of a suite of documents that Regen has produced for Wales & West Utilities (WWU):

- A 'Project Inception and Scope Report' was completed in February 2019 and developed the project scope, methodology and approach.
- In June 2019 the regional future energy scenarios assessment for the WWU South West LDZ was completed. This phase of the work produced a detailed scenario projection dataset and a summarising technical report and results document for the South West LDZ.
- This report and the accompanying dataset are the main deliverables for the regional assessment for the Wales North and Wales South LDZs and was completed in September 2019.

An explanation of some of the more detailed aspects of the methodology and approach used for both the South West and Wales analyses can be found in an accompanying Technical Companion Document.

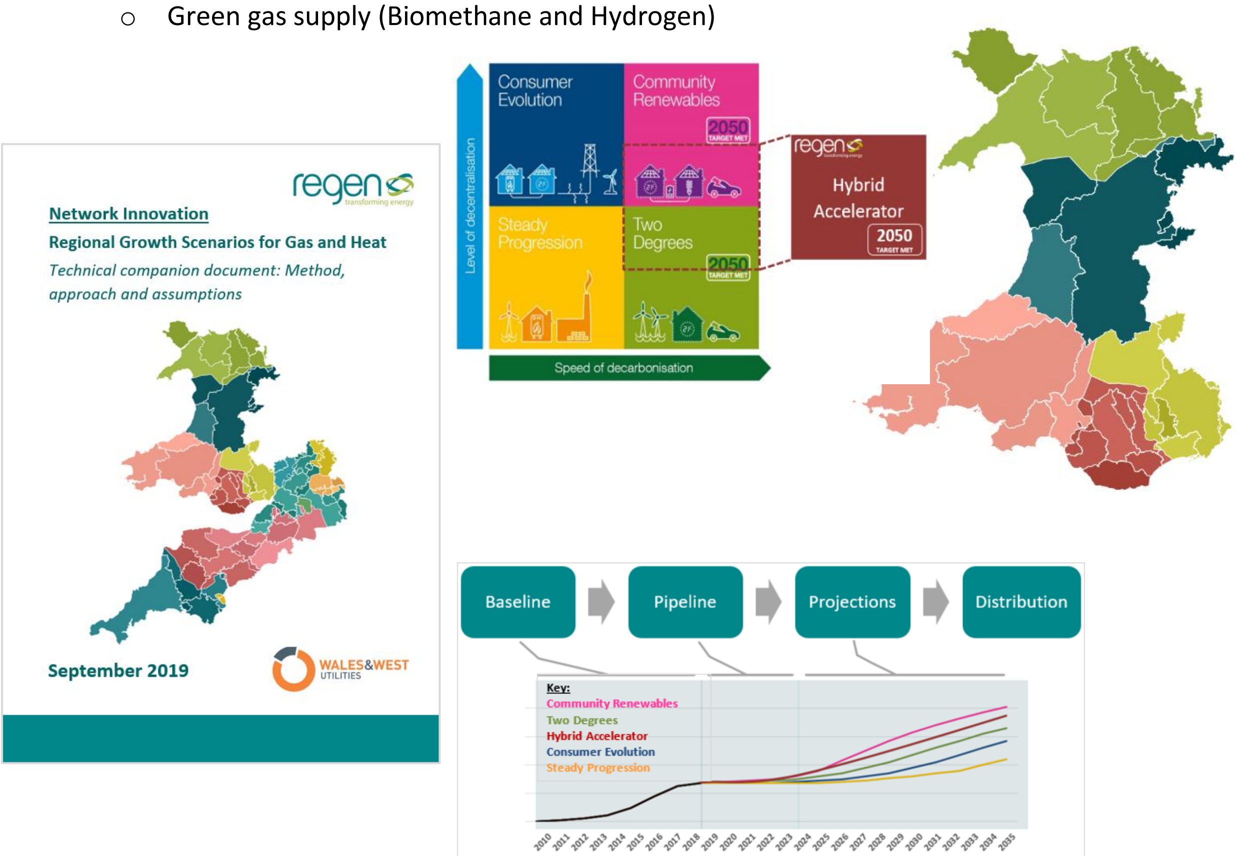


1.1 Reference - Technical Companion Document

A **Technical Companion Document** provides more detail of the approach, assumptions, data, evidence and methods used to undertake the regional future energy scenarios. Readers are encouraged to refer to this document when reviewing the results.

The Technical Companion Document provides the following information:

- A glossary of terms used within this project
- UK energy policy background and considerations around the decarbonisation of heat
- Wider energy system considerations and the role of the gas and electricity networks
- An overview of components of the project's methodology, specifically:
    - Geographical scope
    - Future energy scenario framework
    - Summary of the actual factors and elements being assessed
    - Scenario projection process and timeframe
    - Key data and evidence sources
    - Approach to geographical distribution and Gas Supply Areas
    - Relationship between scenario projection output data and mapping
    - Overview of engagement workshops and stakeholder insights
- A series of technical appendices bespoke to each of the key sources of demand or supply, summarising the analysis process, assumptions and references that are specific to each factor:
    - Domestic heat
    - Commercial and industrial heat
    - Gas fired power generation
    - Gas vehicles and electric vehicles
    - Green gas supply (Biomethane and Hydrogen)



2 Executive summary

The changing role of the gas distribution network during a period of increasing decarbonisation and decentralisation of energy supply is extremely complex. The outcome of the analysis is therefore highly dependent on the scenarios being modelled and the assumptions being made.

This regional assessment focusses on the WWU 'Wales' gas distribution network area, which is made up of the Wales North (WN) and Wales South (WS) local distribution zones (LDZs). These LDZs encompass most of Wales and a small area of England.

The analysis presented in this report has used a number of scenarios in order to explore the impacts on future demands for gas and heat under a number of modelling assumptions. The four core scenarios used are based on the 2018 edition of National Grid ESO's four **Future Energy Scenarios**[1] to which an additional **Hybrid Accelerator** scenario has been added. The scenarios can be summarised as:

Community Renewables – A scenario with high levels of decarbonisation and rapid decentralisation in the energy system. This scenario is compliant with the UK government's previous target to reduce carbon emissions by 80% by 2050, achieved through a higher use of heat pumps, smart technologies and green gas. Future electricity supply is delivered primarily through small decentralised renewables.

Two Degrees – A scenario with high levels of decarbonisation, but slower levels of decentralisation. This scenario is also compliant with the 80% by 2050 carbon reduction target. More centralised low carbon generation, such as offshore wind and nuclear features heavily. Hydrogen (via steam methane reformation) provides a pathway to decarbonising heat, supported by heat networks and heat pumps.

Hybrid Accelerator – This fifth scenario is intended to sit somewhere in between Community Renewables and Two Degrees, and thus is also compliant with the 80% by 2050 carbon reduction target. The development of this scenario enables the modelling to account for an accelerated near-term uptake of hybrid heating solutions, as well as the inclusion of hydrogen blending.

Consumer Evolution – A scenario with lower levels of decarbonisation, but rapid decentralisation. This scenario is one of two which fail to achieve the 80% by 2050 carbon reduction target. Moderate amounts of energy efficiency and heat pump uptake are included in this scenario. Decentralised gas power generation sites, batteries and smaller scale renewables dominate the future power generation mix.

Steady Progression – A scenario with low levels of decarbonisation and decentralisation, also failing to achieve the 80% by 2050 carbon reduction target. Gas boilers remain the dominant heating technology in homes and businesses and limited progress is made to decarbonising heat. Power generation is more centralised, focussing on gas fired power stations, nuclear and offshore wind.

Throughout this assessment, the use of the term "compliant" or "compliant scenarios" refers to aspects of the modelling, or scenario projection outcomes that are in-line with the 80% by 2050 carbon reduction target. The scenarios would not necessarily meet a more ambitious net-zero carbon commitment by 2050, which has recently been adopted by the UK government[2]. However, the trends/trajectories of the scenarios developed for this project (out to 2035), could be considered in the context of a 2050 outcome.

A key dimension of the scenarios is the level of decarbonisation that is achieved. In the long term, meeting the UK's Net Zero carbon reduction targets will require an almost complete reduction in the

[1] FES 2018 document: http://fes.nationalgrid.com/media/1363/fes-interactive-version-final.pdf
[2] https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law

usage of fossil fuels, including natural gas, by 2050. In the period to 2035 however, while natural gas consumption must be reduced significantly, gas can also act as an agent for decarbonisation by, for example, displacing higher carbon fuels such as coal for power generation and for use in industrial processes and replacing oil for heating.

The gas networks can also provide an opportunity to deliver low carbon energy, using greener gases such as biomethane and hydrogen. Given this opportunity to decarbonise, it has therefore become necessary to differentiate between the consumption of natural gas and the total energy delivered by the gas network.

A further dimension of the scenarios is the sources of energy and choice of technologies used. Especially when considering the future of energy for heating, there are still a significant number of potential technologies and strategies that could be adopted, and there is still a high degree of uncertainty about which heating solutions will prevail.

More complexity is added for heat and gas because both the sources of energy and the fuel used are highly interchangeable across technologies and across the energy vectors of heat, power and transport. The analysis has therefore aimed to account for all major potential future gas uses.

Socio-economic and demographic differences can have a significant impact at both a regional and at a local level. For this regional analysis of the Wales LDZs, the devolved government and Welsh policy landscape creates the potential for different outcomes and pathways for a number of the key factors within the study, such as domestic carbon emissions, green gas, waste collection and emissions from power generation in the Wales LDZs.

2.1 Summary results for the Wales gas distribution network

2.1.1 Overall energy demand

At the highest level the total energy demand on the WWU Wales gas distribution network in 2035 is projected to fall from the 2018 baseline in all bar one scenario.

The reduction ranges from a slight increase of **0.8% (246 GWh) in Steady Progression** to a significant reduction of **27% (7,788 GWh)** in **Two Degrees**.

The main reduction is seen from 2025 onwards. In **Two Degrees** there is a notable drop in demand in the early 2030s, reflecting a significant shift to hydrogen by a cluster of industrial consumers in south Wales.

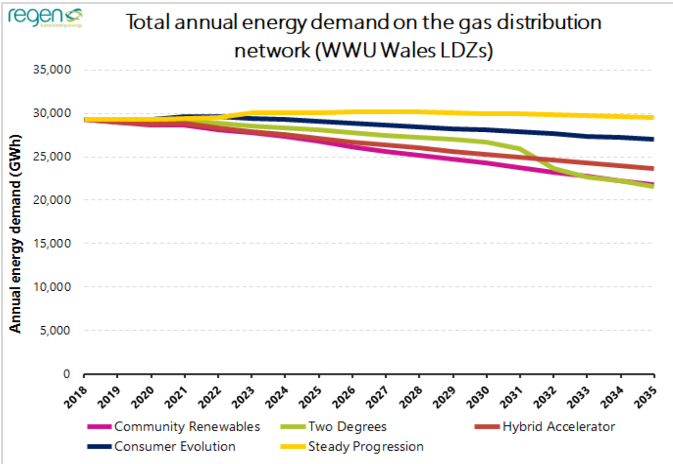


Figure 1: Total energy demand on the WWU Wales gas distribution network from all sources

Within these headline figures there are elements of gas demand which will increase, such as Compressed Natural Gas (CNG) for transportation and, in the near term, gas for power generation in decentralised gas reciprocating engine sites. There is also increase in demand from new domestic and commercial developments.

Overall reduction comes from energy efficiency in homes and businesses, as well as a shift to alternative heating sources such as heat pumps and low carbon heat networks.

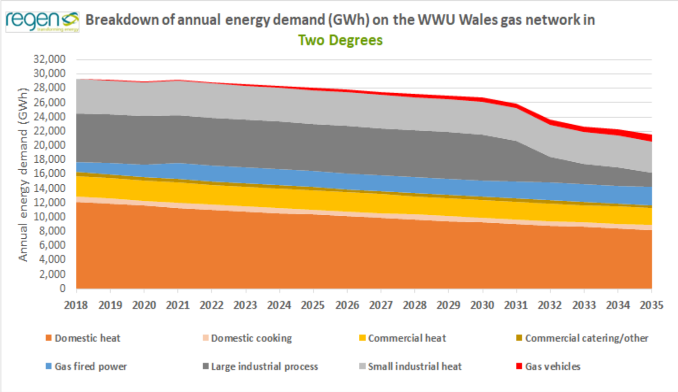


Figure 2: Sources of annual energy demand on the WWU Wales gas distribution network in the Two Degrees scenario.

Whilst significantly less than seen in the South West LDZ, an element of decarbonisation comes through green gas injection (biomethane) and, in both the **Hybrid Accelerator** and **Two Degrees** scenarios, a limited amount of hydrogen blending. In the **Two Degrees** scenario, a proportion of large industrial users are also modelled to switch their gas fuel to a dedicated hydrogen supply network, removing a notable amount of demand from WWU's gas distribution network (

Figure *3*).

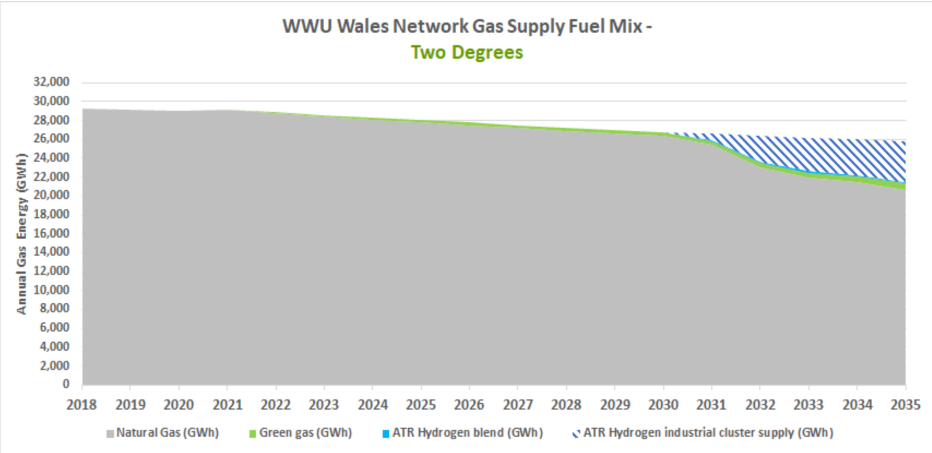


Figure 3: The gas energy fuel mix in the WWU Wales gas distribution network in the Two Degrees scenario

2.1.2 Energy for heat

The modelling of future heat delivery for domestic and non-domestic consumers in Wales showed how different decarbonisation strategies could lead to a large variation in the uptake of heat delivery technologies across the five scenarios. The analysis incorporated Welsh specific factors, such as Welsh Government heating, energy efficiency and decarbonisation policies, as well as the current state of the housing stock and housing growth projections[3] [4].

Aspects such as the rate of heat pump deployment in Wales have been modelled from a very low baseline position, largely reflecting heat pump uptake across the whole of the UK to date. The **Hybrid Accelerator** scenario has been used to model a higher uptake of hybrid heating solutions in the Wales LDZs, comprising a primary electrically driven heat pump with a gas boiler back-up. Factors such as heat energy usage across both electricity and gas networks, existing on-gas network connections and the peak demand on the network need to be considered separately. Some high-level considerations around peak demand in the context of this assessment, can be found in the Technical Companion Document. At

[3] The number of households increases by 7.9% in Wales by 2035, compared to a 15% increase seen in the SW.
[4] Welsh energy efficiency initiatives such as ARBED and NEST have been factored into heat demand modelling.

the highest level the (albeit reduced) majority of homes and buildings remain heated by gas boilers in 2035 in all scenarios.

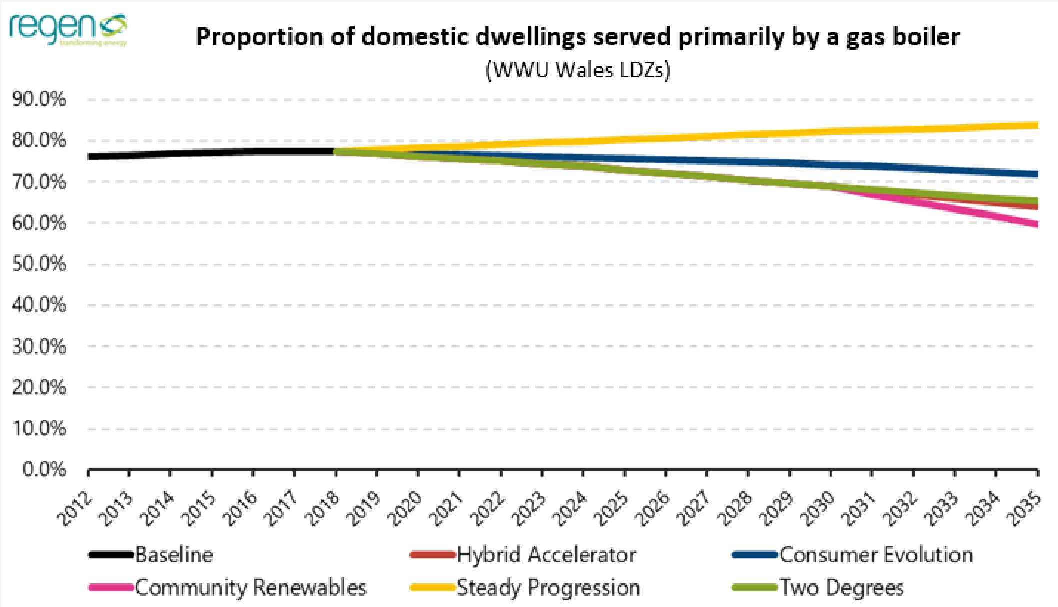


Figure 4: Domestic properties heated by gas boilers in Wales

2.1.3 Energy for power generation

Gas fired power generation assets are expected to play a role as flexible or 'peaking' plant, providing additional capacity during periods of higher electricity prices or when there is an opportunity to provide balancing services. However, as the National Grid FES 2018 scenarios highlight, a significant question remains as to whether the bulk of that plant will be in the form of large scale combined cycle or open cycle gas turbine plants (CCGT or OCGT) connected to the electricity transmission network, or a more decentralised scenario with increasing numbers of smaller gas plants, such as reciprocating engines and CHPs, connected to the electricity distribution network.

Welsh Government aspirations to reduce emissions from power generation could potentially create different, or more focussed pathways for the role that gas generation will play in the region. At a high level, the Welsh Government is aiming to phase out coal, implement new consenting, planning and permitting policy and to develop a policy on combustion of fuels for power. This aspiration aligns quite closely with the compliant scenarios in the FES, specifically around the potential for very large CCGT sites operating in Wales to be phased out[5], whilst smaller, distributed, flexible gas generation sites could well see an increased level of deployment in Wales.

The current restriction on connecting new thermal generation technologies in south Wales[6] potentially limits any significant increase in gas fired generation capacity in Wales until the mid/late-2020s in some scenarios (Figure 5). However, detailed analysis of the existing generation assets connected to the Welsh gas distribution network and an assessment of 24 known developments in the connection pipeline, suggests that there is a significant growth potential for distributed flexible power plant in the Wales LDZs.

[5] For the purposes of this assessment Seven Power power station has been discounted from the scenario modelling
[6] See National Grid Statement of Works letter to Western Power Distribution for the South Wales licence area: https://www.westernpower.co.uk/downloads/3907

It was confirmed at the stakeholder workshops that small, modular gas reciprocating engines and CHPs are currently the power generation technologies seeing the most development activity in the industry and are the most likely technologies to see notable deployment in the near to medium term.

Whilst a projected increase in capacity has been modelled in all scenarios for both the South West and for Wales LDZs, it should be highlighted that the business models for flexible power plants are highly dependent on regulatory and market conditions. Market changes, such as the basis of network charging, which is currently under review by Ofgem, and competition from other forms of flexibility such as battery storage, could significantly impact future growth. A further important point from the scenario analysis is that increased capacity is expected to be accompanied by significantly lower capacity utilisation factors, and therefore lower gas fuel supplied to these sites.

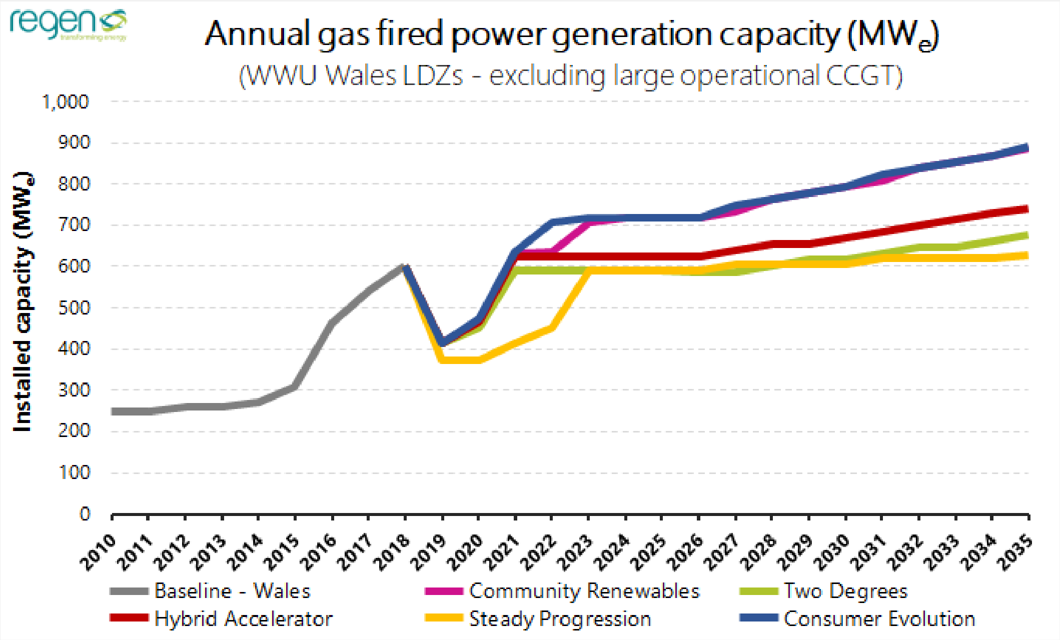


Figure 5: Scenario projections for gas fired power generation capacity in the WWU Wales LDZs, 2018 to 2035

2.1.4 Carbon reduction impacts

The "Prosperity for all: a low carbon Wales" policy suite, confirms that there is a strong carbon reduction ambition in Wales. This includes aspirations to decarbonise domestic heating[7], power generation[8] and industry.[9] This ambition, coupled with Welsh Government's recent adoption of a 95% carbon reduction target by 2050[10], is reflected in very strong decarbonisation outcomes by 2035 in the **Community Renewables**, **Two Degrees** and **Hybrid Accelerator** scenarios within this assessment.

Note: the carbon reduction figures given in this study relate to sources of gas demand included in the scope of the analysis; heat delivery, industrial gas use, gas fired powered generation and gas vehicles.

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[7] See *Decarbonising Welsh Homes* report, July 2019: https://gov.wales/decarbonising-welsh-homes-stage-1-report
[8] See *Welsh Government Power Sector Emission Pathway Factsheet*, June 2019: https://gov.wales/sites/default/files/publications/2019-06/power-sector-emission-pathway-factsheet.pdf
[9] See *Welsh Government Industry Sector Emission Pathway Factsheet*, June 2019: https://gov.wales/sites/default/files/publications/2019-06/industry-sector-emission-pathway-factsheet.pdf
[10] See https://gov.wales/wales-accepts-committee-climate-change-95-emissions-reduction-target

The combination of a reduction in the amount of gas being supplied by the WWU Wales gas distribution network and a moderate increase in biomethane entering the network, leads to an overall net reduction in carbon emissions in all scenarios. In the Wales LDZs this could be as high as a **33%** carbon emission reduction (CO_2e), against a 2018 baseline in both the **Two Degrees** and **Community Renewables** scenarios, reducing annual emissions by **2,096 ktCO_2e** and **2,086 ktCO_2e** respectively by 2035.

While clearly not net zero carbon or in line with a 95% reduction for Wales, this level of decarbonisation would be a significant step towards the long term 2050 climate change targets, in the most difficult sector to decarbonise. Assessing these two compliant scenarios against each other also highlights how different approaches might achieve equivalent carbon reductions. In the **Community Renewables** scenario, carbon savings are made via domestic and non-domestic heat measures and by some biomethane injection, that increases throughout the timeframe of the assessment. In the **Two Degrees** scenario carbon reduction is more dependent on the creation of an industrial hydrogen cluster in the 2030s.

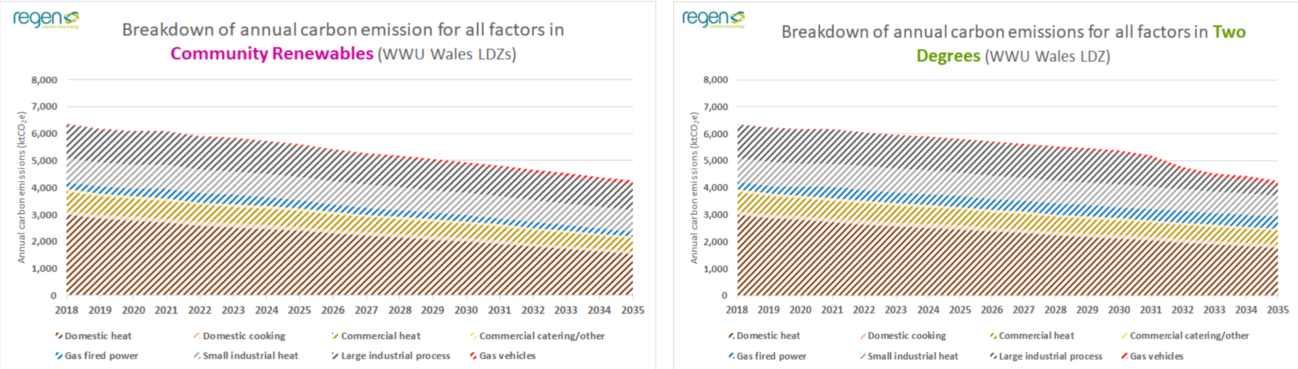

Figure 6: Annual carbon emissions by demand source in Community Renewables and Two Degrees in the WWU Wales LDZs

2.2 Next steps

With the regional scenario assessments completed for all three of the WWU LDZs[11], the Wales & West Utilities team are now using the scenario projection data to feed in to their RIIO-GD2 business plans.

A follow up piece of work could combine regional scenario assessments for both electricity and gas distribution networks that share equivalent geographies, developing a bottom-up, whole system view of energy network planning for individual regions and sub-regional areas/zones.

[11] South West (England), Wales North, Wales South.

3 Scenario projection results for the Wales LDZs

Note on report structure
For each key factor and projection sub-elements the results of the scenario analysis are summarised as: • A brief description of the factor and its sub-elements • Headline outputs of the baseline, pipeline analysis and scenario projections • A high-level summary of the approach taken to scenario modelling • Summary tables of scenario results, by milestone year (2018, 2020, 2025, 2030 and 2035) • Graphs showing the scenario results by scenario (2018 – 2035) • Gas Supply Area (GSA) maps showing the 2018 baseline and scenario versions of the 2035 position A regional carbon impact of the projections shown for each scenario in 2035 has also been completed. A set of appendices are included in the Technical Companion Document that detail some of the core assumptions, scenario logic, evidence sources and data that have been used to determine the outputs.

3.1 Overall annual energy demand on the Wales gas network

As can be seen in Table 1 and Figure 7, the annual demand for energy on the WWU Wales gas distribution network reduces in four of the five scenarios by 2035. The largest reduction is seen in **Two Degrees**, with a reduction of **7,788 GWh** by 2035 (**27%**). In the **Steady Progression** scenario, overall demand for energy on the WWU Wales gas network is modelled to increase by **246 GWh** (**0.8%**).

Table 1: Overall annual energy demand on the WWU Wales gas distribution network

Note: Severn Power Power Station is discounted from the scenario modelling and the annual demand from this site is subsequently not included in the WWU Wales network demand analysis

Scenario	Annual energy demand on the WWU Wales network (GWh)					Reduction from 2018
	In 2018	By 2020	By 2025	By 2030	By 2035	
Community Renewables	29,316	28,607	26,814	24,315	21,799	26%
Two Degrees		28,997	28,061	26,709	21,528	27%
Hybrid Accelerator		28,746	27,143	25,317	23,626	19%
Consumer Evolution		29,304	29,120	28,084	27,003	8%
Steady Progression		29,280	30,120	30,000	29,562	-0.8%

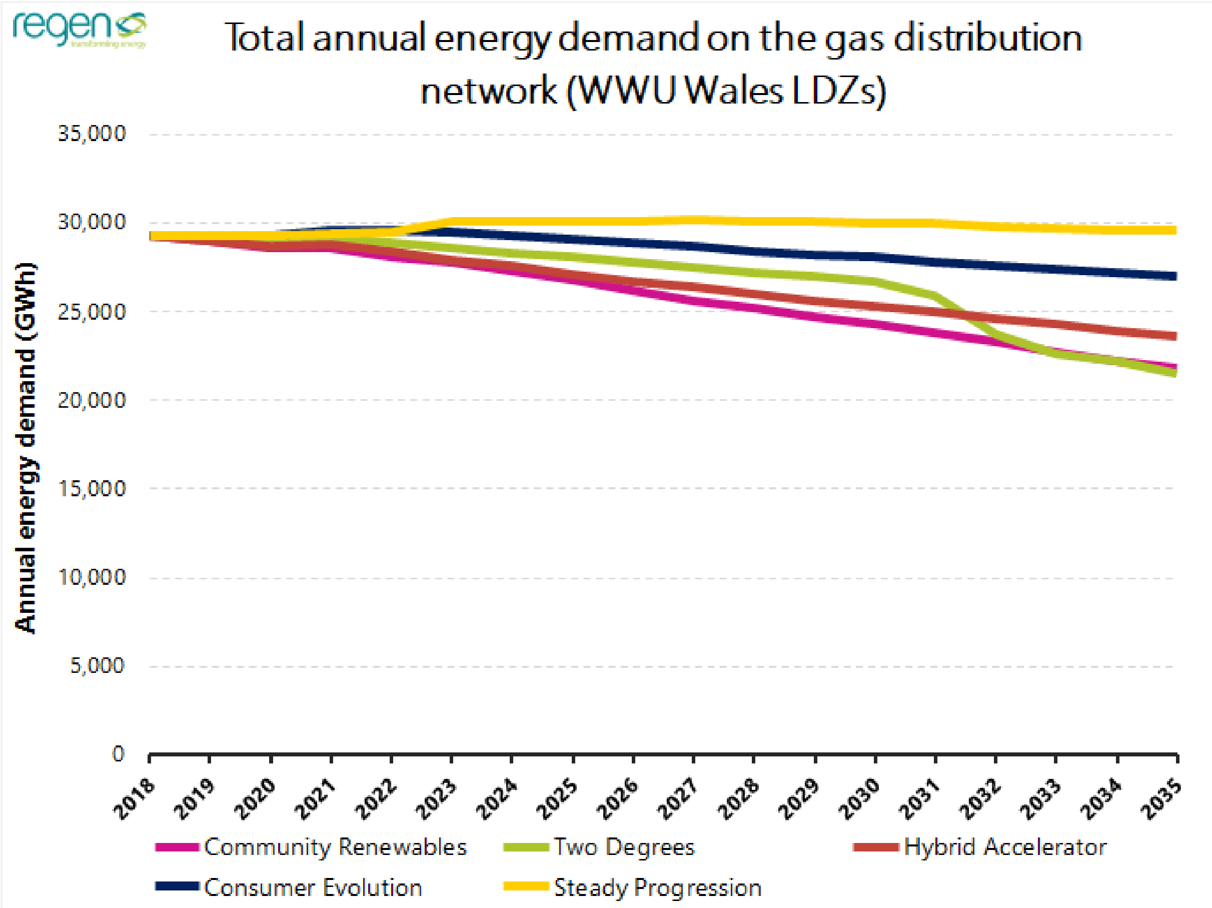

Figure 7: Total energy demand on the WWU Wales gas distribution network in each scenario for all known factors

Changes in the annual energy demand on the WWU Wales gas distribution network can be attributed to:

- **An efficiency-led reduction in overall heat demand in households and businesses across all scenarios in the Wales LDZs, which offsets the proposed development of new dwellings and commercial properties.**
- **A reduction in the use of gas boilers as the primary heat delivery technology for existing households, which varies by scenario.**
- **A significant reduction in the installation of gas boilers as the heat delivery technology for new dwellings and commercial properties, in the three compliant scenarios.**
- **A moderate amount of process efficiency improvements for large gas fired industrial processes in the Wales LDZs, in all scenarios. In the Two Degrees scenario, a significant proportion of industrial gas demand is modelled to switch to dedicated hydrogen supply in the 2030s.**
- **An increase in gas fired power generation capacity (MW_e) and electricity generation demand for gas in the Wales LDZs. This demand for gas from power generation peaks in the mid-2020s and reduces annually out to 2035 in some scenarios and increases in others.**
- **A low-to-moderate uptake of gas fuelled vehicles, from an extremely low base, to 2035.**

The total annual energy demand for each scenario shown in Table 1 is broken down into specific sources of demand in Figure 7 to Figure 11.

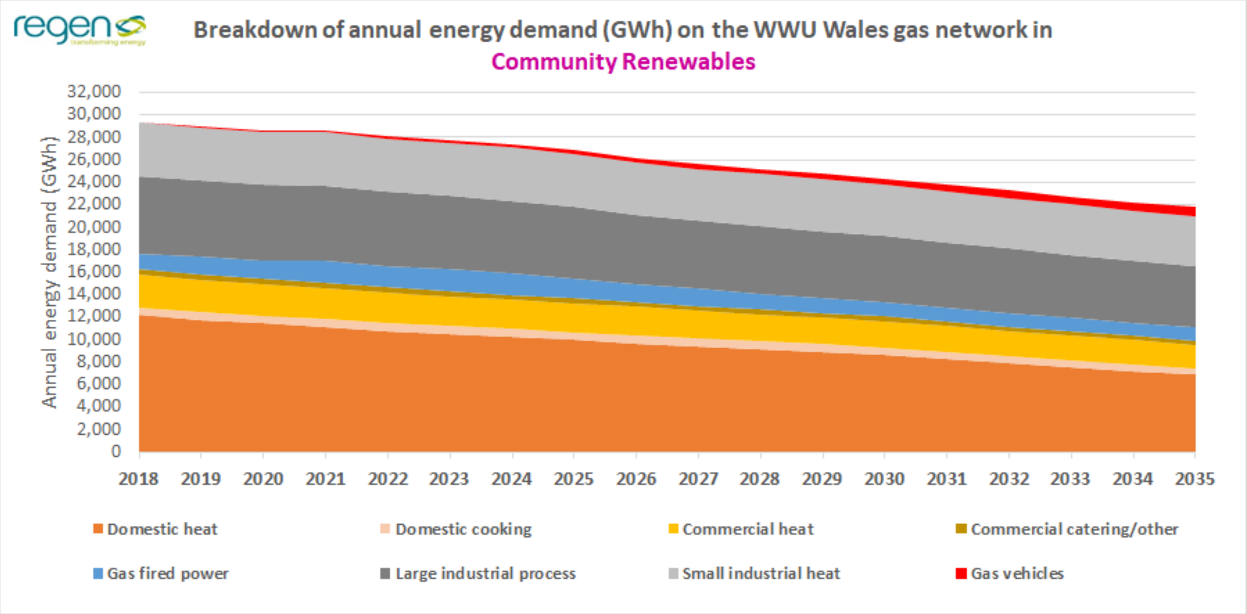

Figure 7: Graph of sources of annual energy demand on the WWU Wales gas distribution network in the Community Renewables scenario

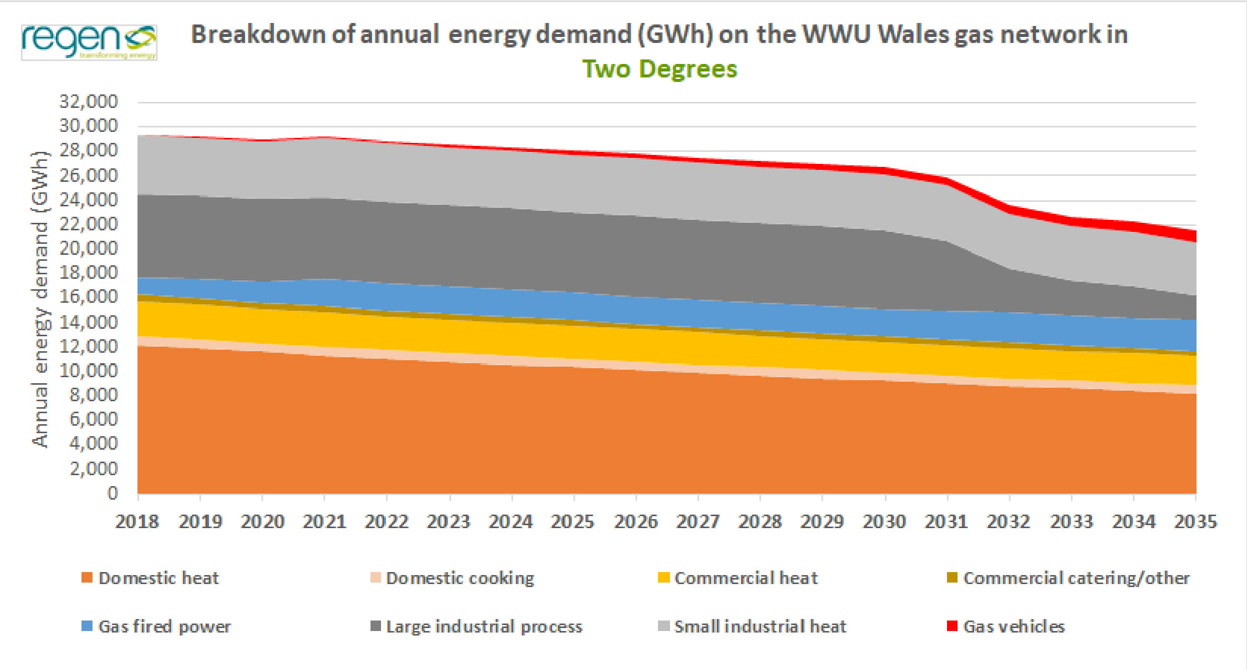

Figure 8: Graph of sources of annual energy demand on the WWU Wales gas distribution network in the Two Degrees scenario

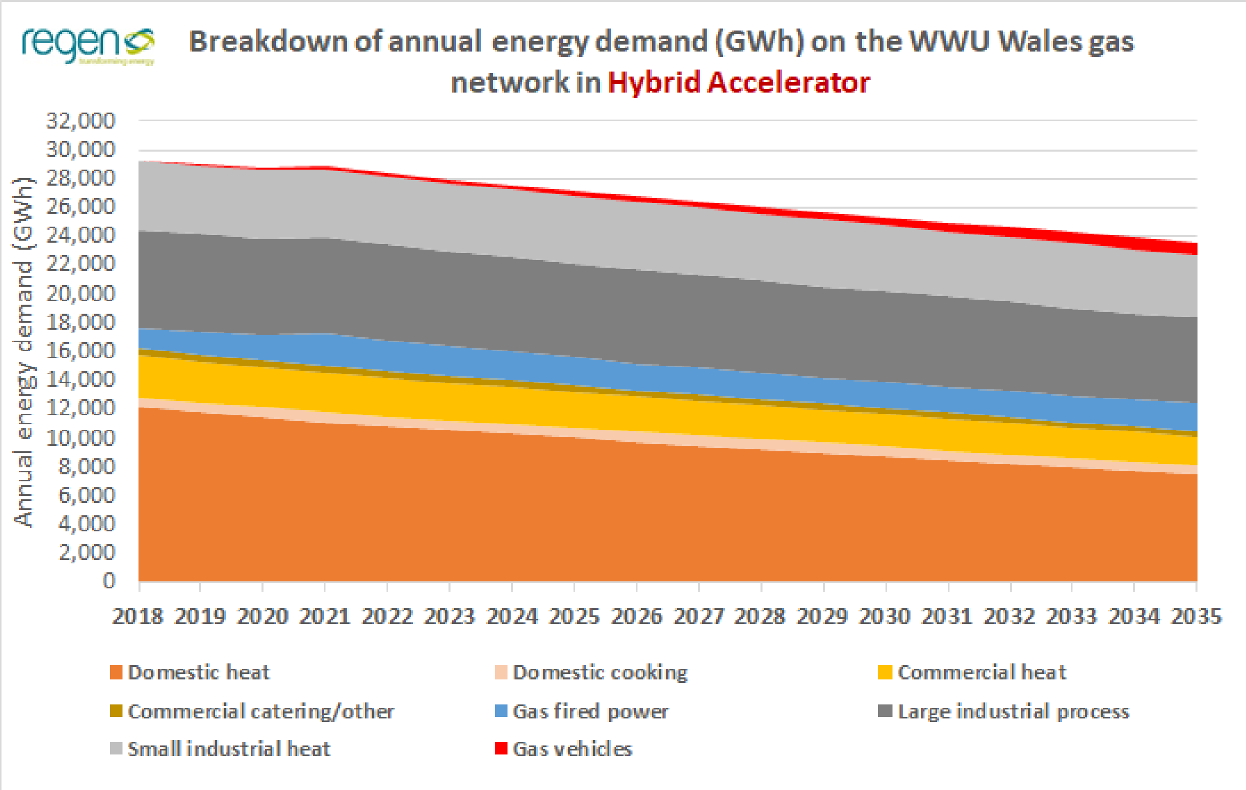

Figure 9: Graph of sources of annual energy demand on the WWU Wales gas distribution network in the Hybrid Accelerator scenario

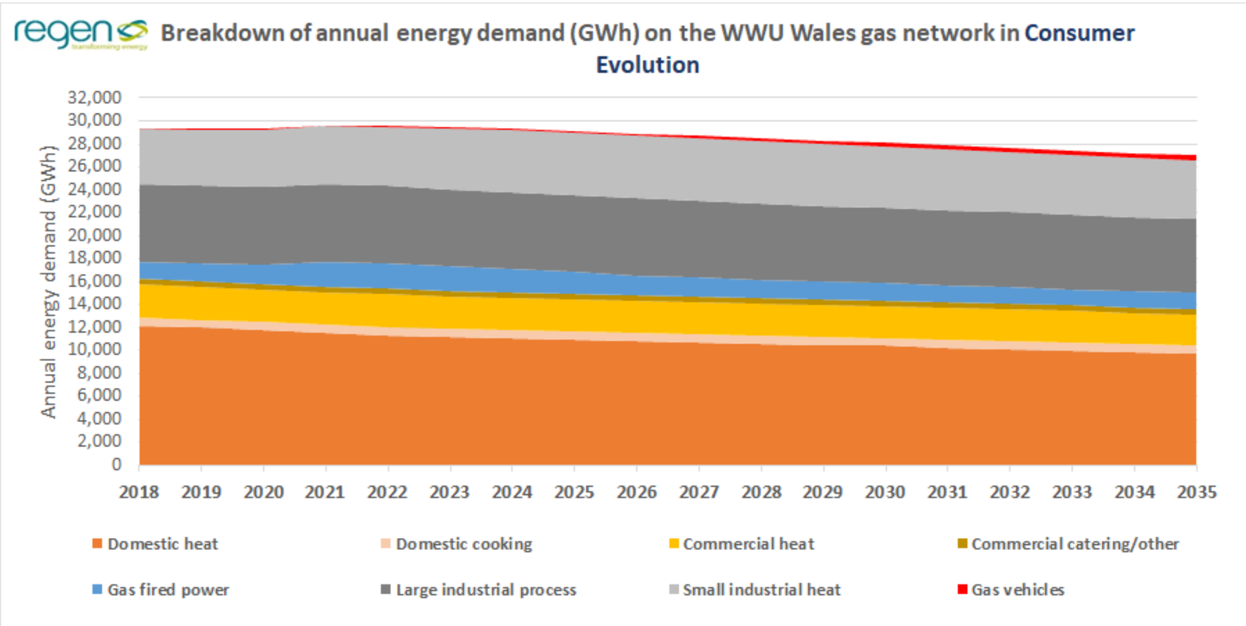

Figure 10: Graph of sources of annual energy demand on the WWU Wales gas distribution network in the Consumer Evolution scenario

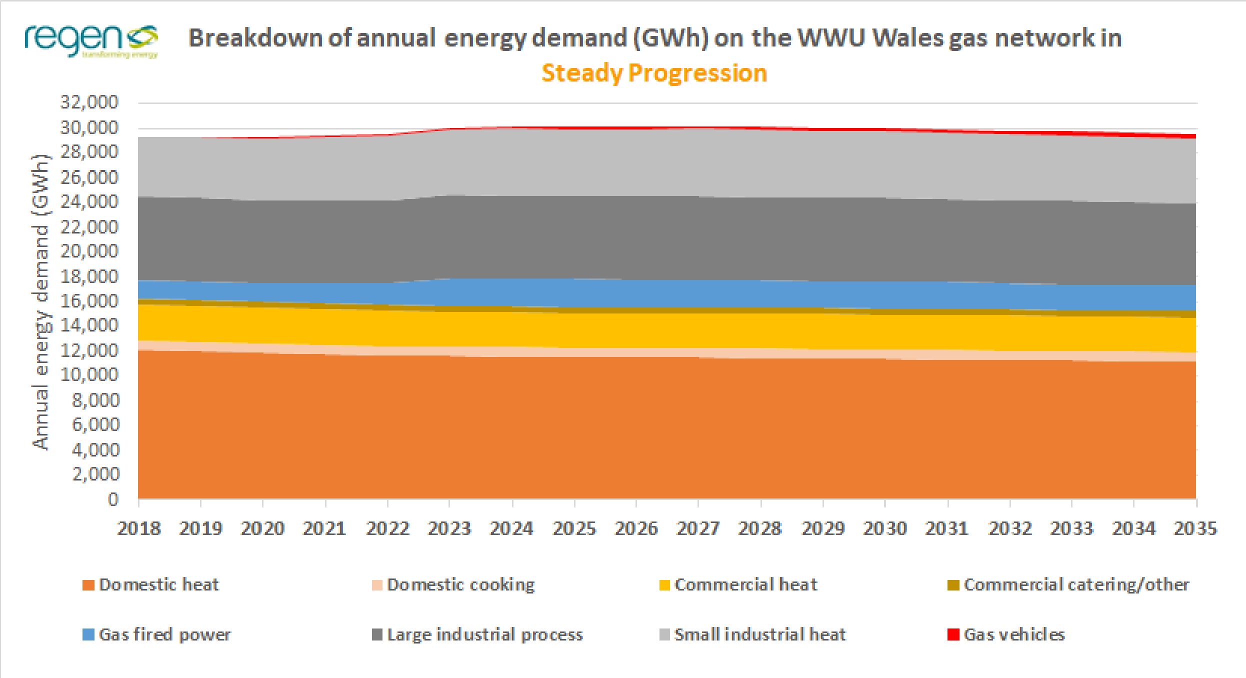

Figure 11: Graph of sources of annual energy demand on the WWU Wales gas distribution network in the Steady Progression scenario

3.2 Changes to the network gas blend in Wales

Analysis of future scenarios for biomethane injection (section 4.6), hydrogen blending (section 4.7) and the modelling of a hydrogen industrial cluster (section 4.2) has been combined to assess the annual gas blend being delivered by the WWU Wales gas distribution network. This analysis shows that, while the gas supply fuel mix in the WWU Wales LDZs remains predominantly natural gas from the National Transmission System (NTS[12]), in all scenarios out to 2035 the volume of green gas injection increases.

The projected annual amount of green gas blended into the WWU Wales gas network ranges between **965 GWh in Community Renewables** and **171 GWh in Steady Progression** by 2035. This equates to **4.4%** of the energy delivered by the WWU Wales gas network in **Community Renewables** and **0.6%** of the energy delivered by the WWU Wales gas network in **Steady Progression**.

In addition to green gas, the potential for a small proportion of hydrogen blending[13] has also been included in the **Hybrid Accelerator** and **Two Degrees** scenarios, in the 2030-2035 period. This equates to **490 GWh** of energy (**2.1%** of the energy delivered by the WWU Wales gas network), that is supplied by hydrogen blending in 2035 in the highest scenario (**Hybrid Accelerator**).

Table 2: WWU Wales gas distribution network fuel mix (by energy content) in each scenario

Scenario	Gas Fuel	2018	2020	2025	2030	2035
Community Renewables	Natural gas	100%	100%	98.9%	97.9%	95.6%
	Green gas	0%	0%	1.1%	2.1%	4.4%
	Hydrogen blend	0%	0%	0%	0%	0%
Two Degrees	Natural gas	100%	100%	99%	98.6%	95.9%
	Green gas	0%	0%	1%	1.4%	3.1%
	Hydrogen blend	0%	0%	0%	0%	1%
Hybrid Accelerator	Natural gas	100%	100%	99%	97.9%	94.5%
	Green gas	0%	0%	1%	1.6%	3.4%
	Hydrogen blend	0%	0%	0%	0.4%	2.1%
Consumer Evolution	Natural gas	100%	100%	99.6%	99.4%	98.2%
	Green gas	0%	0%	0.4%	0.6%	1.8%
	Hydrogen blend	0%	0%	0%	0%	0%
Steady Progression	Natural gas	100%	100%	99.9%	99.8%	99.4%
	Green gas	0%	0%	0.1%	0.2%	0.6%
	Hydrogen blend	0%	0%	0%	0%	0%

An increase in biomethane injection sites and thus more biomethane entering the network can present operational challenges to WWU, such as additional pressurisation in areas where green gas injection may be concentrated. The amount of biomethane currently entering the network in the Wales LDZs and proposed in the all scenarios out to 2035 is notably lower than that seen in the analysis for the South West LDZ. This may reduce the severity of the pressure management challenges in Wales, even in the scenarios with the more significant increases in biomethane entry. The annual blend of gas sources in each scenario out to 2035 is shown in Figure 12 to Figure 16. A more rapid increase in green gas

[12] For the purposes of this assessment, we have assumed that the NTS natural gas supply is 100% methane
[13] Assumed to be via electrolysis co-located with renewable electricity generation that would otherwise be curtailed.

injection in the Wales LDZs may be possible, but will depend heavily on feedstock availability and more disruptive business models driving green gas production, usage and specifically injection.

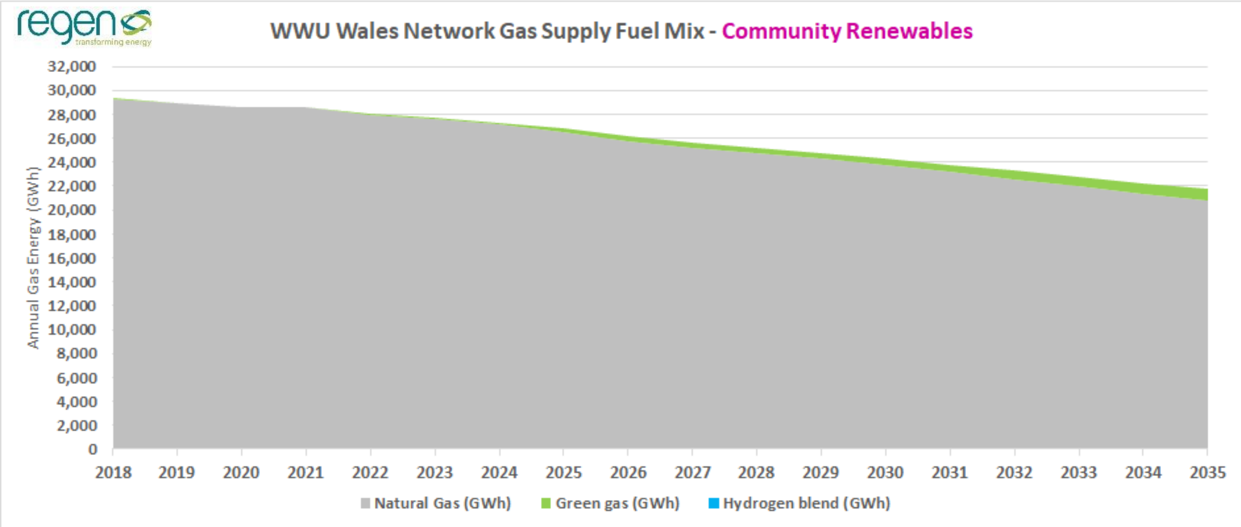

Figure 12: The gas energy fuel mix in the WWU Wales gas distribution network in the Community Renewables scenario

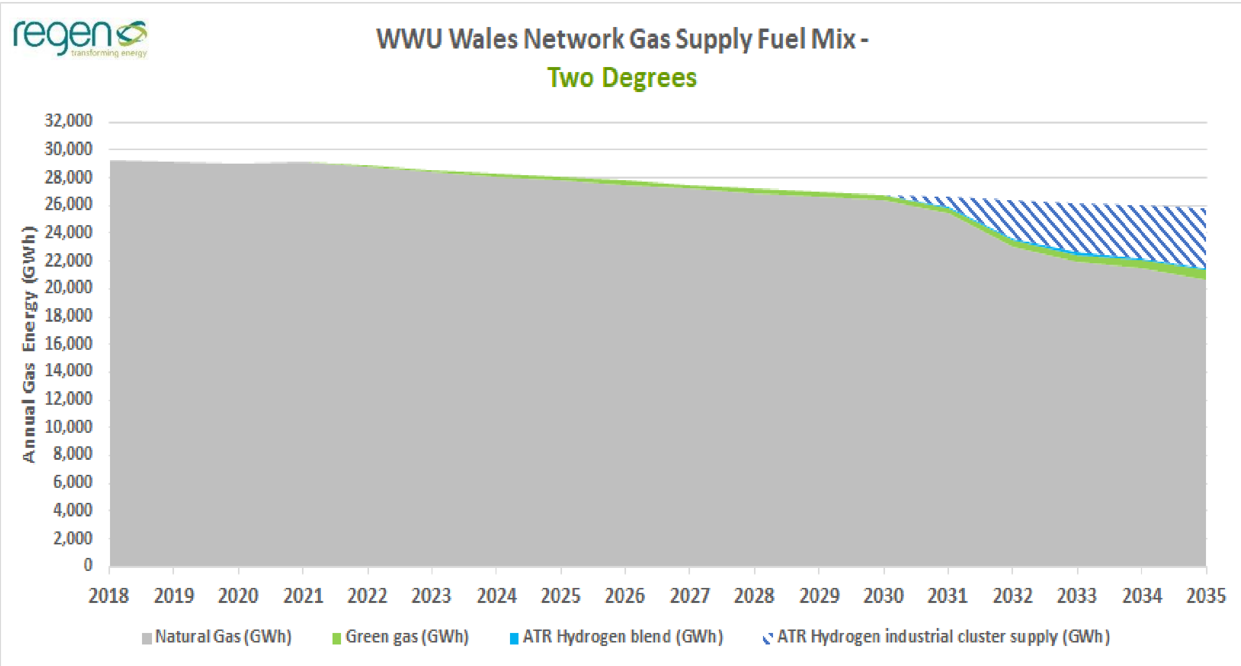

Figure 13: The gas energy fuel mix in the WWU Wales gas distribution network in the Two Degrees scenario (including hydrogen produced by Autothermal Reformation (ATR) that is blended and supplied to a hydrogen industrial cluster in Wales

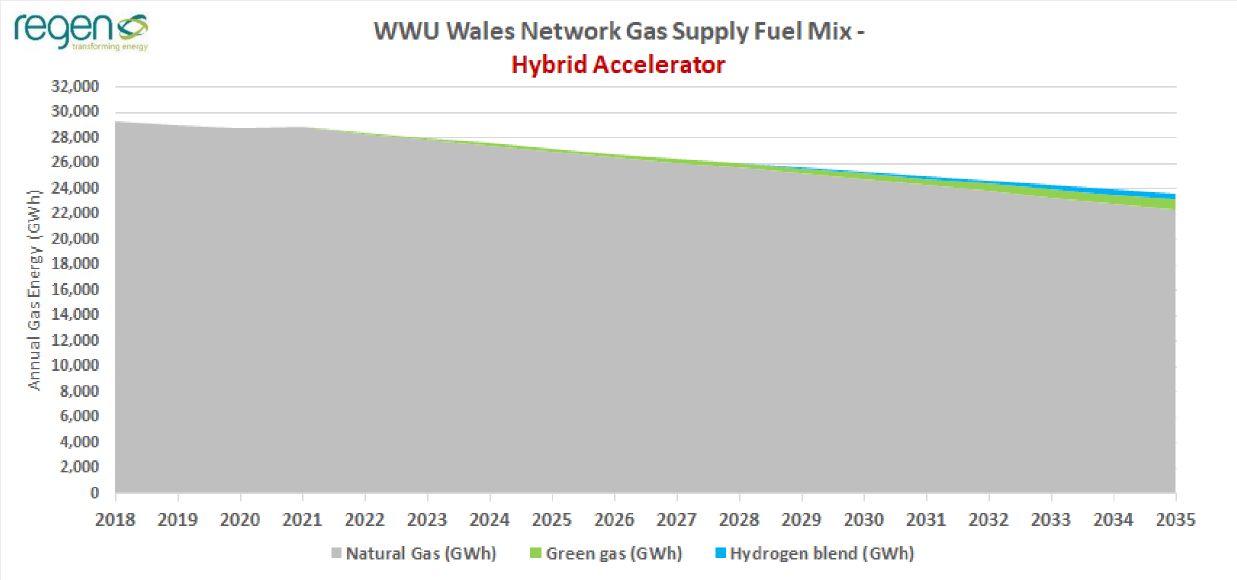

Figure 14: The gas energy fuel mix in the WWU Wales gas distribution network in the Hybrid Accelerator scenario

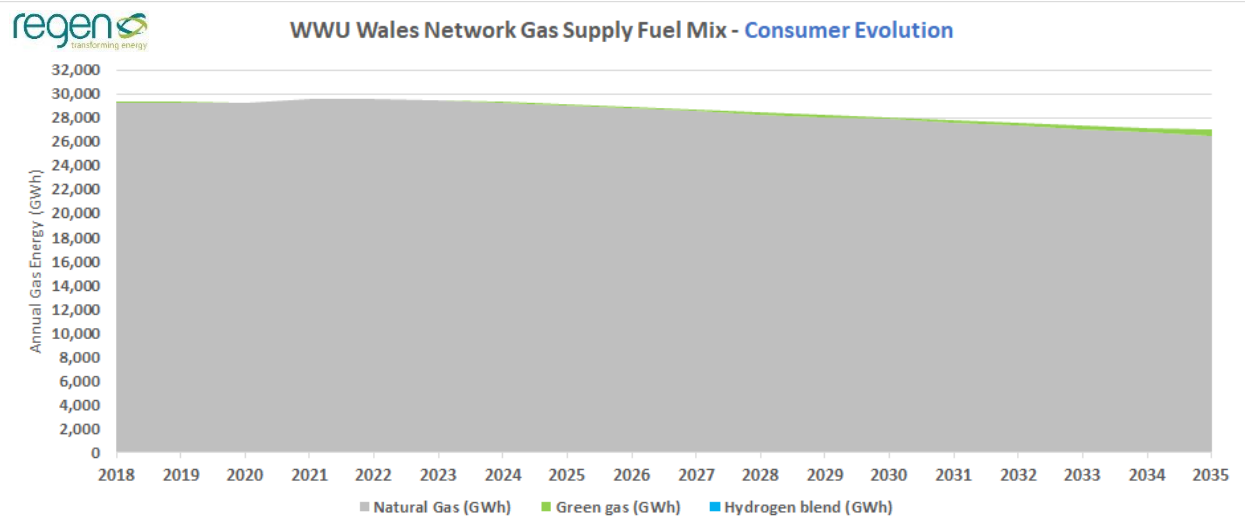

Figure 15: The gas energy fuel mix in the WWU Wales gas distribution network in the Consumer Evolution scenario

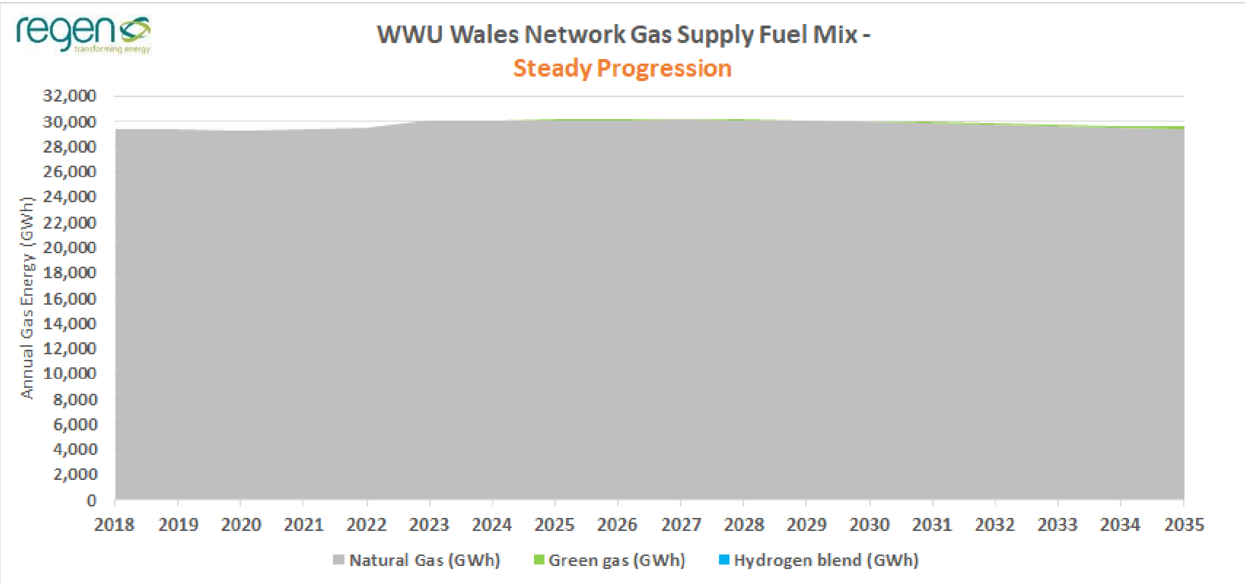

Figure 16: The gas energy fuel mix in the WWU Wales gas distribution network in the Steady Progression scenario

3.3 Carbon emissions impact assessment

3.3.1 Overview of approach

The primary purpose of the scenario analysis was to understand the changes in energy demand to support long term network planning and investment appraisal. Given that many of the significant changes are likely to be driven by carbon abatement policies, the project has also undertaken a high-level assessment of the carbon emission impact, for the key factors and elements within the scope of this study. This assessment does not account for all direct or indirect carbon emissions for elements outside the scope of the Wales gas distribution network, for example:

- The carbon reduction from coal power station closures or increased deployment of renewable energy generation on the electricity system in Wales, is not included in the impact assessment.
- Similarly, the knock-on carbon reduction effect of electric vehicles (EVs) replacing internal combustion engine vehicles has not been calculated.

The methodology for determining the carbon footprint for all in-scope elements is outlined in Table 3.

Table 3: Summary methods to determine the carbon impact of each of the key gas and heat elements

Category	Factor	Carbon Emission Calculation Method
Sources of demand	**Domestic heat demand**	Capturing the carbon emission value for each of the resultant fuel demands for domestic and C&I heat in 2035. Including **network supplied gas** (accounting for increasing levels of low carbon gases blended over time), **electricity, biomass, oil** and **LPG**.
	Commercial & industrial heat	
	Gas fired power generation	Capturing carbon emissions of the resultant network supplied gas demand only[14] for power generation in 2035, netting off the proportion of green gas injection for each scenario.
	Other industrial processes	Capturing carbon emissions of the resultant network supplied gas demand for industrial processes on the network in 2035, netting off the green gas injection volumes for each scenario. Hydrogen direct supply under one scenario, produced through Autothermal Reformation (ATR) is also considered.
	Gas fuelled vehicles	Capturing the carbon emissions of the network supplied gas demand for gas fuelled vehicles in the network area in 2035, netting off the green gas injection volumes for each scenario.
	Electric Vehicles (EVs)	Capturing carbon emissions for the resultant electricity use for EVs in 2035 in each scenario.
Alternative supply	**Green gas injection**	Capturing the carbon reduction from the green gas injected in 2035 in each scenario.
	Hydrogen blending	Capturing the carbon reduction for the resultant volume of hydrogen, depending on the method of hydrogen production[15], in 2035 for each scenario.

[14] The carbon impact on the resultant electricity generation fuel mix, is not within the scope of this assessment
[15] Assumed to be produced through electrolysis from surplus renewable generation and blended into the network

The carbon conversion factors in Table 4 have been used to determine the 2018 and 2035 carbon emission values described in Table 3.

Table 4: Carbon emission conversion factors for fuels used in the scenarios assessment in 2018 and 2035
The carbon conversion factors used within this analysis are based on direct emissions of carbon-emitting fuels.

Which scenario	Fuel Source	Carbon Conversion Factor ($kgCO_2e/kWh$)	
		Used in 2018[16]	Used in 2035[17]
Factors fixed for all scenarios	Natural gas (i.e. network gas)	0.184	
	Green gas (biomethane)	0.00022	
	Oil fuel	0.260	
	Biomass (average of multiple feedstocks)	0.0146	
	Solid fuel (coal)	0.345	
	LPG	0.214	
	Bio-LPG	0.0004	
Factors that vary according to scenario	Grid electricity – Community Renewables		0.0465
	Grid electricity – Two Degrees		0.0296
	Grid electricity – Hybrid Accelerator	0.216	0.0380
	Grid electricity – Consumer Evolution		0.0939
	Grid electricity – Steady Progression		0.0621
	Hydrogen ATR supply[18] – Two Degrees	0.026	0.009
	Hydrogen blending – Hybrid Accelerator	0.36	0.0634

3.3.2 Results of carbon emissions assessment

As can be seen in Figure 17 and Table 5, the total annual carbon emissions related to all relevant sources of demand and modes of supply reduces by 2035 in all scenarios for the Wales LDZs. The highest reduction in emissions is seen in Two Degrees, with a 33% reduction from the 2018 baseline.

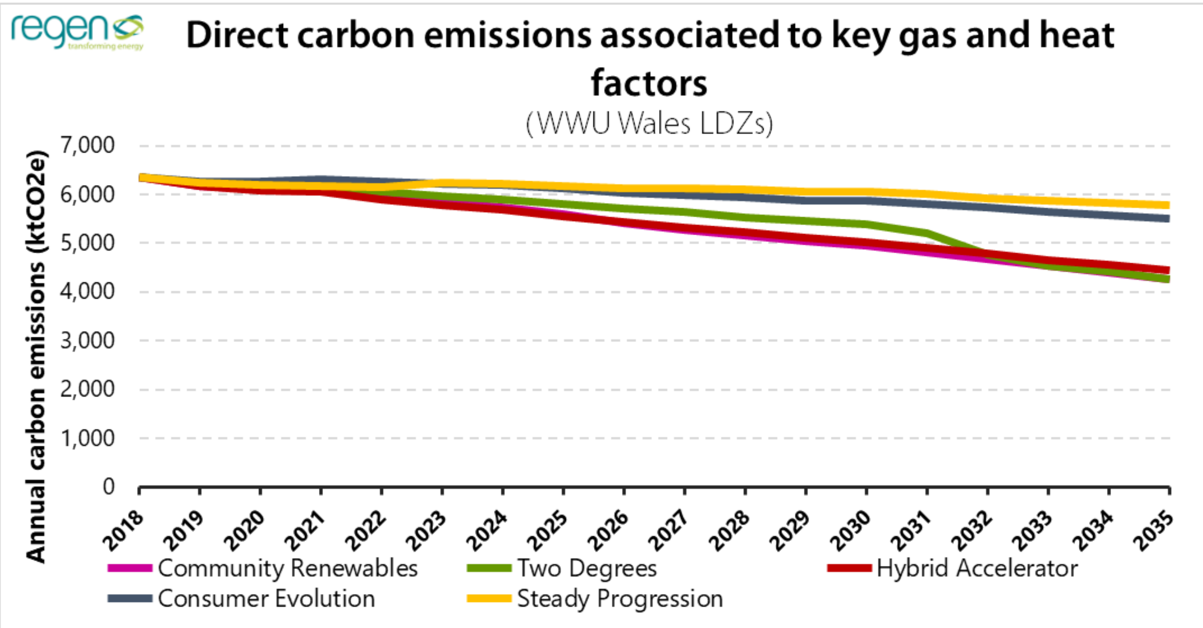

Figure 17: Annual carbon emissions from all heat demand and supply factors in each scenario for the WWU Wales LDZs

[16] Based on BEIS and DEFRA *Greenhouse gas reporting: conversion factors 2018*: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018
[17] Based on the National Grid FES 2018 projections for grid electricity carbon emission factors
[18] Based on Regen modelling and analysis of HyNet project findings: https://hynet.co.uk/

Table 5: Table of milestone scenario projections for annual carbon emissions for all sources of demand and modes of supply relating to the WWU Wales LDZs

Scenario	Annual carbon emissions ($ktCO_2e$)					Reduction from 2018
	In 2018	By 2020	By 2025	By 2030	By 2035	
Community Renewables	6,355	6,096	5,602	4,944	4,269	33%
Two Degrees		6,162	5,811	5,383	4,259	33%
Hybrid Accelerator		6,088	5,557	5,111	4,443	30%
Consumer Evolution		6,266	6,122	5,866	5,502	13%
Steady Progression		6,191	6,170	6,063	5,787	9%

The reduction in carbon emissions from the 2018 baseline ranges between 33% in Two Degrees and Community Renewables to 9% in Steady Progression.

The biggest contributions to carbon reduction are:

- **The reduction in underlying demand for energy from the gas network (Table 1) through energy efficiency (including boiler efficiency) and a shift to low carbon heating technologies**
- **The moderate increase in green gas injected into the network in all scenarios**
- **The hydrogen supply industrial cluster modelled in the Two Degrees scenario**
- **A significant reduction in the carbon intensity factor of grid electricity (Table 4)**

The breakdown of potential carbon reduction seen for each source of demand in each scenario is shown in Figure 18 to Figure 22.

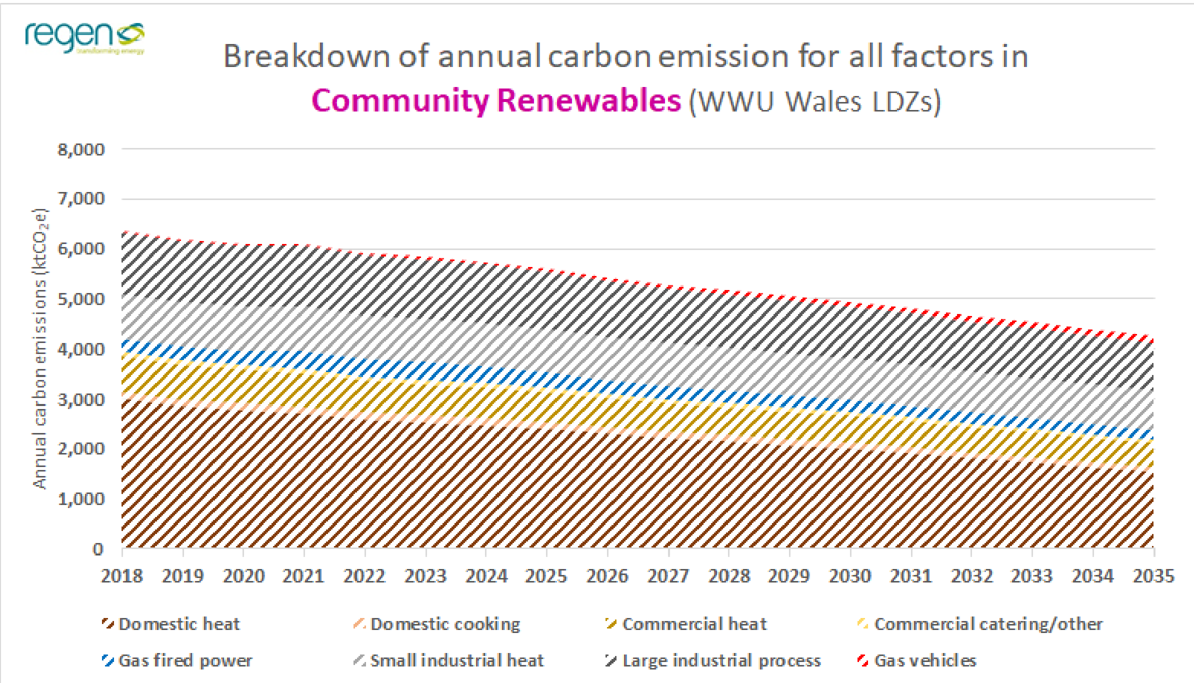

Figure 18: Breakdown of annual carbon emissions for all demand sources in Community Renewables in the WWU Wales LDZs

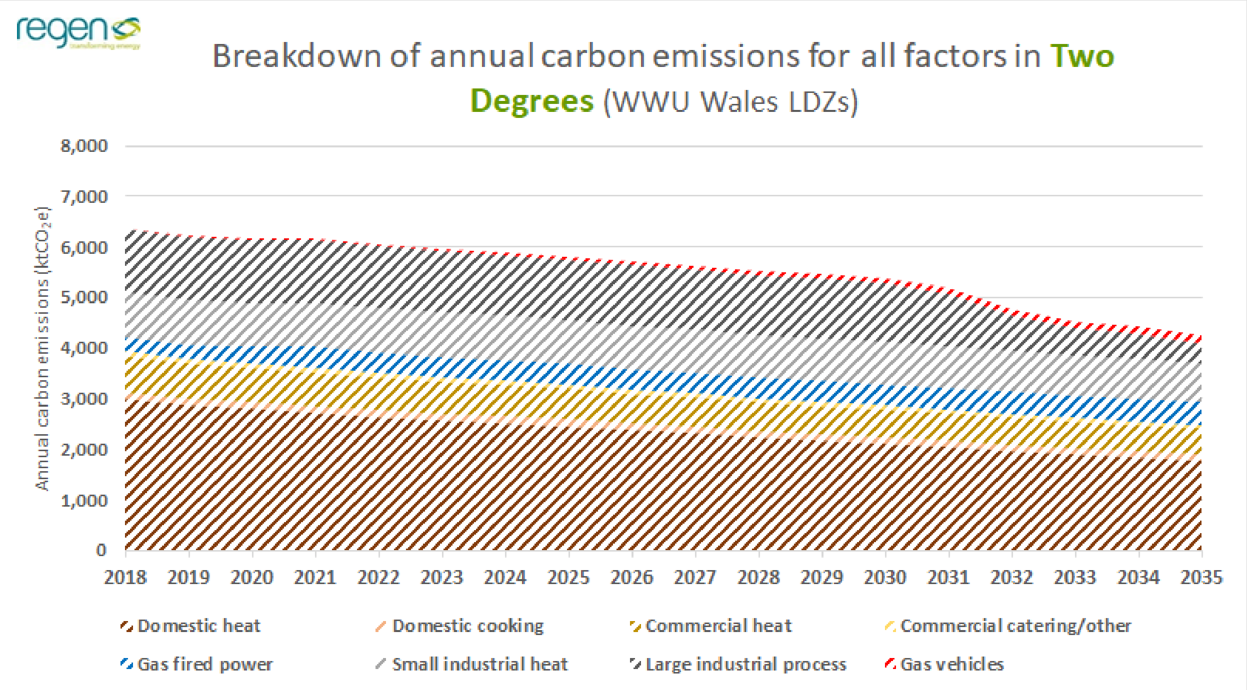

Figure 19: Breakdown of annual carbon emissions for all sources of demand in Two Degrees in the WWU Wales LDZs

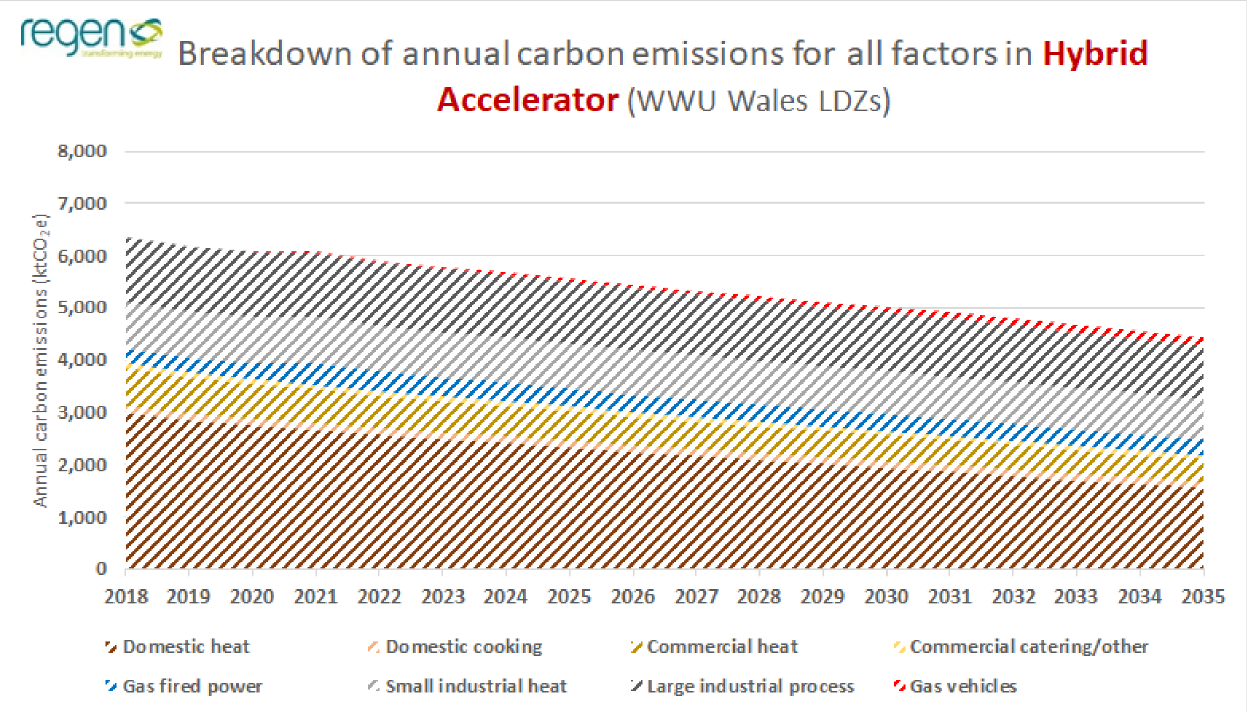

Figure 20: Breakdown of annual carbon emissions for all sources of demand in Hybrid Accelerator in WWU Wales LDZs

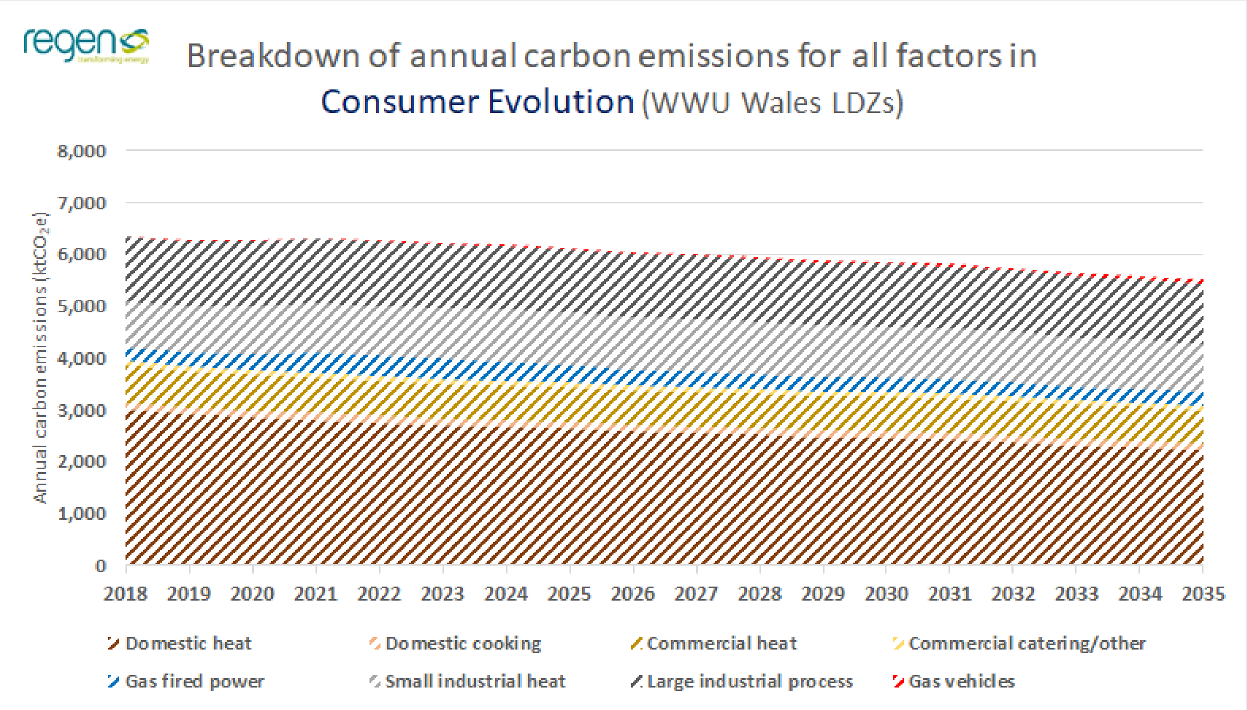

Figure 21: Breakdown of annual carbon emissions for all sources of demand in Consumer Evolution in the WWU Wales LDZs

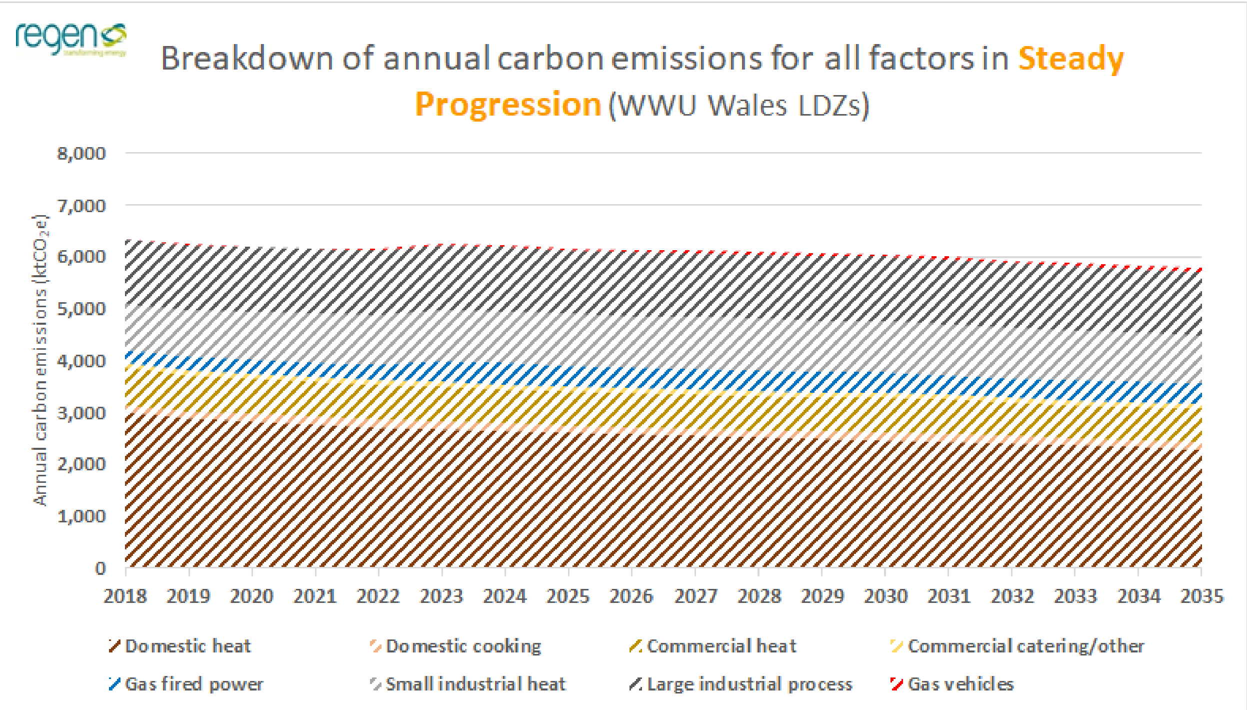

Figure 22: Breakdown of annual carbon emissions for all sources of demand in Steady Progression in the WWU Wales LDZs

4 Detailed scenario results for key gas and heat system factors

Table 6 provides an index of the results for each of the key factors that form the basis of this regional scenario assessment and the overall regional results seen in section 3.

Table 6: Index of category and factor scenario results subsections

Category	Factor	Report section
Sources of demand	Domestic heat demand	**Section 4.1** and **Appendix 1***
	Commercial & industrial heat	**Section 4.2** and **Appendix 2***
	Gas fired power generation	**Section 4.3** and **Appendix 3***
	Other industrial processes	**Section 4.4** and **Appendix 3***
	Gas fuelled vehicles	**Section 4.5** and **Appendix 4***
	Electric Vehicles (EVs)	
Alternative supply	Green gas injection	**Section 4.6** and **Appendix 5***
	Hydrogen blending	**Section 4.7**
	Unconventional natural gas	**Section 4.8**

* For all Appendices referenced, please refer to the **Technical Companion Document**.

4.1 Domestic heat

Domestic heat is a multifaceted source of heat demand, driven by several key elements. Within this analysis domestic heat has been calculated as the total demand for energy to provide space heating and domestic hot water within dwellings.[19] The demand for domestic heat is strongly influenced by a range of factors including dwelling type, availability of the gas grid, appliance type and conversion efficiency. Different trends in these factors can be seen amongst the three key types of tenure:

- Owner occupier (69% of all stock in Wales)
- Social housing (18%)
- Private rented (13%)[20]

These trends are considered when geographically distributing the results of the analysis. Significant changes in demand for domestic heat are expected to vary strongly depending on the specific geographical area and could therefore have a significant impact on local infrastructure requirements.

[19] At present, the majority of households use gas as the main source of heat, it is assumed they also use gas for cooking. Gas used for cooking has been excluded from the analysis of domestic heat by removing a fixed amount per gas-connected household. For the purposes of modelling total demand on the gas distribution network, this amount has been calculated and included in all data relating to the total network.
[20] See Welsh Housing Conditions Survey Report 2017 to 2018: https://gweddill.gov.wales/docs/statistics/2018/181206-welsh-housing-conditions-survey-headline-report-2017-18-en.pdf

4.1.1 Headlines from scenario analysis

The key outcomes of the scenario analysis for domestic heat are:

- **In all scenarios, the number of households increases by 7.9% from a baseline of 1,381,707 in 2018 to 1,490,903 in 2035.**
- **Scenarios where long-term UK carbon emission targets are not met (Steady Progression and Consumer Evolution) see the average annual heat demand per dwelling fall to 88% of the baseline by 2035. This is a result of continued 'no-regret' efficiency improvements in the existing stock and a modest improvement in new builds, but limited 'extra mile' measures such as deep retrofit or zero energy new homes.**
- **Scenarios whose trajectory is compliant with long term carbon targets (Community Renewables, Two Degrees and Hybrid Accelerator) have differing approaches to improving efficiency in the domestic stock. The Community Renewables and Hybrid Accelerator scenarios see the average annual heat demand per dwelling fall to 74% of the baseline by 2035 whereas in Two Degrees a still ambitious 81% is achieved. Rapid growth in the market for whole house retrofit approaches such as Energiesprong in the social housing stock occurs in addition to a continued trend of efficiency improvement in all existing stock. Standards for new dwellings are significantly improved, reaching Passivhaus levels of energy demand within the timescale of the analysis and approaching one of the Governments 'Grand Challenge Missions' of at least halving energy use in new buildings by 2030.**
- **Gas boilers remain the most common domestic heating technology, however the proportion of households served primarily by a gas boiler[21] varies by scenario. The use of gas boilers continues to increase from a 2018 baseline of 77% to reach 84% of households in 2035 in a Steady Progression scenario. The proportion falls slightly in a Consumer Evolution scenario and more significantly in the compliant scenarios to circa 60% - 65% of households by 2035.**
- **Air source heat pumps (ASHP) see the largest increase in market share for heating technologies in four of the five scenarios. From a low baseline of deployment in 0.41% of dwellings in 2018, ASHPs are deployed in up to 13% of dwellings in Community Renewables, becoming one of the top four heat technologies in all scenarios by 2035.**
- **The reduction in boiler use as a primary heating technology is offset to some degree by the use of gas boilers as a secondary heating technology in hybrid heat pump systems. This is especially true in the Hybrid Accelerator scenario.**
- **Other technologies seeing increased uptake are Ground Source Heat Pumps (GSHPs), Hybrid Heat Pumps (HHPs)[22], heat networks and boilers using bioenergy.**
- **The impact of the growth of district heat networks varies by scenario. In the near-term, heat networks fired by gas boilers or gas-fired CHP plant could increase energy demand on the gas network. It is expected however that heat networks will improve in efficiency and increasingly be supplied by low carbon heat either as waste heat or from low carbon sources.**

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[21] Standalone gas boilers, i.e. excluding those with a hybrid heat pump system.

[22] A hybrid heat pump combines a traditional fossil fuelled boiler with an electrically driven heat pump (usually air source). This enables a poorly insulated building to meet much of its demand with a modestly sized, lower cost heat pump, reverting to fossil fuel to meet peak demand on cold days and for provision of domestic hot water.

The overall technology and fuel demand position for domestic heating in Wales is shown in Figure 23.

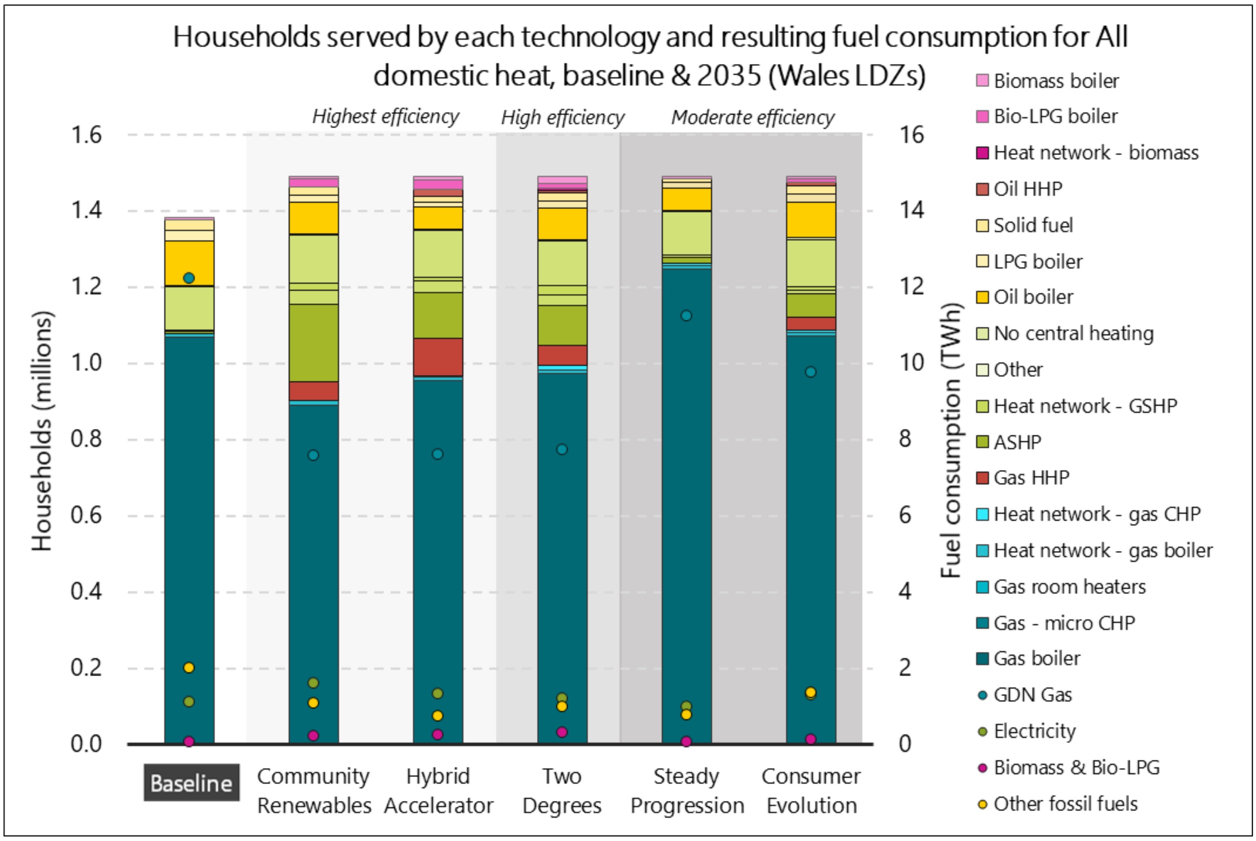

Figure 23: Overall summary of technology and fuel demand for domestic space heat and hot water

4.1.2 Summary of the approach taken

The high-level method by which domestic heat has been assessed is described in Figure 24.

(1) Established baseline data components (2010 – 2018)

Number of existing dwellings

Average heat demand trends in existing and new (MWh/year/dwelling)

Delivery technology types and % of dwellings served by each type in existing and new

Rate at which existing appliances are replaced

Conversion efficiency of each technology in existing and new

(2) Produced scenario-aligned components (2019 – 2035)

Assess potential future shifts in the identified baseline components for each scenario, giving consideration to:

FES framework

New build completions

Changes in building regulations (Parts L, F, J)

Trends in energy efficient retrofit for existing

Potential policies aligned with certain scenarios (e.g. proposed ban of fossil fuel boilers in new build from 2025)

(3) Calculation of scenario outputs

Components used to calculate:

Number of each technology type, by year, by scenario

Total demand for heat and fuel, by technology type, by year, by scenario

Total demand for each key fuel, year by scenario

4) Geographically distributed into GSAs

Distributed annual, scenario specific capacity into the 37 GSAs, using weighted distribution factors, such as:

- Existing heating technologies
- Proximity to the gas network
- Tenure, such as socially rented housing
- Dwelling types, such as flats
- Affluence
- Urban / rural land
- Average heat demand per household

Figure 24: High level scenario assessment stages for domestic heat

The following sections outline the detailed scenario projection results for domestic heat, as well as showing the geographical distribution into the GSAs for the WWU Wales gas network area.

More detail on the method, assumptions and references used to inform the domestic heat analysis is outlined in Appendix 1 in the Technical Companion Document.

4.1.3 Detailed results

Demand for energy from the gas network

From a baseline demand of just over **12,000 GWh/year**, the demand for gas from the network for domestic heat and hot water in Wales decreases in all scenarios by 2035. This ranges from a moderate reduction in **Steady Progression** of **8%**, to a **38%** reduction from the baseline to **7,584 GWh/year** in **Community Renewables** (see Table 10). The reduction in demand for all scenarios reflects trends in domestic energy efficiency and shifting popularity of heating appliance types which offsets a steady increase in the number of new dwellings.

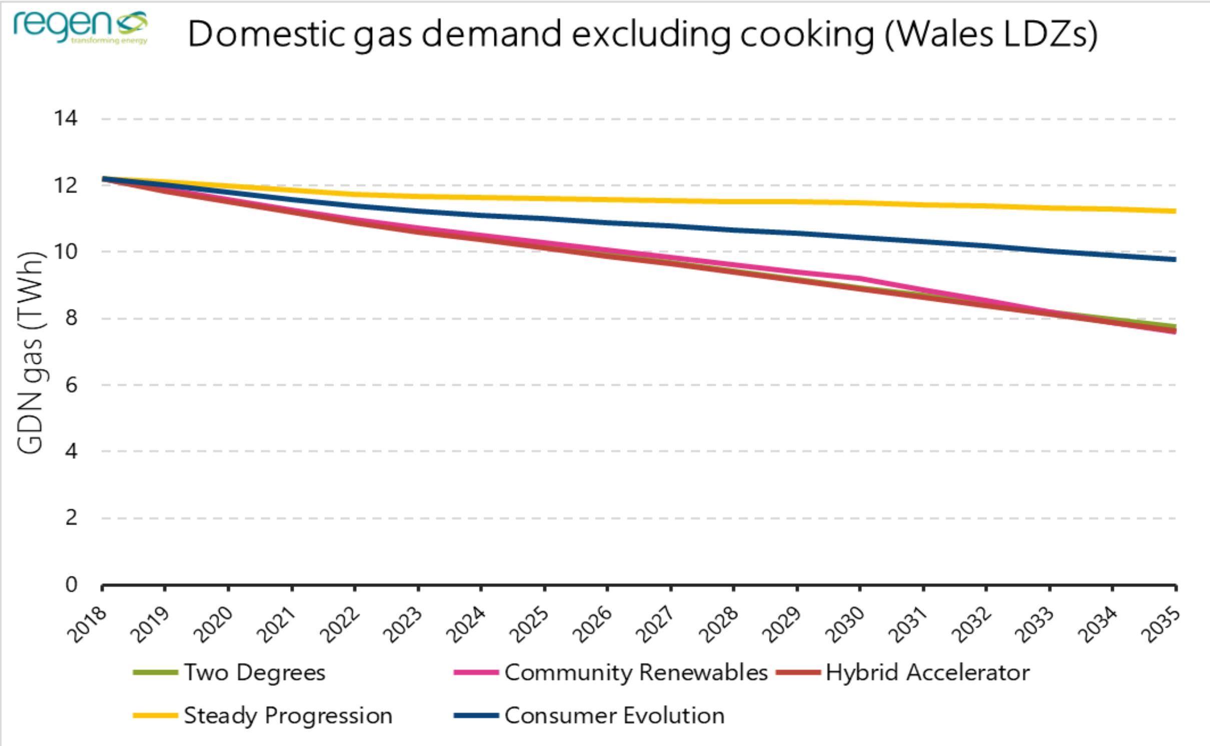

Figure 25: Changing demand for gas for domestic heat and hot water within the WWU Wales LDZs to 2035

Number of dwellings and their demand for heat

The number of properties within the WWU Wales LDZs has steadily increased by around 0.6% per year over the past decade, reaching nearly 1.4 million households in the 2018 baseline year (Figure 26). Reflecting local development plans, and government targets to accelerate the delivery of new dwellings, an increased house build completion rate is expected out to 2023, with an annual increase in housing stock of up to 0.9% in these near-term years. In later years, it is assumed that house build rates will align more closely with the 0.6% per year historic trend. By 2035, there are expected to be a total of 1.5 million houses in the WWU Wales gas network area, representing an 8% increase from the 2018 baseline. The spatial distribution of these new households is expected to be focused around major urban areas, with a 21% growth in numbers of households expected in the Cardiff GSA by 2035 and around 10% growth in the Swansea, Newport and Wrexham GSAs. Conversely, heavily rural areas such as Powys, Anglesey and Caerphilly are not expected to see an increase in housing stock above current levels.

While this remains a relatively small proportion of the overall housing stock, the profile of new housing is different to that of existing housing. The absolute number of houses built has not been varied by scenario, however, the efficiency of this housing stock and the technologies supplying this heat are significantly different depending on the factors and drivers of the future energy scenarios.

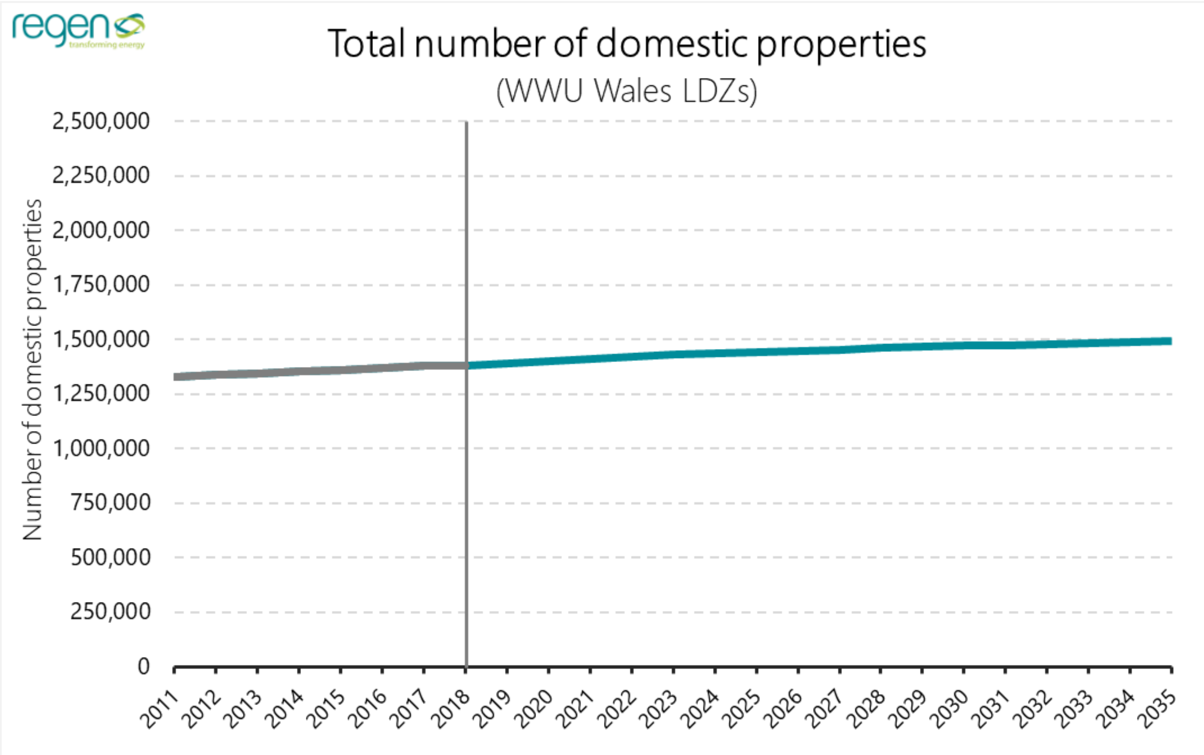

Figure 26: Projected total number of domestic dwellings within the WWU Wales LDZs, 2018 to 2035

The analysis has partitioned the housing stock into two archetypes; ‘existing’ covering all dwellings constructed by the baseline year, ‘new’ covering all dwellings constructed 2019 -2035. A more detailed breakdown of the existing stock into separate archetypes would be desirable but outside the scope of this piece of analysis. Year by year modelling has been carried out for all new dwellings, allowing changes in efficiency standards and heating appliances to be modelled in detail. Three scenarios for changing efficiency of dwellings have been modelled as shown in Table 7 and applied across the five scenarios as shown in Figure *27*.

Table 7: Overview of the two domestic efficiency scenarios for Wales

Scenario	Changes in existing dwellings	Changing standards in new build
Community Renewables	Over 84,000 dwellings undergo deep retrofit by 2035	38% reduction in average demand by 2035
Hybrid Accelerator	21% reduction in average demand of all other dwellings by 2035	
Two Degrees	17% reduction in average demand of all dwellings by 2035	38% reduction in average demand by 2035
Consumer Evolution	10% reduction in average demand by 2035	10% reduction in average demand by 2035
Steady Progression		

Non-compliant scenarios

Non-compliant scenarios see heat demand in existing dwellings reduce to 90% of the baseline by 2035. This corresponds to an annual reduction in demand of 0.6%[23], which assumes that deployment via ECO and similar schemes continues at low levels and that the efficiency improvements are harder to deliver.[24]

Compliant scenarios

Two differing approaches to efficiency in existing dwellings have been modelled for the compliant scenarios. In **Community Renewables** and **Hybrid Accelerator** it has been modelled that heat demand continues to reduce at a steady rate of approximately 1.4%/year with the assumed policy environment being that Welsh Government takes up the recommendation from the 'Decarbonisation of homes in Wales Advisory Group' to retrofit all homes (where practicable) to an EPC A. In addition, strong growth of the market for deep retrofit approaches (such as Energiesprong) that provide a typical heat demand reduction in the region of 60% per dwelling is seen.

In **Two Degrees** we see a moderated version of this approach where significant levels of retrofit take place but the deployment of more significant measures and use of deep retrofit is less widespread. In this scenario, efforts are spread to more centralised approaches to decarbonisation as well as distributed effort into energy efficiency in dwellings.

The graph in shows the resulting average across all stock for the efficiency scenarios that have been modelled, however the analysis carried out uses a shifting average for all existing dwellings and a construction year specific figure for new dwellings.

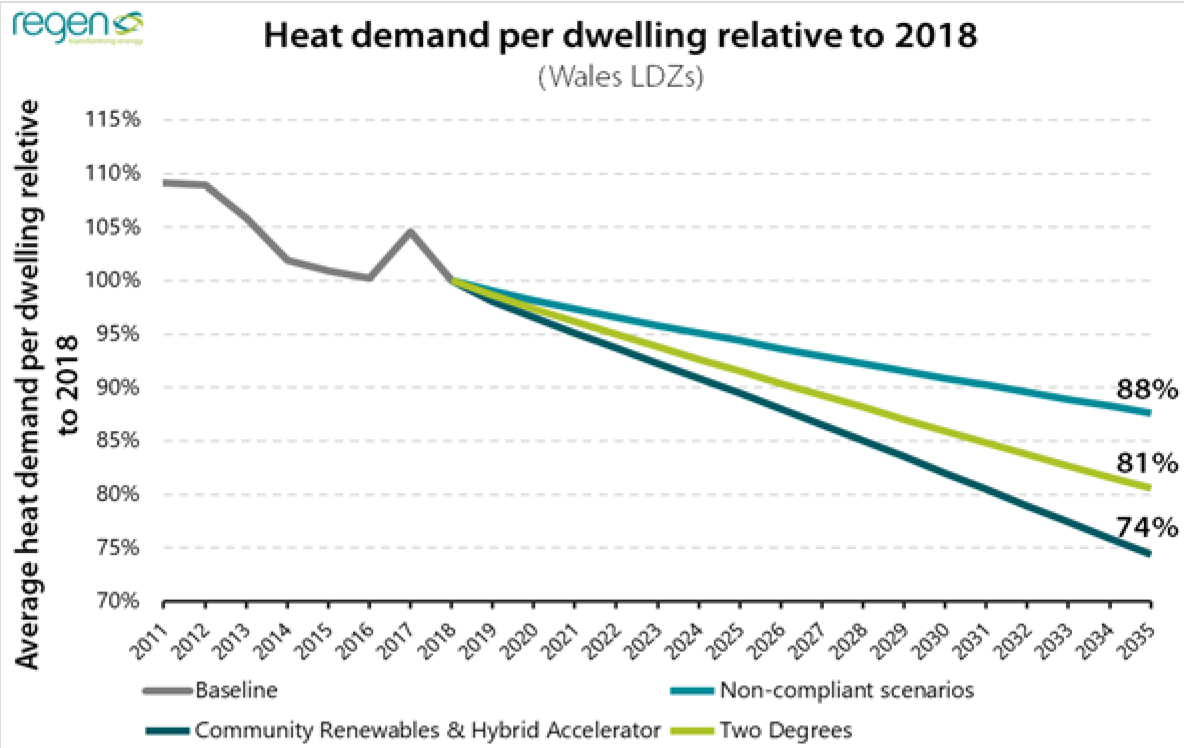

Figure 27: Changing demand for heat and hot water as an average across all domestic properties within the WWU Wales LDZs, 2018 to 2035

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[23] The current levels of reduction are ~1.2%/year

[24] Green Alliance – Reinventing Retrofit

Technology trends

Within the timescale of this analysis gas boilers remain the most common heating technology in all scenarios, as shown in Figure 28.

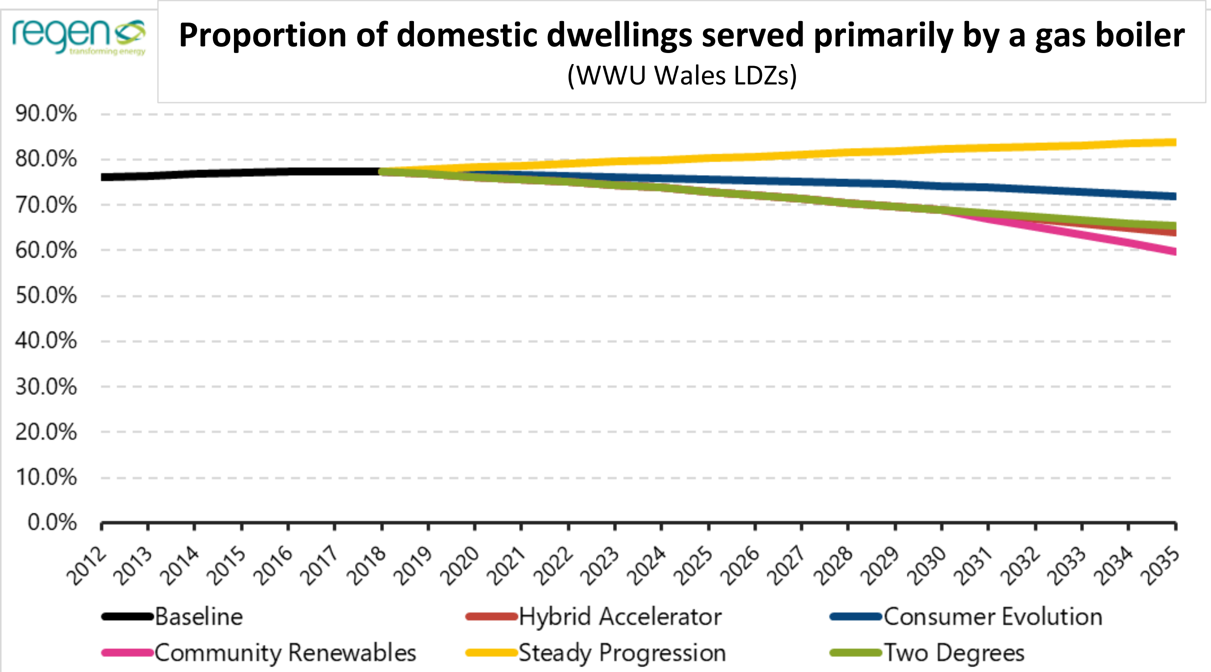

Figure 28: Changing share of domestic dwellings served by gas boilers within the WWU Wales LDZs to 2035

In the three compliant scenarios the total number of gas boilers used as primary heat source peaks in 2025. This is a result of a ban on fossil fuel appliances[25] in new build domestic dwellings combined with a trend of 10% of the gas boilers due for replacement each year being exchanged for alternative heat sources (such as heat pumps and heat networks).

Despite this, in many of the scenarios the decline in use of a gas boiler as the primary source of central heating is partially offset by increasing deployment of gas hybrid heat pump appliances, as illustrated for the **Hybrid Accelerator** scenario in Figure 29.

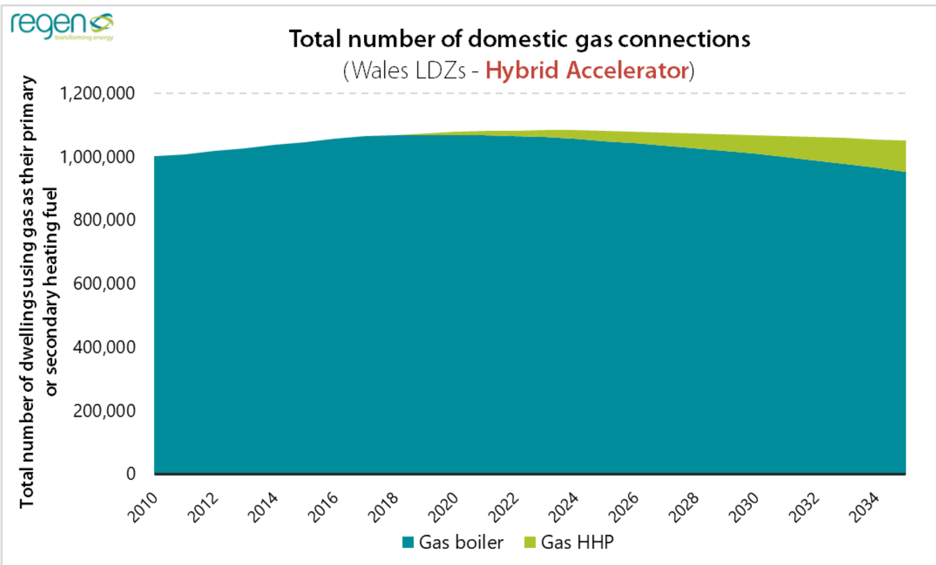

Figure 29: Changing number of domestic properties served primarily by gas boilers (or with hybrid heat pumps with gas boiler backups), alongside total domestic gas connections within the WWU Wales LDZs, 2018 to 2035.

[25] https://www.carbonbrief.org/daily-brief/gas-heating-ban-for-new-homes-from-2025

As shown in Table 8 the total number of domestic gas connections peaks in the mid-2020s and then decreases in all of the compliant scenarios. The demand profile of these connections can be expected to change, with gas hybrid heat pumps typically using the gas connection to deliver only the peak demands, amounting to an estimated 30%[26] of the typical annual heat demand.

Table 8: Table of milestone scenario projections for domestic gas connected households in the WWU Wales LDZs

Scenario	Baseline 2018	By 2020	By 2025	By 2030	By 2035
Community Renewables	1,068,934	1,073,327	1,062,033	1,032,481	940,134
Two Degrees		1,074,872	1,067,439	1,043,798	1,024,861
Hybrid Accelerator		1,079,506	1,083,658	1,069,867	1,052,824
Consumer Evolution		1,082,996	1,100,813	1,109,839	1,106,005
Steady Progression		1,099,118	1,157,238	1,208,038	1,248,433

A significant increase in the number of households using a heat pump as the primary heat source is projected in all scenarios, as shown in Table 9, **Steady Progression** sees the smallest growth in this area as gas boiler numbers continue to increase.

Table 9: Table of milestone scenario projections for households where a heat pump is the primary source of heat in the WWU Wales LDZs. This includes Air Source (ASHP), Ground Source (GSHP) and Hybrid Heat Pumps (HHP).

Scenario	Baseline 2018	By 2020	By 2025	By 2030	By 2035
Community Renewables	8,496	23,711	65,413	141,358	289,670
Two Degrees		19,843	51,457	116,574	189,698
Hybrid Accelerator		33,263	98,429	178,290	265,431
Consumer Evolution		16,442	37,107	78,339	115,605
Steady Progression		9,730	12,894	16,781	21,181

ASHPs make up much of this increase, as either the sole appliance or as part of a hybrid system. GSHP numbers increase, albeit at a slower rate which is reflective of the additional complexity and higher capital costs associated with deployment of ground or water loops. Business models making use of communal ground and water loops could help increase this rate of deployment.

[26] 30% figure used as a benchmark from Regen's Swansea Bay City Region analysis (https://www.regen.co.uk/publications/swansea-bay-city-region-a-renewable-energy-future/) and sitting within the boundaries of similar studies such as Project Freedom (https://www.wwutilities.co.uk/media/2829/freedom-project-final-report-october-2018.pdf) and the Committee on Climate Change (https://www.theccc.org.uk/publication/net-zero-technical-report/).

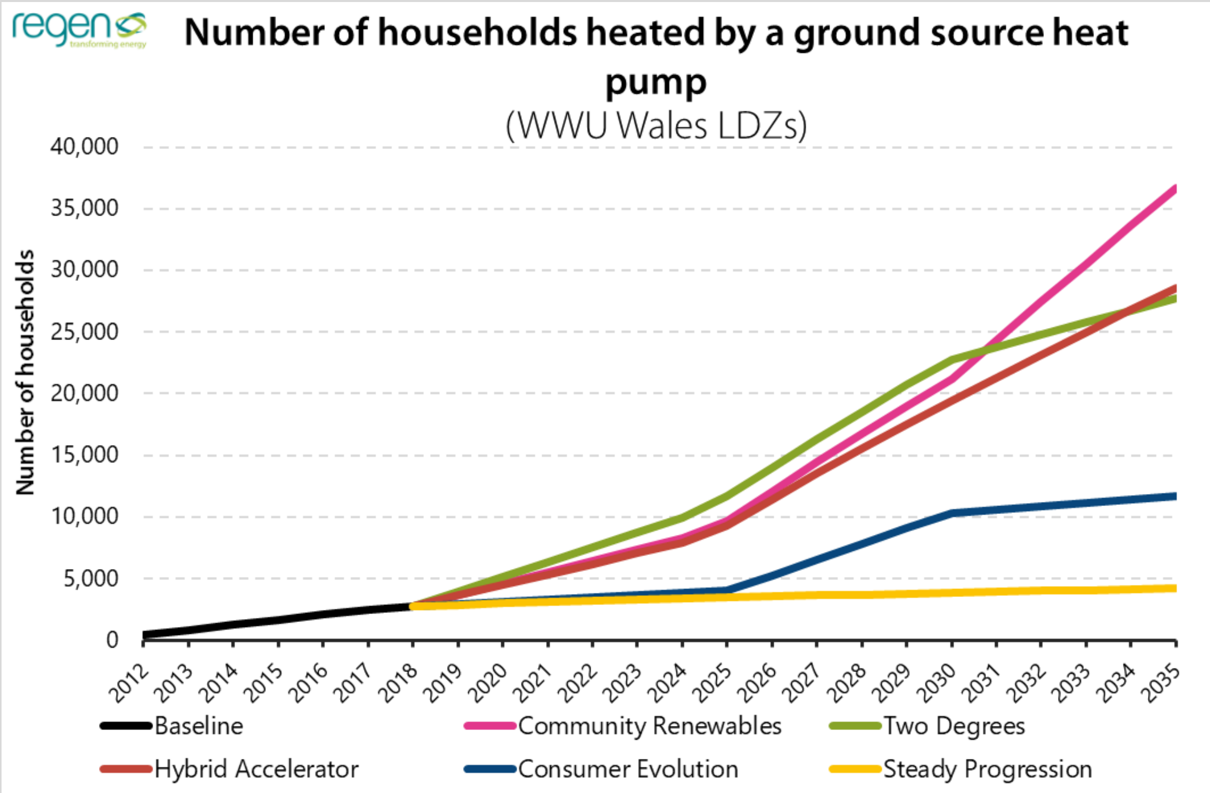

Figure 30: Total domestic dwellings served by a ground source heat pump within the WWU Wales LDZs, 2018 to 2035

The number of households served by a district heat network increases significantly in four of the five scenarios (Figure 31). In the non-compliant scenarios, these networks are predominantly heated by gas-fired boilers and gas-fired CHP plant, in line with current data on pipeline and in-progress networks. Due to the losses associated with the distribution element of a heat network (underground pipes, risers and heat interface units which are usually kept warm 24/7 in order to rapidly meet demand), low-carbon heat sources must be deployed in the compliant scenarios for this sector to continue to grow. In compliant scenarios all heat networks deployed after 2025 rely predominantly on ground and water source heat pumps as well as biomass boilers rather than gas, in order to decarbonise. Existing gas-fired heat networks (i.e. those commissioned up to 2025) do not transition to an alternative heat source within the timescale of this analysis, however it would be anticipated that this would occur just outside the boundary of this assessment.

The demand for heat through gas-fired heat networks (and the resultant demand for gas) has been included within the domestic heat data for clarity. It is worth noting that operationally speaking each cluster of dwellings served by a gas-fired heat network would be seen by WWU and local authorities as a single commercial connection, rather than numerous domestic connections.

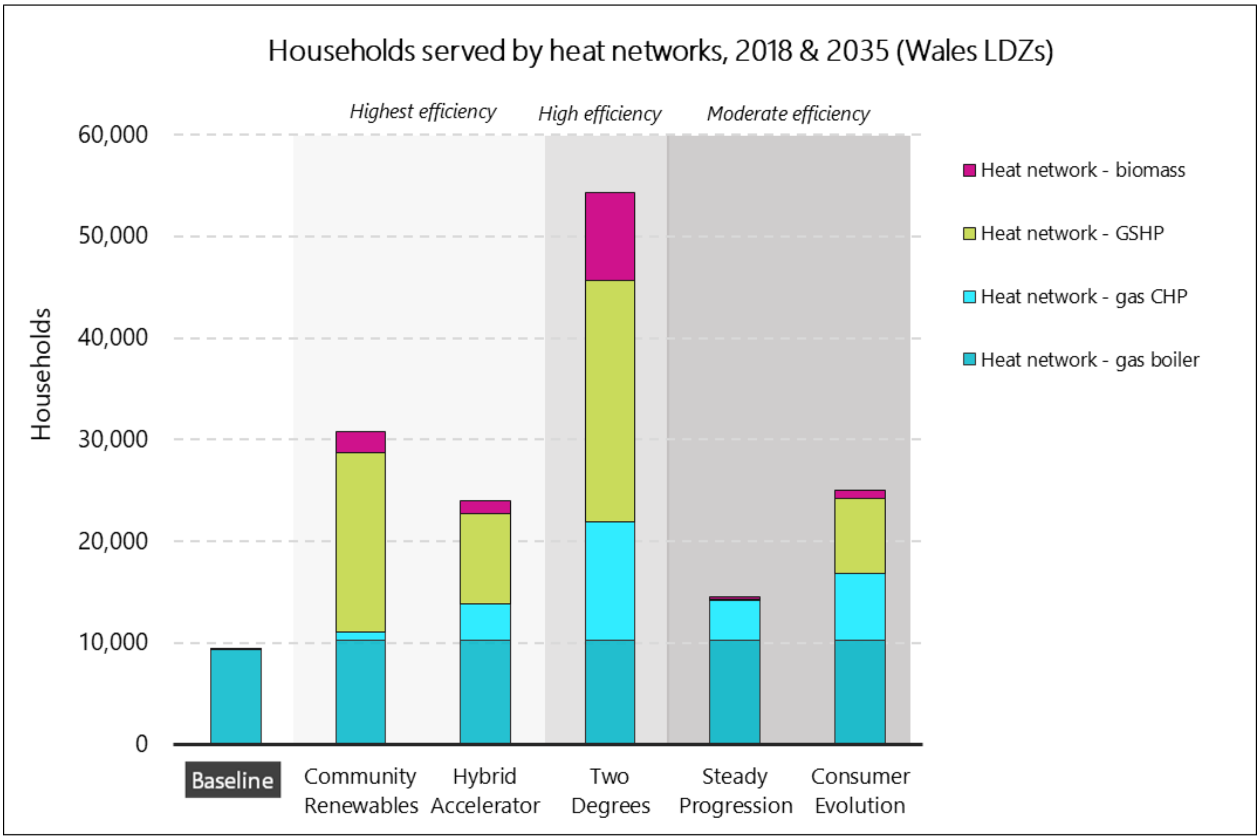

Figure 31: Changing share of households served by a district heat network within the WWU Wales LDZs, 2018 to 2035

Table 10: Milestone scenario projections for domestic heat demand delivered by the gas network in the WWU Wales LDZs

Scenario	Baseline 2018 (GWh)	By 2020 (GWh)	By 2025 (GWh)	By 2030 (GWh)	By 2035 (GWh)
Community Renewables	12,216	11,586	10,270	9,200	7,584
Two Degrees		11,537	10,192	8,931	7,743
Hybrid Accelerator		11,516	10,131	8,901	7,619
Consumer Evolution		11,800	11,003	10,443	9,769
Steady Progression		11,986	11,606	11,469	11,242

4.1.4 Geographical distribution

Number of households and their demand for heat

The total demand for domestic heat in each GSA is a result of two distribution factors: the number of households in the GSA, and the average heat demand per household in that GSA. Overall, for the WWU Wales gas network area, the number of households increases over the projection period while heat demand per household falls, as a result of insulation retrofit and more efficient new builds. However, these factors vary by GSA, which will impact the overall gas demand for each area.

Since the method by which the GSAs are produced results in a broad range of GSA sizes and populations (Figure 32) the results in this section will typically be presented on a proportional or per square kilometre basis.

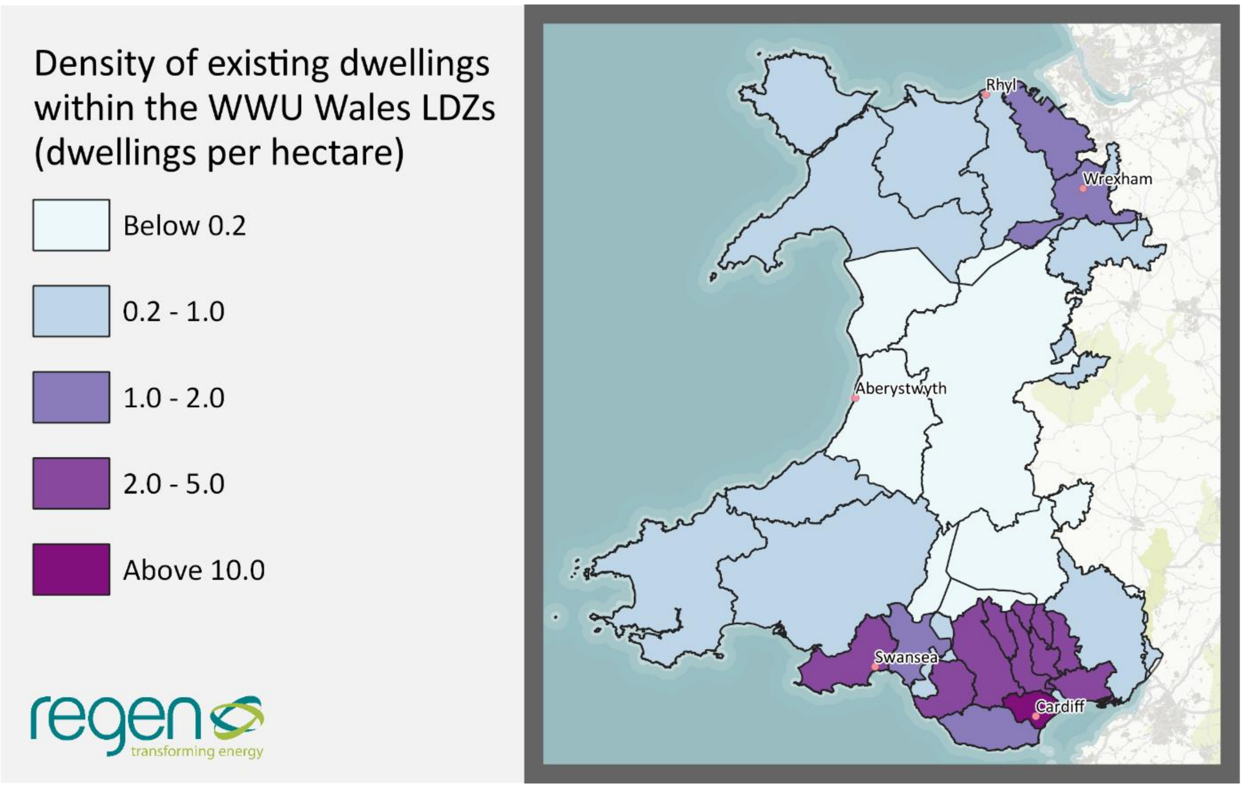

Figure 32: Number of domestic dwellings in Wales by GSA, as of 2018

New build dwellings are distributed according to a combination of local plan allocations, for the near-to-medium term, and the current location of housing in the long term. The current heat demand per household is the result of a number of factors:

- **Temperature** – the more coastal GSAs, with higher average annual temperatures, naturally display lower annual heat demand, while the cooler areas such as the Brecon Beacons similarly display higher annual heating demands
- **Urban/rural split** – more urban areas display lower heat demand than surrounding areas, due to smaller average dwelling sizes, higher proliferation of flats and terraced housing, and 'heat island' effects. Social housing (which tends to have lower heat demand) is also more common in urban areas
- **Affluence** – less affluent areas typically show a lower heating demand than that seen in a comparable, more affluent area
- **Housing stock** – areas with older, less efficient housing show greater levels of heat demand

As these distribution factors will not significantly change during the 2018-2035 projection period, the distribution of heat demand assumes that areas of low demand will generally remain low, and vice-versa for areas of higher demand. Reductions in heat demand, through steady continuation of insulation roll-out or deeper retrofit schemes, would be driven by nationwide initiatives and therefore variation at a GSA scale is limited. However, the distribution modelling includes socially rented housing and particularly expensive to heat housing (off-gas housing with an EPC rating of an F or G) as more likely to receive targeted or subsidised insulation and deep retrofit measures, and areas with currently higher demand as containing more 'headroom' to reduce demand in the analysis timeframe.

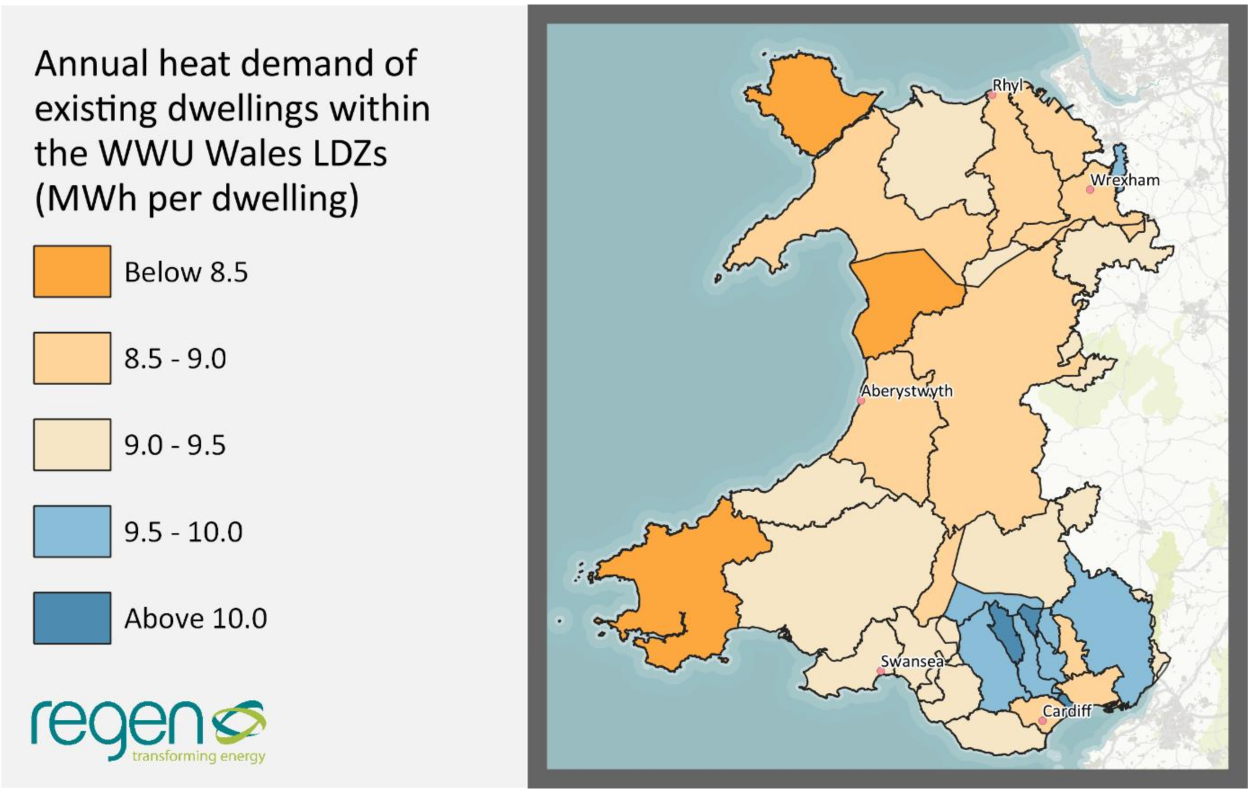

Figure 33: Mean annual heat demand in WWU Wales LDZs per domestic dwelling by GSA, as of 2018

Technology distribution trends

The challenge of domestic heat decarbonisation has potential to see significant changes in the technologies supplying heat to households. The WWU Wales gas network area could see a number of trajectories in terms of domestic heating technologies. The proportions of these technologies, such as gas boilers, oil boilers, heat pumps and heat networks, are geographically controlled by many factors, and so uptake and removal of heating technologies will show spatial variation.

Using the **Regen Distributor Model**, each GSA is characterised through factors that are most likely to influence uptake or removal of specific technologies. The weighting and usage of these factors are determined through assessment of the existing baseline, market research and engagement events, and vary throughout the projection period. The key factors identified for distributing domestic heat technologies are:

Affluence – defined by 2011 Census data on number of people in NRS[27] social grades A and B, representing average salaries typically above £30,000 per year, affluence has been utilised as a factor in the uptake of more capital-intensive heating technologies, such as ground source heat pumps.

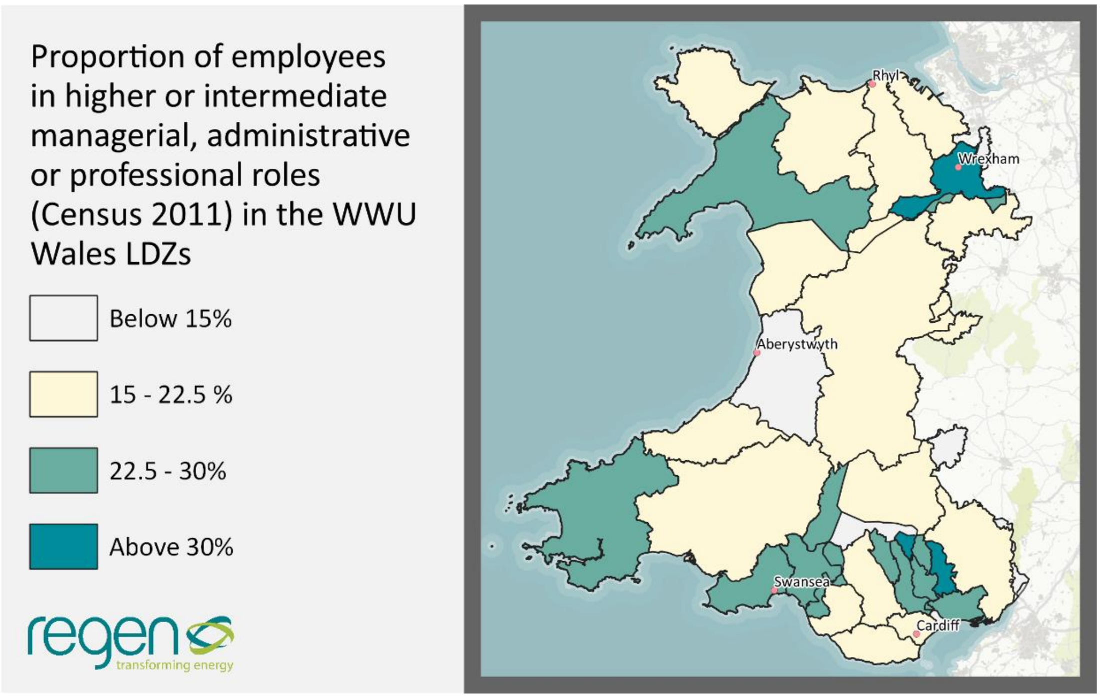

Figure 34: Proportion of affluent employees in WWU Wales LDZs, by GSA

Tenure – directly from 2011 Census data, tenures such as socially rented properties (below) or home ownership will impact heating technology uptake. For example, baseline data suggests that heat pumps are more likely to be installed in socially rented properties in the near term.

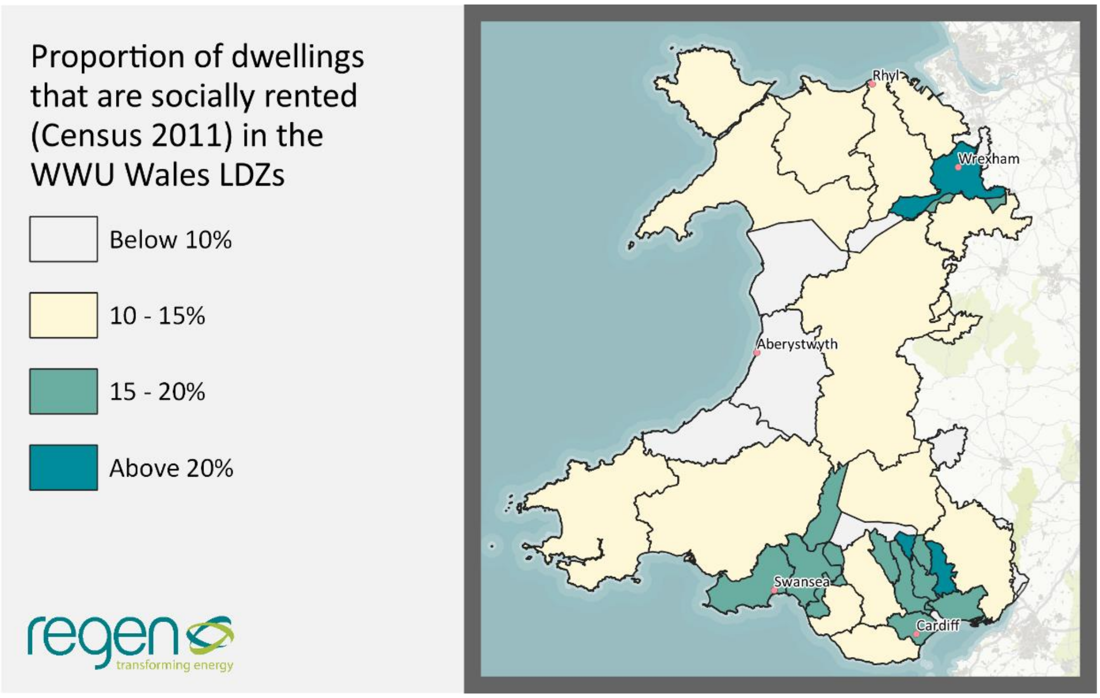

Figure 35: Proportion of socially rented properties in WWU Wales LDZs by GSA

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[27] http://www.nrs.co.uk/nrs-print/lifestyle-and-classification-data/social-grade/

Dwelling type – GSAs with a greater proportion of flats or terraced housing (below) are more likely to be served by gas or heat networks, owing to the higher density of heat demand, while detached and semi-detached housing may be more likely to be served by off-network technologies such as oil boilers or ground source heat pumps. The lower demand of these dwelling types also makes them suitable for air source heat pumps.

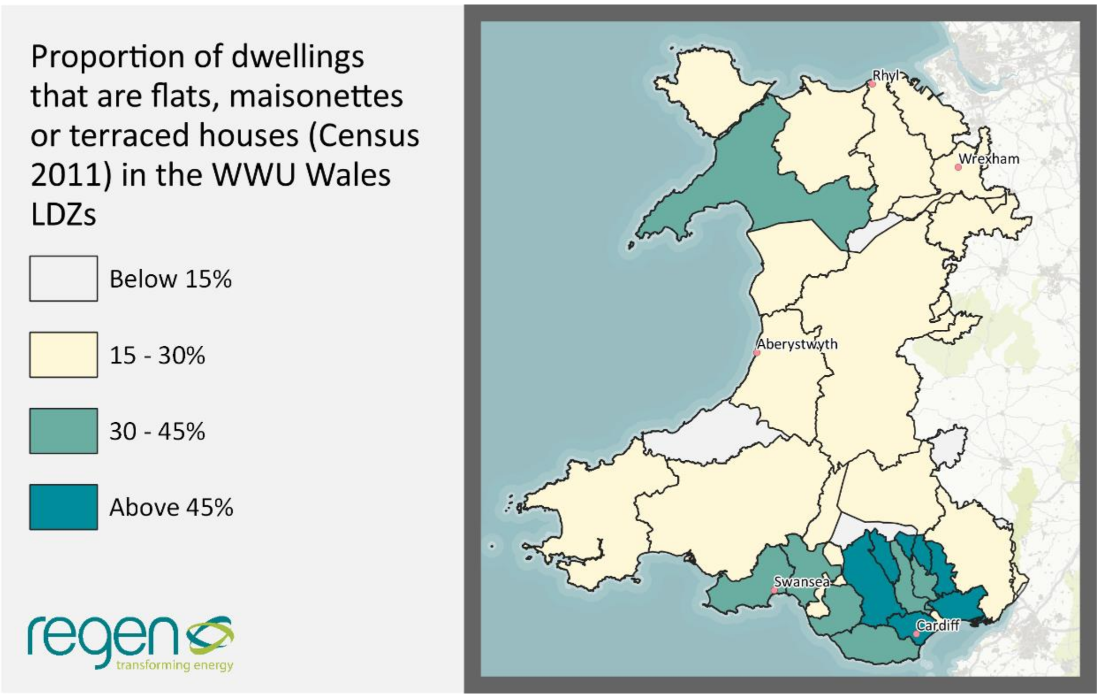

Figure 36: Proportion of flats, maisonettes and terraced housing in WWU Wales LDZs by GSA

Urban/rural – dwellings in urban GSAs are typically smaller, have lower heat demand and are more likely to be connected to the gas network. Therefore, distribution of non-gas heating technologies such as oil, LPG and biomass boilers are weighted more towards rural areas in the near term, while urban areas are dominated by gas boilers and gas heat networks.

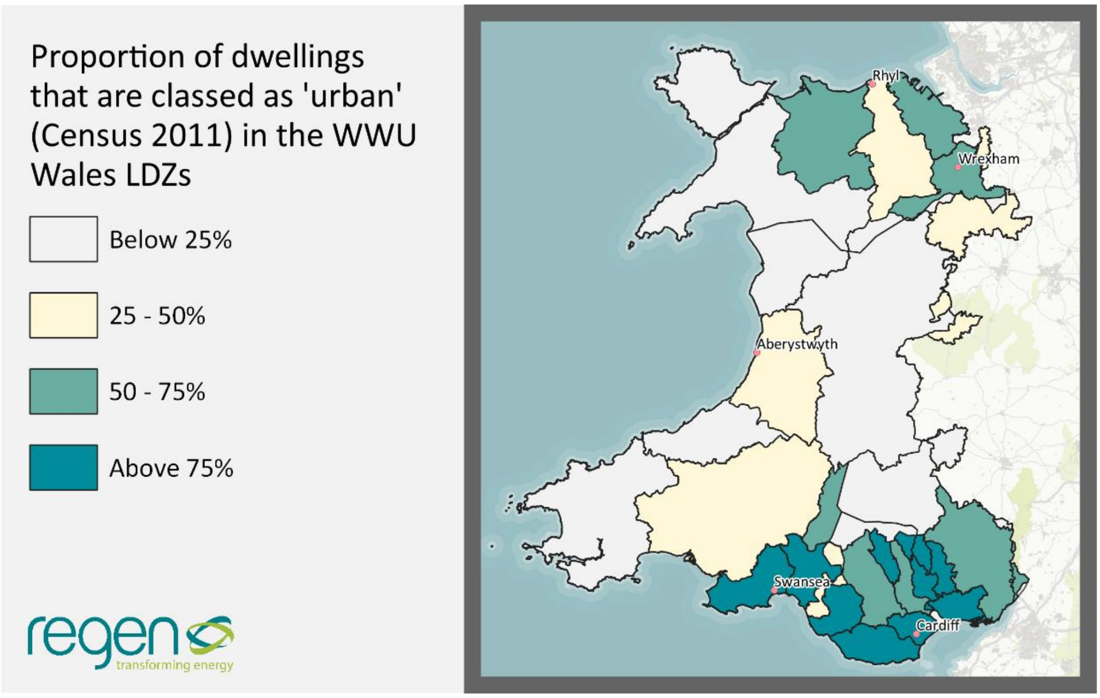

Figure 37: Proportion of urban classified housing in WWU Wales LDZs by GSA

In addition to these key factors, the distribution considers the current position in terms of on-gas, electrically heated, on-oil etc. dwellings, in addition to the average heat demand per household, as detailed earlier in this chapter. Below are four key technology classes that are projected to undergo significant changes in the timeframe of this analysis, with significant variability depending on the future energy scenario.

Gas boilers (Figure 38)

Gas boilers are currently located in the more densely populated south, south-east and north-east of the WWU Wales gas network area, with concentrations of over 80% in the main urban areas. This distribution has been projected to continue, as it is tied to the location of the gas distribution network, however the uptake of alternative technologies results in variation across GSAs. The **Steady Progression** scenario sees a continued extension of the gas network, with new gas connections to both new and existing dwellings resulting in an increase in gas boiler proportions in all GSAs. By contrast, **Community Renewables** shows decreasing proportions of gas boilers across the region by 2035, as a result of a proposed restriction on gas boilers in new build dwellings from 2025 and a switch from gas boilers to low carbon alternatives such as electric heat pumps, hybrid heat pumps and low carbon heat networks in the later years.

Air and ground source heat pumps (Figure 39)

Uptake of air and ground source heat pumps is projected to rapidly increase under the compliant scenarios, particularly **Community Renewables**, with a steadier increase in the non-compliant scenarios. While it is projected that most of these installations are air source, ground source heat pumps also see a major increase in uptake, with a distribution weighted more towards rural dwellings with larger heat demands and more outdoor space. In **Community Renewables** and **Hybrid Accelerator**, the uptake of electric heat pumps is initially restricted to off-gas areas, providing a lower-carbon and lower-cost alternative to oil, LPG and direct electric heating. By 2035 a small amount of gas boiler to heat pump switching occurs, as carbon emissions reduction targets are achieved under these scenarios. **Two Degrees** sees a high level of uptake, but lower than the other compliant scenarios, in particular in urban areas. This is a result of the centralised nature of the scenario, with heat networks and future hydrogen network conversion supressing growth in heat pump installations in urban areas.

Hybrid heat pumps (Figure 40)

Hybrid heat pumps feature heavily in the **Hybrid Accelerator** scenario. Uptake is highest in areas with both high annual heat demand and an extensive gas network, for example in south-east Wales such in Blaenau Gwent, Merthyr Tydfil and Rhondda Cynon Taf. The remaining scenarios, with significantly lower uptake of hybrid heat pumps, show similar distributions.

Heat networks (Figure 41)

The current distribution of heat networks (of any type) is limited, with no GSA showing more than 0.8% of households primarily heated by a heat network. The most significant scenario for heat networks, **Two Degrees**, sees heat networks providing heat to over 5% of households in the major urban areas of the WWU Wales LDZs, while the sparser areas of the west coast and Mid Wales show lower heat network uptake, heating less than 1% of households in these areas.

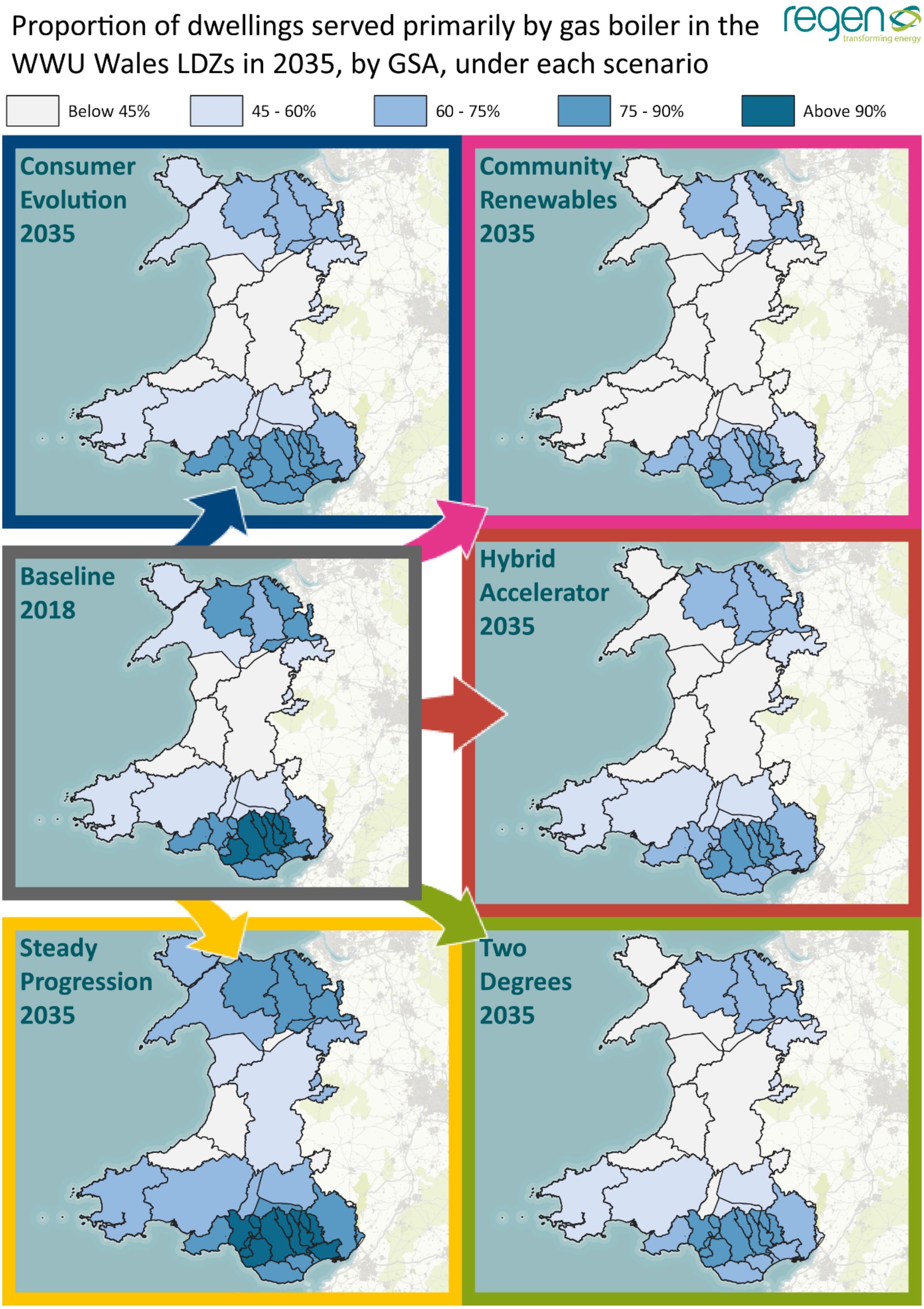

Figure 38: Proportions of domestic dwellings in WWU Wales LDZs heated by a gas boiler in 2035, by scenario and GSA

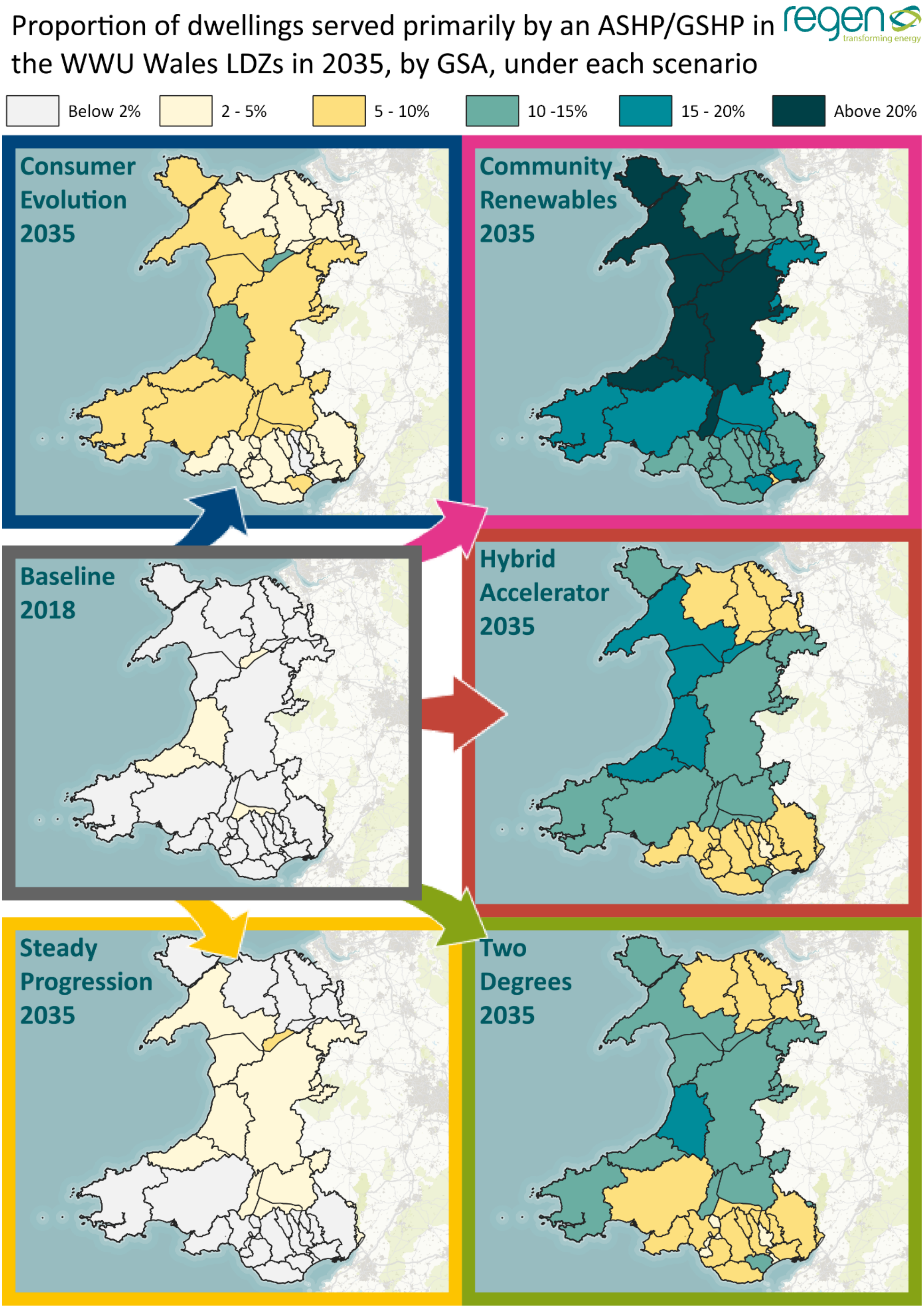

Figure 39: Proportions of households heated by an ASHP or GSHP in WWU Wales LDzs, in 2035, by scenario and GSA

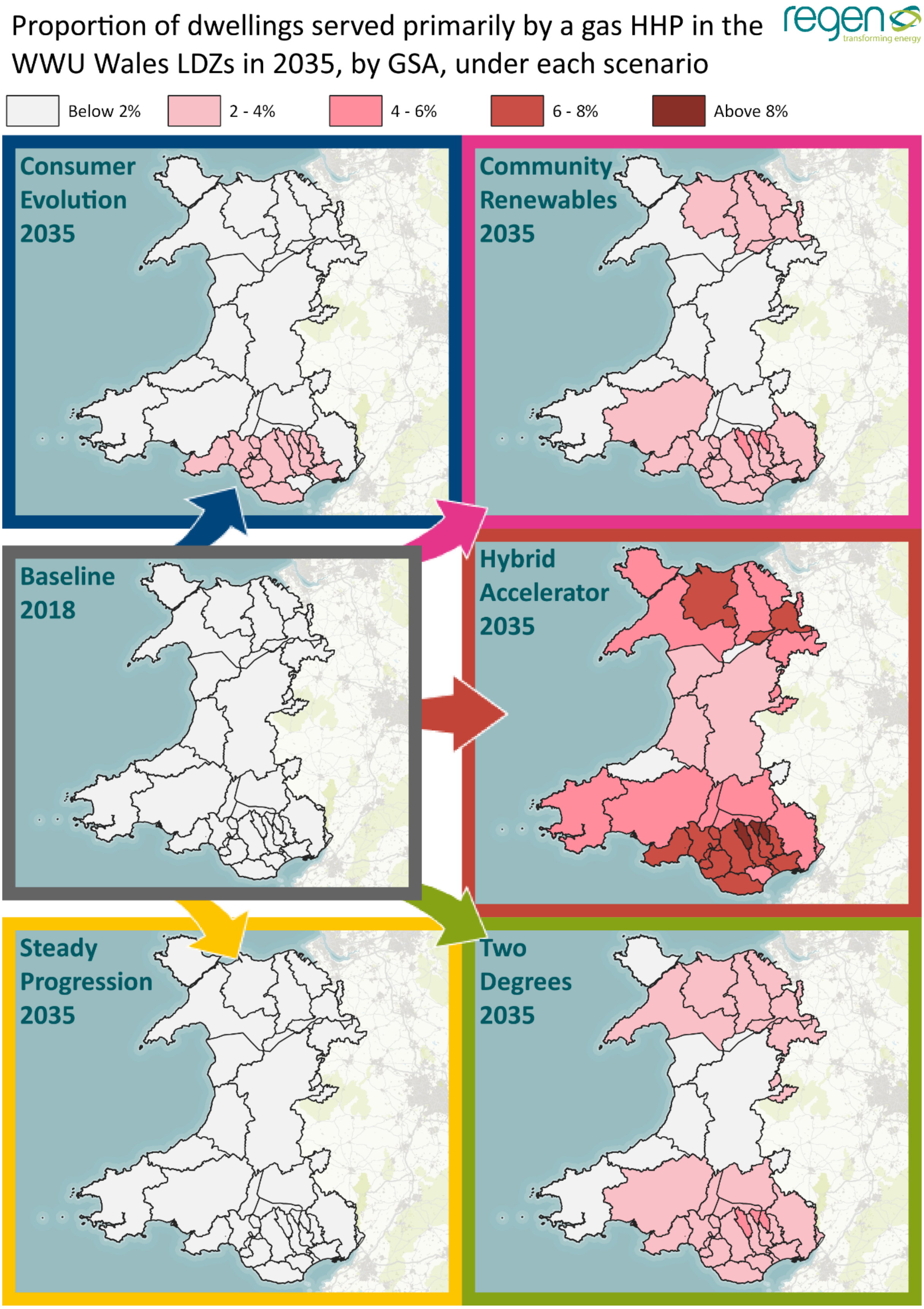

Figure 40: Proportions of households heated by a gas hybrid heat pump in WWU Wales LDZs in 2035, by scenario and GSA

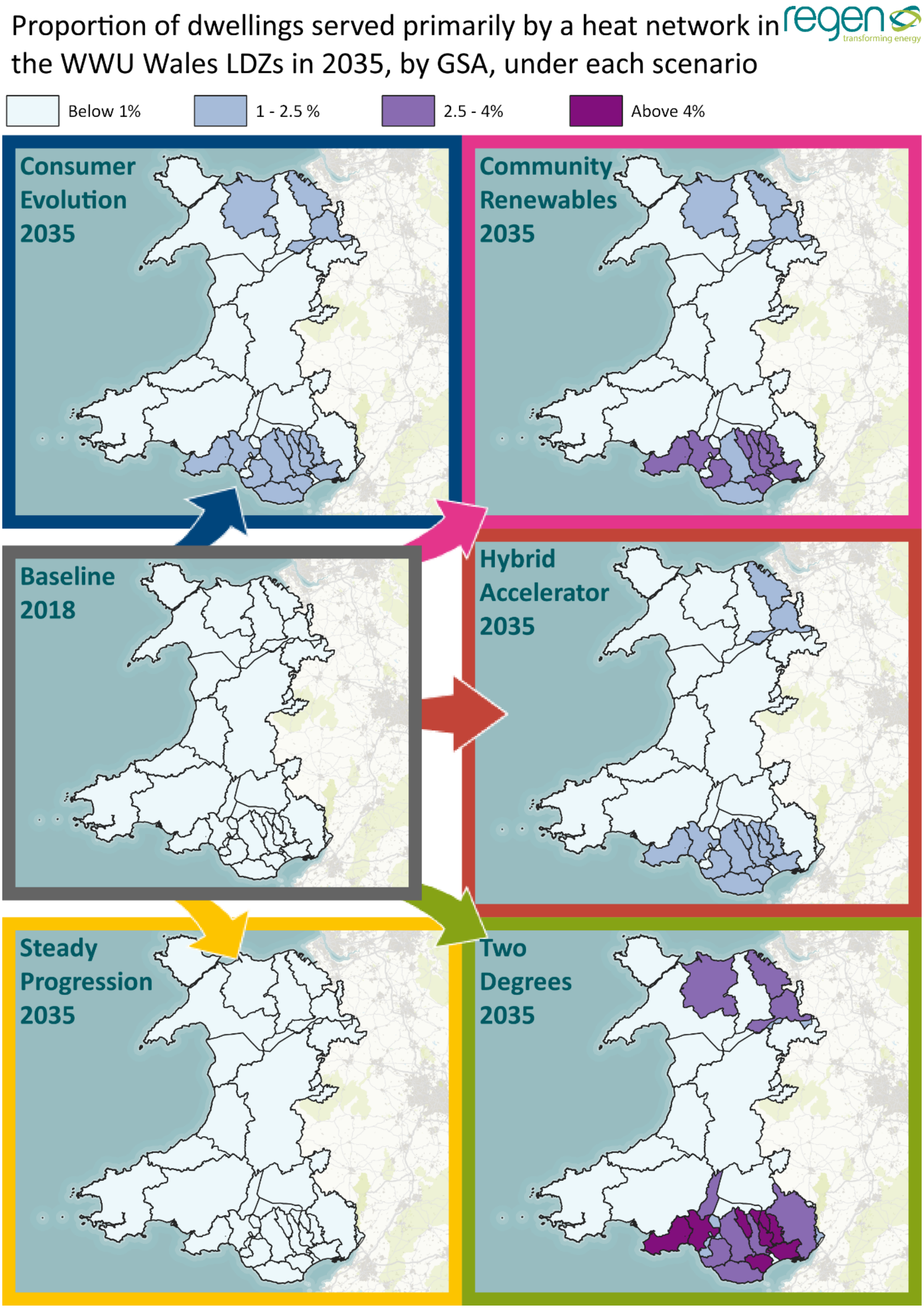

Figure 41: Proportions of households heated by a heat network (driven by gas boiler, gas CHP, biomass or ground source heat pump) in WWU Wales LDZs in 2035, by scenario and GSA

4.2 Commercial and industrial heat

Demand for commercial and industrial heat has been calculated as the total demand for energy to provide space heating and hot water within commercial properties, and all gas demand in industrial properties. For the purpose of this analysis, the term commercial and industrial includes schools, public buildings, hospitals and other non-domestic properties as defined by WWU's connection classification.

Commercial properties have been segmented according to their rateable classification and those deemed as not requiring heat (e.g. football grounds, beach huts and cash machines) have been excluded from the analysis. Industrial heat in this chapter relates to all space heat and process heat demand associated with industrial properties that is *not* large enough to warrant daily metering of gas consumption, as this is addressed in Section 4.4. This energy demand is determined by the number of commercial and industrial buildings, their requirement for heat and how this demand is met in terms of technology, fuel source and conversion efficiency.

4.2.1 Headlines from scenario analysis

The key outcomes of the scenario analysis for non-domestic heat are:

- **The number of heated commercial and industrial properties increases by 25% from a baseline of 144,810 to 181,470. This increase is based on analysis of local authority development plans and long-term historic trends.**
- **Non-compliant scenarios (Steady Progression, Consumer Evolution) see the average annual heat demand per commercial property fall to 87% of the baseline by 2035. This is a result of a slowing trend of improvement in the existing stock along with a less ambitious improvement in the energy efficiency of new build properties (due to a lack of support for the policy and skills required to deliver nearly zero energy buildings).**
- **Compliant scenarios all see a continued trend of efficiency improvement in all existing stock, although this is less ambitious in Two Degrees as there is more investment in centralised solutions. In addition, standards for new commercial properties are significantly improved, and levels of energy demand fall to support one of the UK Governments' 'Grand Challenge missions' of at least halving energy use in new buildings by 2030. Community Renewables and Hybrid Accelerator see the average annual heat demand per commercial property fall to 73% of the baseline by 2035. Two Degrees sees a lower improvement to 78%.**
- **The baseline analysis suggests that 59% of all commercial properties are currently served by gas boilers. Gas boilers continue to be a significant heat technology in all scenarios by 2035, serving from 38% of properties in Community Renewables, to 55% in Steady Progression**
- **Heating technologies fuelled by electricity[28] start from a baseline of serving 32% of commercial properties. In the compliant scenarios these technologies become the most common form of primary heating, serving 42-47% of commercial properties by 2035. See Figure 48.**
- **From a low baseline of serving 0.1% of properties, ASHPs see the largest increase in market share for heating technologies in four of the five scenarios, the exception being Steady Progression where air conditioning is ahead. ASHP increase share of properties served by between 1% and 15%.**
- **Industrial gas demand per property marginally decreases due to efficiency improvements, to 95% of the baseline in non-compliant scenarios and 85% in complaint scenarios.**

[28] Included here are all air-to-water systems including hybrids, air conditioning (air-to-air heat pumps) and direct electric heating.

4.2.2 Summary of the approach taken

The method by which commercial and industrial heat has been assessed, is described in Figure 42:

(1) Established baseline data components (2010 – 2018)

Number of existing properties

Average heat demand trends in existing and new (MWh/year/property)

Delivery technology types and % of dwellings served by each type in existing and new

Rate at which existing appliances are replaced

Conversion efficiency of each technology in existing and new

(2) Produced scenario-aligned components (2019 – 2035)

Assess potential future shifts in the identified baseline components for each scenario, giving consideration to:

FES framework

New build completions

Changes in building regulations (Parts L, F, J)

Trends in energy efficient retrofit for existing

Potential policies aligned with certain scenarios (e.g. proposed ban of fossil fuel boilers in new build from 2025)

(3) Calculation of scenario outputs

Components used to calculate:

Number of each technology type, by year, by scenario

Total demand for heat and fuel, by technology type, by year, by scenario

Total demand for each key fuel, year by scenario

4) Geographically distributed into GSAs

Distributed annual, scenario specific capacity into the 37 GSAs, using weighted distribution factors, such as:

- Baseline distribution of existing C&I properties, including gas-heated, electric-heated and oil-heated
- Proximity to the gas network
- Urban or rural

Figure 42: High level scenario assessment stages for commercial and industrial heat

The following sections outline the detailed scenario projection results for commercial and industrial heat and shows the geographical distribution into the 37 GSAs in the WWU Wales gas network area.

More detail around the method, assumptions and references used to inform the commercial and industrial heat analysis, is outlined in Appendix 2 of the Technical Companion Document.

4.2.3 Detailed results

From a baseline annual demand of **7,685 GWh**, the demand for energy from the gas network for commercial and industrial heat and hot water decreases in compliant scenarios. **Steady Progression** sees an increase of **3.8%** by 2035, with decreases in demand from efficiency and fuel switching marginally outweighed by additional demand from new properties. **Community Renewables** and **Hybrid Accelerator** show **16%** reductions from the baseline to around **6,500 GWh/year** (Figure 43). The change in demand reflects greater ambition and implementation of energy efficiency measures and shifts to low carbon heat delivery technologies.

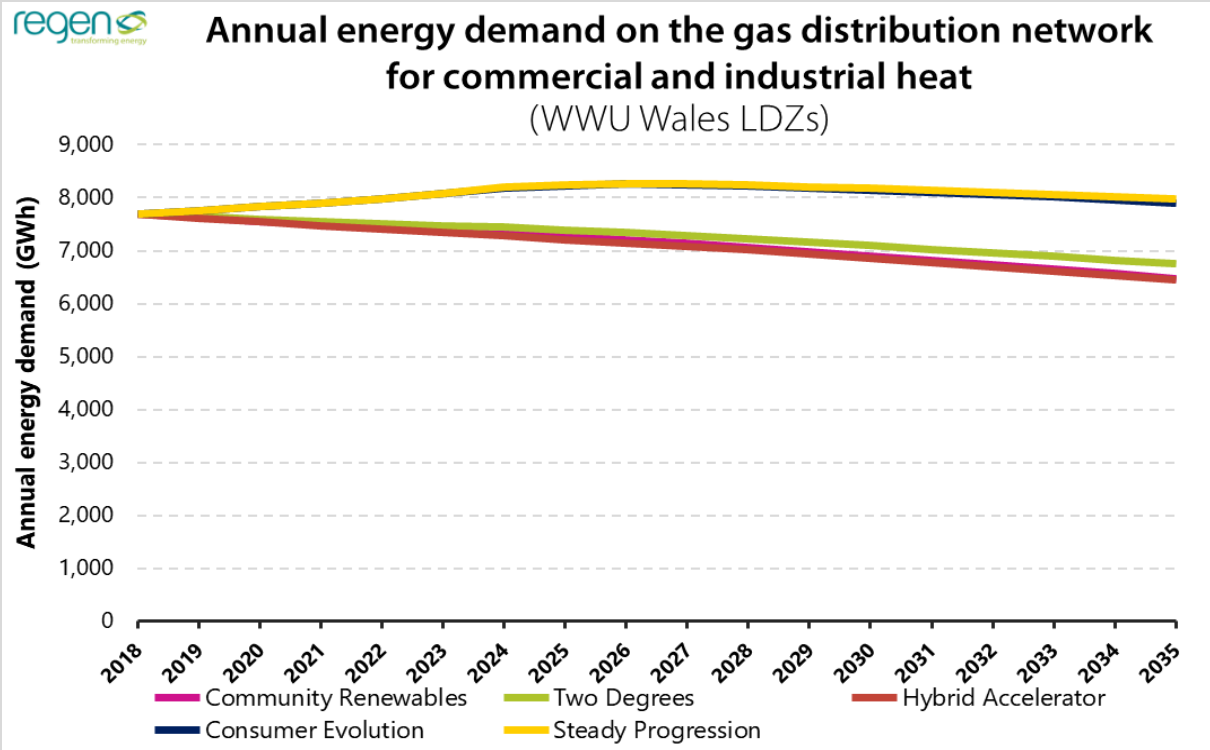

Figure 43: Annual demand for energy from the gas network for commercial and industrial heat and hot water within the WWU Wales gas network area, 2018 to 2035

Number of properties and their demand for heat

The number of commercial and industrial properties in the WWU Wales gas network area has been modelled through analysis of non-domestic rateable properties[29] combined with BEIS data for non-domestic gas meters and WWU connections data. Historic data shows a steady increase in employment buildings, in the form of offices and industrial buildings, but a stagnation in commercial retail buildings.

Recent years have seen the total number of commercial properties in the WWU Wales gas network area to be increasing by between 0.5% and 4.0% per year with a long-term average increase of ~1.7% per year. The last two years, 2017 and 2018, have seen an acceleration in commercial property building (Figure 44). Using input from local development plan allocations, this trend has been projected forwards for the analysis timeframe, resulting in a 25% increase in commercial and industrial properties by 2035, compared to the 2018 baseline. Within this figure properties classed as industrial represent 21.3% of the baseline non-domestic property stock, and 20.0% of the 2035 stock.

[29] https://www.gov.uk/government/collections/non-domestic-rating-stock-of-properties-collection

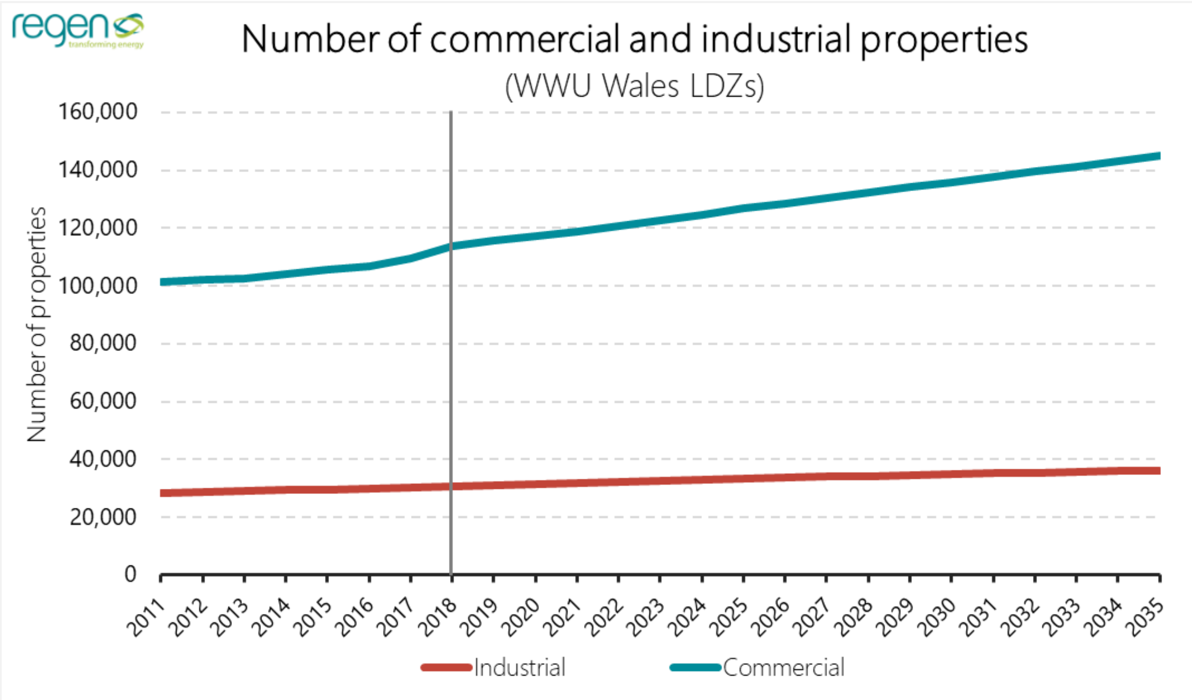

Figure 44: Projected number of commercial & industrial properties requiring heating within the WWU Wales gas network area, 2018 to 2035

As with domestic heat, this analysis has segmented commercial and industrial properties into two archetypes; 'existing' covering all properties constructed by the baseline year and 'new' covering all properties constructed 2019 -2035.

For commercial properties, year by year modelling has been carried out for all new properties, allowing changes in efficiency standards and heating appliances to be modelled in detail. Three scenarios for changing efficiency of properties have been modelled as shown in Table 11 and applied across the five scenarios as shown in Figure 45. **Two Degrees** sees a slightly less ambitious policy environment in comparison to the other compliant scenarios, as more focus is put on centralised routes to decarbonisation. For industrial properties, compliant scenarios show an immediate focus on decreasing gas demand through process efficiency and heat recovery implementation, while non-compliant scenarios show current demand trends continuing until the mid-2020s, after which efficiency improvements are encouraged.

Table 11: Overview of the three commercial energy efficiency scenario assumptions

Scenario	Changes in existing non-domestic properties	Changing standards in new build
Community Renewables	**20% reduction in average demand of all properties by 2035**	**38% reduction in average demand by 2035**
Hybrid Accelerator		
Two Degrees	**13% reduction in average demand of all properties by 2035**	**38% reduction in average demand by 2035**
Consumer Evolution	**5% reduction in average demand of all properties by 2035**	**10% reduction in average demand by 2035**
Steady Progression		

For clarity, Figure 45 and Figure 46 shows the resulting average across all stock for the two efficiency scenarios that have been modelled, however the analysis carried out uses a shifting average for all existing properties and a construction year specific figure for new properties.

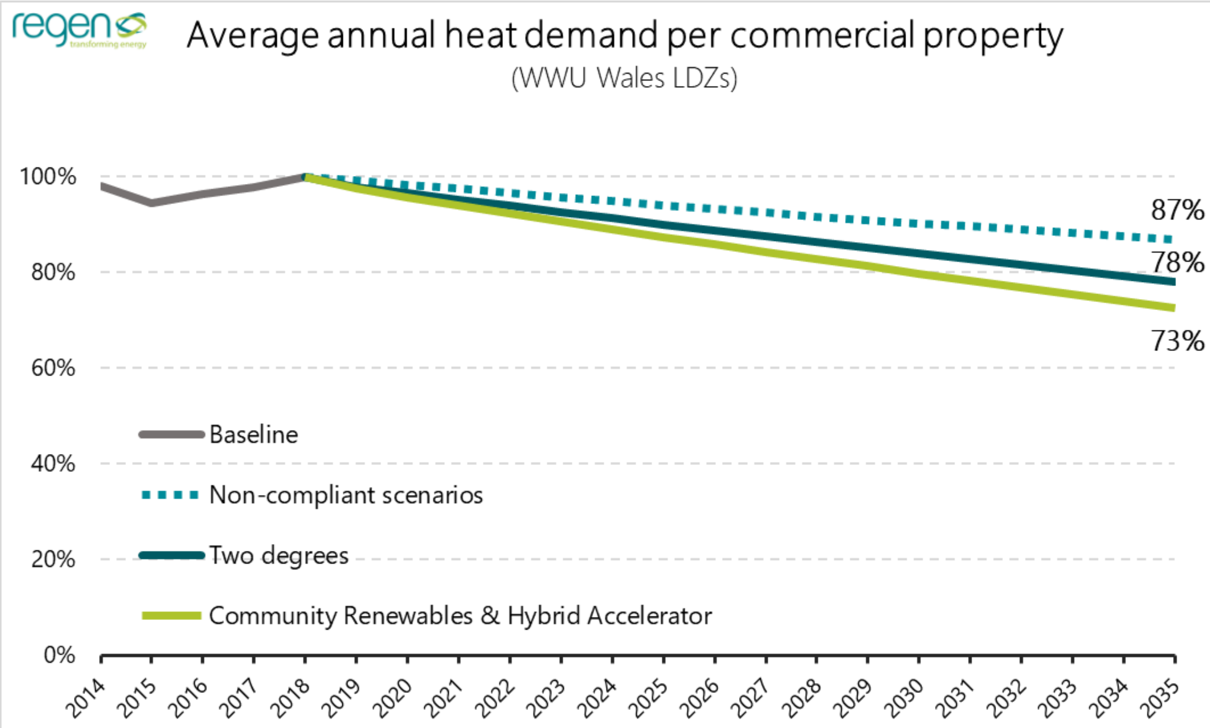

Figure 45: Changing demand for heat and hot water as an average across all commercial properties within the WWU Wales LDZs, 2018 to 2035

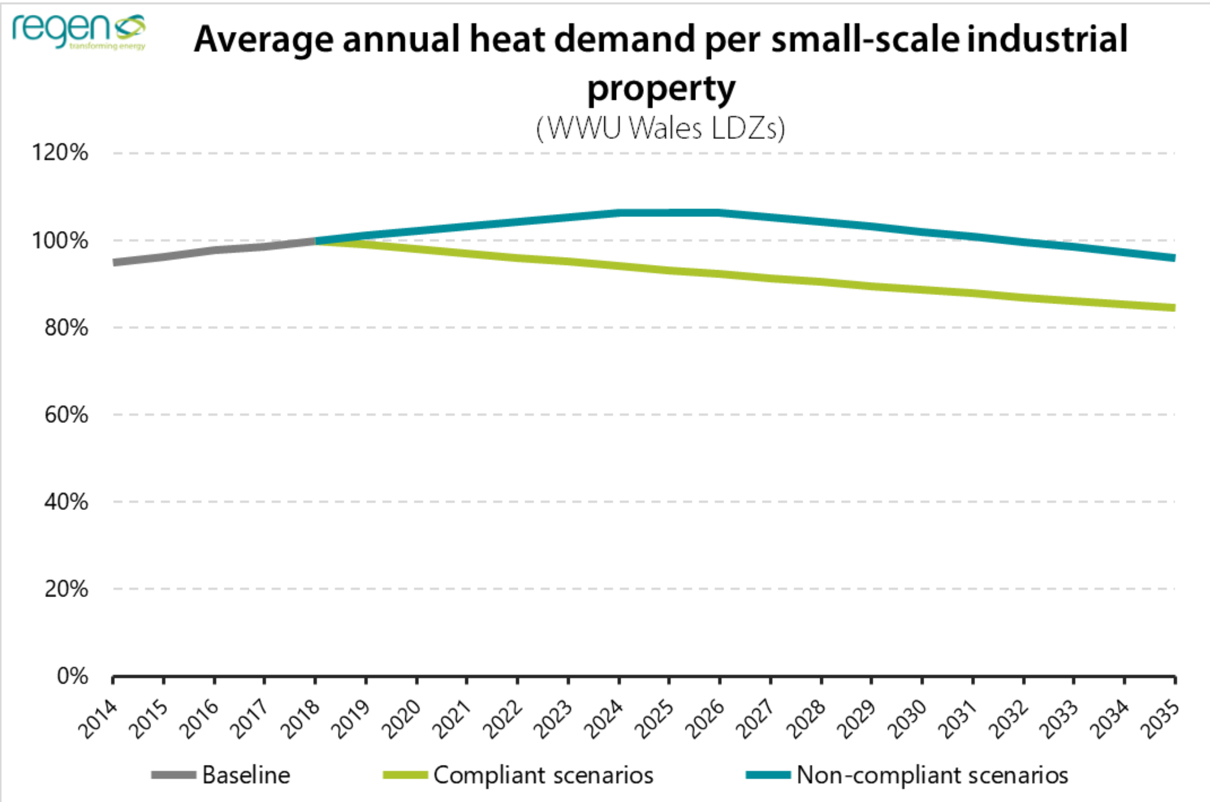

Figure 46: Changing demand for gas per industrial property within the WWU Wales LDZs, 2018 to 2035

Technology trends

Within the timescale of this analysis the number of properties served by gas boilers does not change dramatically, as shown in Figure 47. However, the total demand for energy from the gas network shows significant potential to shift, depending on the scenario, as uptake of heat pump technology increases, as shown in Figure 48.

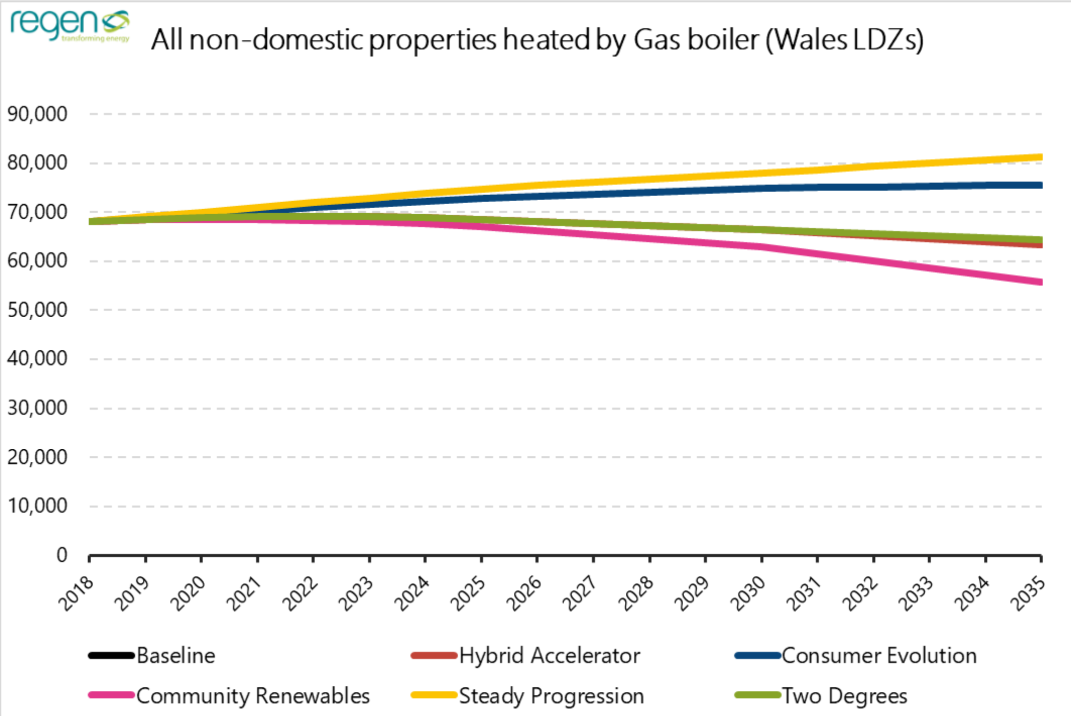

Figure 47: Number of commercial properties served by gas boilers within the WWU Wales LDZs, 2018 to 2035

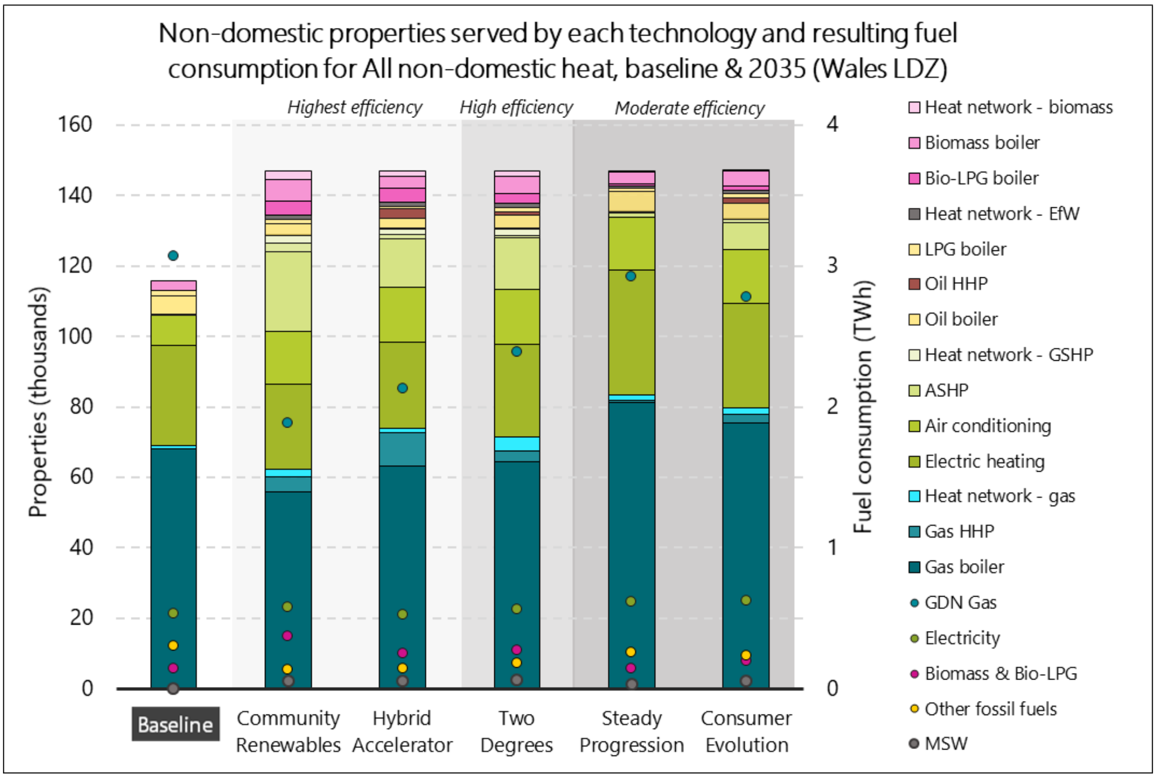

Figure 48: Number of space-heating appliances and resulting fuel consumption for space heat in commercial buildings within the WWU Wales LDZs, 2018 to 2035

Much of this change is attributable to increasing use of heat pumps, significant deployment of hybrid heat pumps in the **Hybrid Accelerator** scenario results in a retained gas connection but much changed consumption profile in over 9,000 properties.

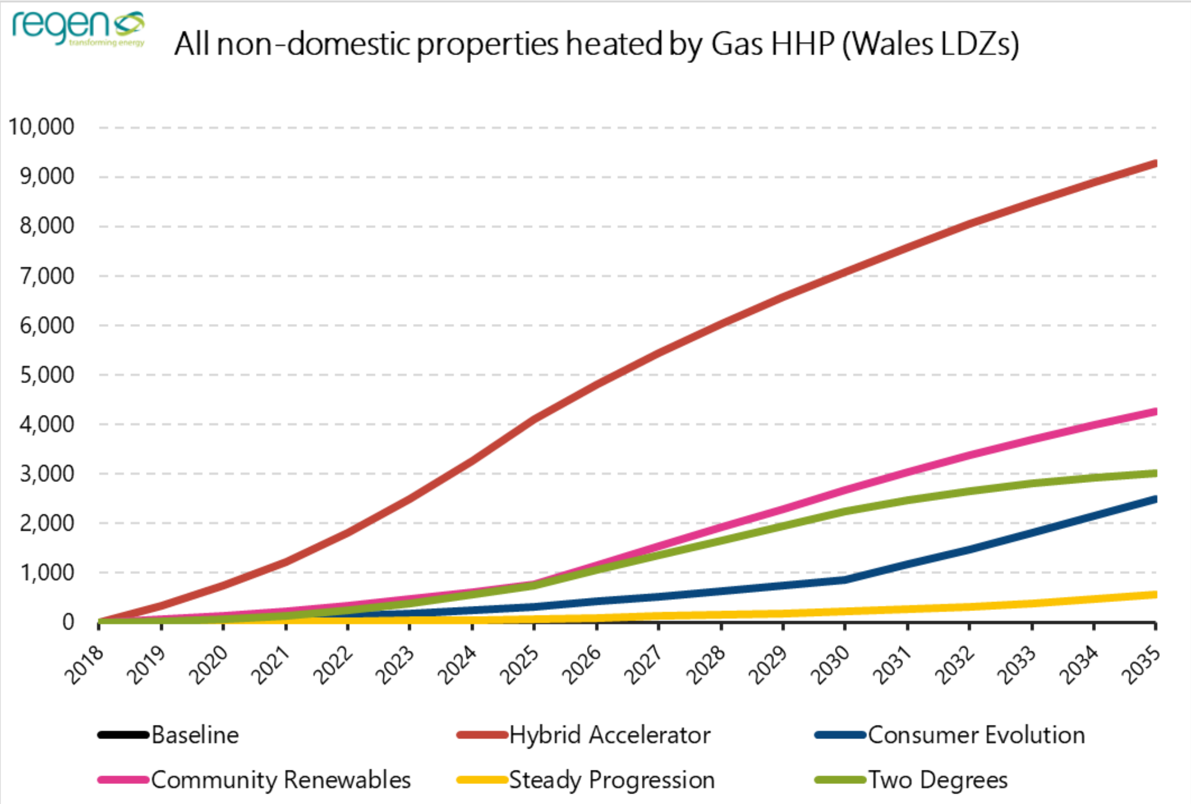

Figure 49: Number of commercial and industrial properties served by gas hybrid heat pumps in the WWU Wales LDZs to 2035

A significant increase in the number of commercial properties using a heat pump as the primary heat source is seen in all scenarios, as shown in Table 12. **Steady Progression** sees the least change, as gas boiler numbers continue to increase. Air source heat pumps make up the majority of this increase, as either the sole appliance or as part of a hybrid system as these represent relatively low investment costs relative to other options.

Table 12: Table of milestone scenario projections for commercial properties where a heat pump is the primary source of heat in the WWU Wales LDZs. *(This includes air source, ground source and hybrid heat pumps)*

Scenario	Baseline 2018	By 2020	By 2025	By 2030	By 2035
Community Renewables	223	1,440	6,648	17,828	29,581
Two Degrees		522	3,305	11,726	19,290
Hybrid Accelerator		1,715	8,000	18,519	26,922
Consumer Evolution		617	2,261	8,454	12,353
Steady Progression		270	689	1,296	2,106

The use of district heat networks sees some growth in all scenarios, with the waste-fuelled Cardiff Heat Network being partially realised in **Steady Progression** and fully realised in all other scenarios.[30] In the non-compliant scenarios other heat networks make use predominantly of gas-fired plant, in line with current data on pipeline and in-progress networks (Figure 50). In compliant scenarios, heat networks rely on either biomass or gas boilers, dependent on location. Existing gas fired heat networks (i.e. those commissioned up to 2025) do not transition to an alternative heat source within the timescale of this analysis, however it would be anticipated that a transition to low carbon sources would occur from the late 2030s onwards.

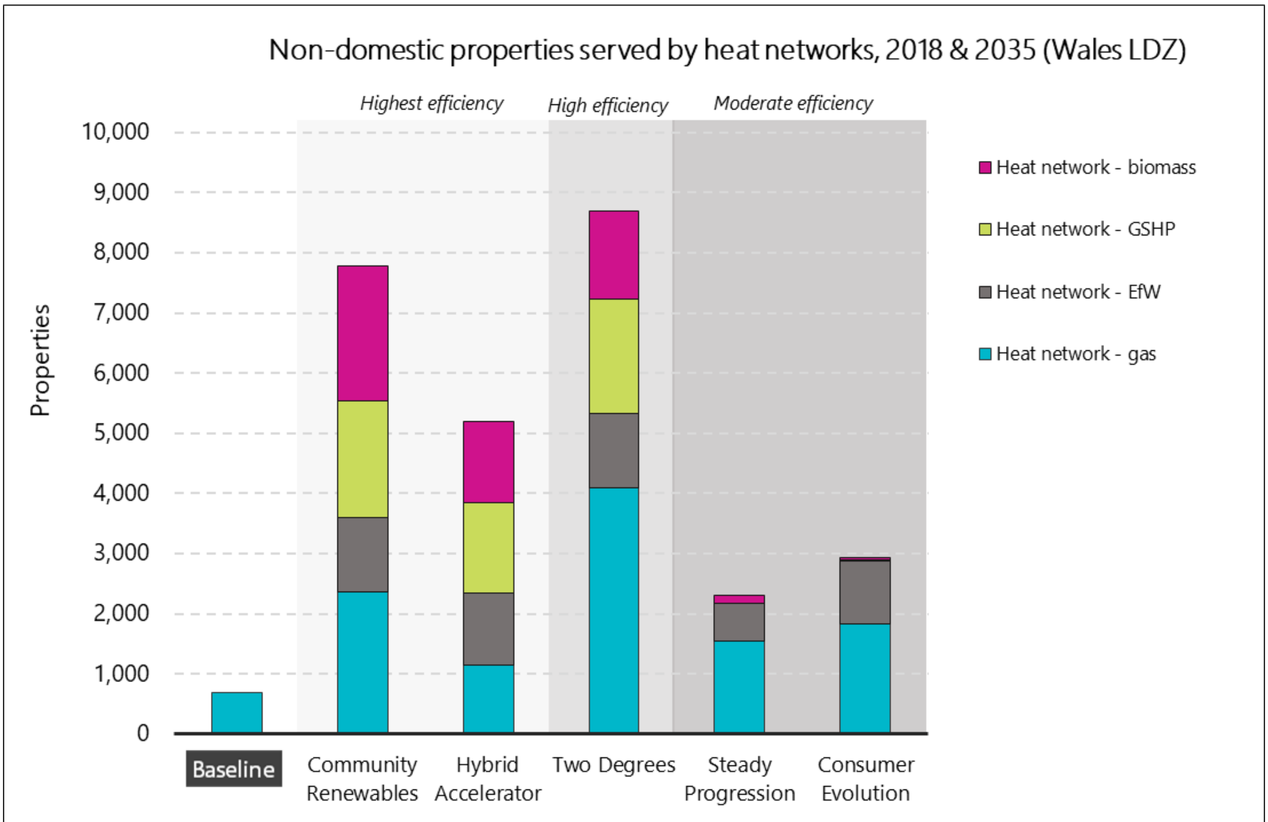

Figure 50: Changing number of commercial and industrial properties served by a district heat network within the WWU Wales LDZs, 2018 to 2035

[30] Scale of network is taken from the Q2 2019 HNDU pipeline summary.

4.2.4 Geographical distribution

Number of properties and their demand for heat

Commercial and industrial properties in the WWU Wales gas network area are distributed similarly to domestic properties (see Figure 51 and Figure 52), with industrial demand particularly concentrated north-western Wrexham and Flintshire local authorities. Therefore, Swansea and Carmarthenshire in south Wales; Cardiff and the surrounding local authorities in southeast Wales; and Wrexham and Flintshire in northwest Wales are centres of industrial heat demand. This continues throughout the projection period, with distribution of new build properties informed by local plans typically situated around these urban areas. The demand for heat from these non-domestic buildings is similarly concentrated.

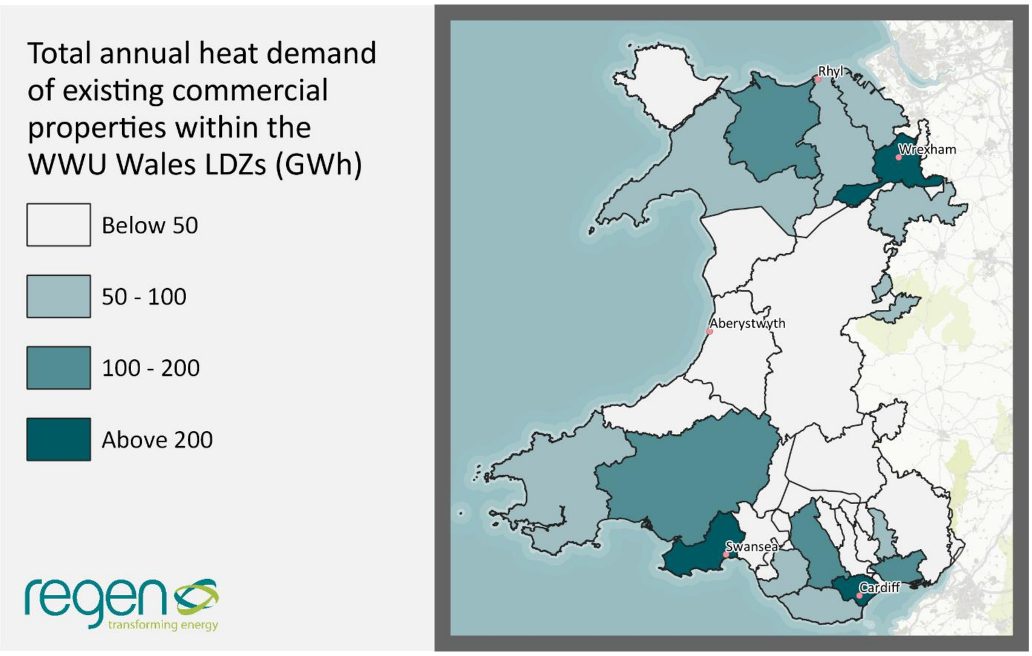

Figure 51: Density of commercial and industrial properties in the WWU Wales LDZs by GSA, as of 2018

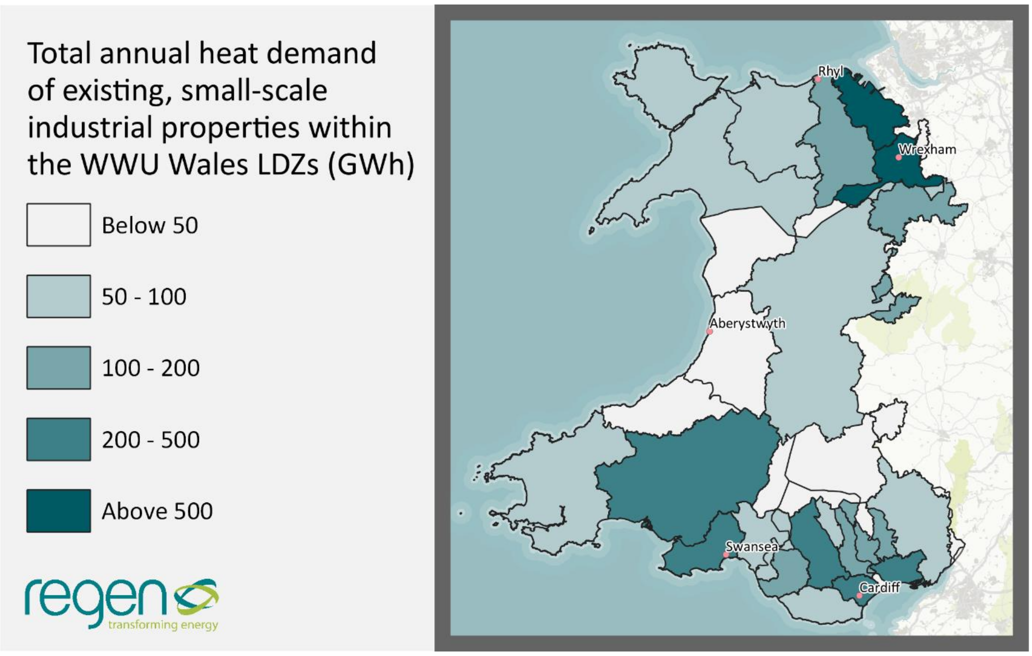

Figure 52: Annual heat demand of small (i.e. not daily metered) industrial properties in the WWU Wales LDZs by GSA, as of 2018

Technology trends

Gas boilers are the most common commercial heat technology in the WWU Wales gas network area (Figure 53). The distribution follows a similar pattern to domestic properties, with heavily on-gas areas in the southeast of the network area showing over 60% of commercial properties served by gas boilers. Under **Steady Progression** it is expected that this trend continues, with gas boilers serving a similar proportion of commercial buildings in all GSAs by 2035. Conversely, the **Community Renewables** scenario shows a trend away from gas boilers towards low carbon heating technologies, with less than half of commercial properties served by a gas boiler in the vast majority of GSAs.

Heat pumps become an increasingly disruptive commercial heating technology in the compliant scenarios, with **Community Renewables** and **Hybrid Accelerator** having over 10% of properties with heat pump (excluding air conditioning) in almost all GSAs by 2035 (Figure 54), with many GSAs showing over 20% heat pumps. In more off-gas, rural areas, these heat pumps are typically ASHPs or GSHPs, which on-gas areas display a mixture of electric and gas hybrid heat pumps. This reflects the high proportions of commercial properties served by either direct electric heating or oil in every GSA, greater than domestic properties, both of which are prime candidates for conversion to a more efficient and lower carbon heat pump. In the **Steady Progression** and **Consumer Evolution** scenarios, it is expected that the uptake of heat pumps is consistently low across the network area, reflecting a lack of encouragement for heat pumps at a national level under non-compliant scenarios.

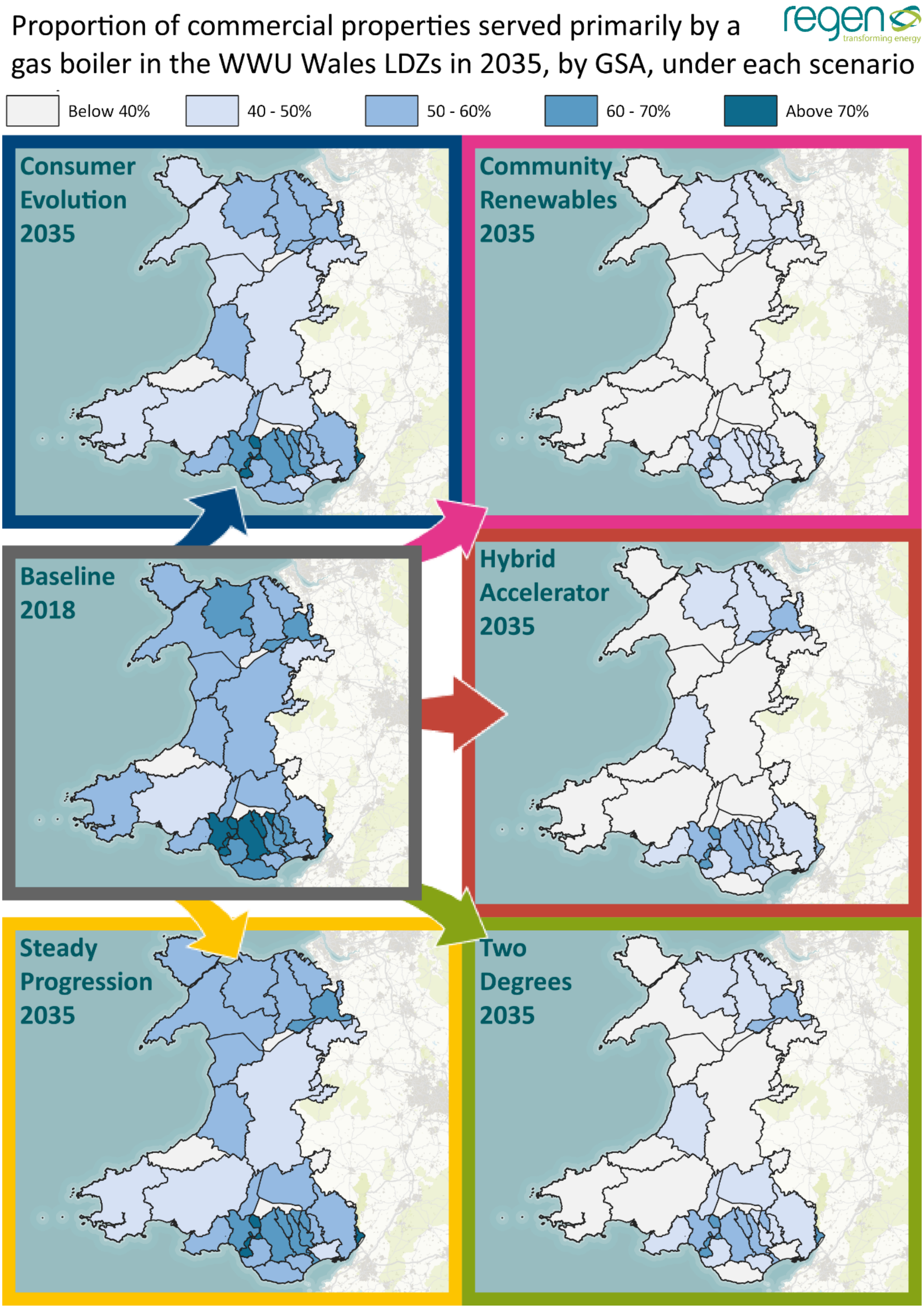

Figure 53: Proportions of commercial properties heated by a gas boiler in 2035 in WWU Wales LDZs, by scenario and GSA

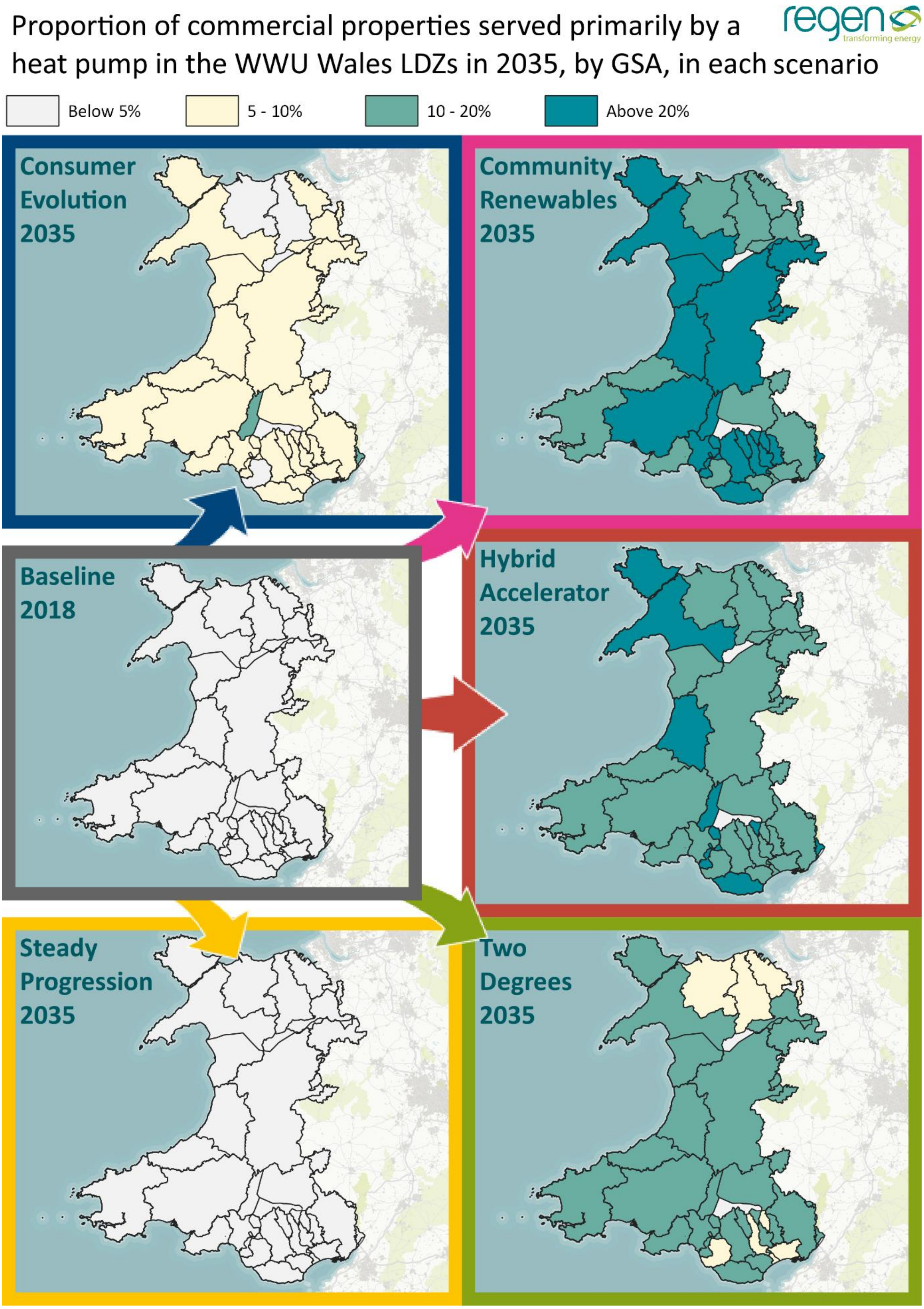

Figure 54: Proportions of commercial properties heated by a heat pump (air source, ground source or hybrid, not including air conditioning units) in 2035 in the WWU Wales LDZs, by scenario and GSA

4.3 Gas fired power generation

This section of analysis has focused on generation plant connected to the WWU Wales gas distribution network whose primary purpose is electricity generation for grid export. For the purposes of this assessment, the Severn Power site (a very large generator that is connected to electricity transmission network but also connected to the WWU Wales gas distribution network) has been discounted from the modelling. This is due to the capacity and the associated significant volume of annual gas consumption. Barry Power Station, another electricity transmission connected generator that decommissioned in March 2019, has been included in the modelling.

Power generation sites are identified within the WWU connection database as industrial power generation plants whose gas supply is Daily Metered (DM). Some 'behind the meter' gas generators exist acting as back-up, (e.g in a hospital or water treatment works), these are associated with other existing commercial or industrial gas connections and as such covered in section 4.4. These 'behind the meter' sites have not been specifically included in the gas fired power generation scenario analysis. Instances of 'behind the meter' generation operating commercial or flexible generation business models, have been included in the pipeline and future projections.

Gas fired generation has been sub divided into the following gas generation technology classes:

- **Combined Cycle Gas Turbines (CCGT)**
- **Open Cycle Gas Turbined (OCGT)**
- **Gas reciprocating engines**

Feedback received during the stakeholder engagement workshops suggests that these technology classes will have different market growth prospects under different scenarios, reflecting different operating characteristics (such as ramp-up time and flexible capacity output). This is also reflected in the National Grid 2018 FES[31] which suggests that by 2035 (nationally):

- The removal of all 422 MW of the current UK decentralised CCGT capacity in 3 out of 4 scenarios
- A wide range of outcomes for decentralised OCGT capacity, ranging from a 33% reduction in the **Community Renewables** scenario to a 55% increase in the **Consumer Evolution** scenario
- A major increase in decentralised gas reciprocating engine capacity across all 4 scenarios, ranging from a 406% increase in **Two Degrees** to a 1,821% increase in **Community Renewables**.

The analysis of gas generation technologies considers the baseline and future location of individual sites, their installed electrical capacity (MW_e), their generation capacity factor, their annual electricity generation and equivalent demand for energy from the gas network.

As before, energy demand for other classes of generating plant including 'behind-the-meter' smaller backup generators, that are typically Non-Daily Metered (NDM), are included within analysis of section 4.4. There is some overlap here and there could potentially be a new class of small gas generation, replacing diesel generators, whose purpose may be both to provide back-up and self-consumption power with occasional grid export.

[31] See National Grid FES 2018 data workbook, ES1 'Electricity Supply data table' worksheet: http://fes.nationalgrid.com/media/1366/2018-fes-charts-v2_as-published.xlsx

4.3.1 Headlines from scenario analysis

The outcome of the scenario analysis for gas fired power generation shows the following:

- **There are 24 operational gas fired electricity generation sites operating in the WWU Wales LDZs, totalling 1.45 GW$_e$ of installed capacity with an average capacity of 61 MW$_e$. For the purposes of this assessment, Severn Power (850 MW) was removed from scenario modelling to 2035. This reduces the in-scope installed capacity to 603 MW$_e$ and the average capacity to 25 MW. A breakdown of the proportions of generation technologies in this baseline is shown in Table 13.**
- **There are 24 sites in the near-term pipeline totalling 365 MW$_e$, all of which are reciprocating engines with an average capacity of 15 MW$_e$. A varying amount of these sites/capacities have been modelled to go through to connection under different scenarios in different years, based on the assessment logic outlined in Appendix 3 in the Technical Companion Document.**
- **Installed capacity in the WWU Wales LDZs increases in all scenarios to 2035. The largest increase in capacity is in Consumer Evolution with 891 MW$_e$ by 2035 (increase of 288 MW$_e$). The smallest increase (27 MWe) was in Steady Progression with 630 MW$_e$ by 2035. The full scenario outcomes are shown in Table 15.**
- **The wide range of installed gas fired power capacity (MW$_e$) reflects the uncertain business model currently facing small scale flexible generators. These uncertainties include regulatory changes affecting gas and electricity network charging, the potential for the next generation of large-scale electricity generating technologies, and other assets such as energy storage, offering lower costs and greater flexibility. Evolving Welsh Government policy[32] around decarbonising the emissions from power generation in Wales is also targeting large fossil fuel generators in the near term, and perhaps eventually may target smaller distributed fossil fuel generators in the longer term.**
- **The annual capacity factors[33] are different for CCGT and reciprocating engine technologies. Using actual metered gas flow data, where available, capacity factors ranged from 7.4% for CCGT and 18% for reciprocating in 2018.**
- **Future capacity factors for these technologies (sourced from the FES data) varied *significantly* out to 2035, with the capacity factor for CCGT going as low as 0.3% in Steady Progression and 2.8% in Consumer Evolution. These low capacity factors can be attributed to the potential that gas turbines may not compete with the rapid ramp-up capabilities of reciprocating engines.**
- **The capacity factor for gas fired reciprocating engine sites varied between 7.4% in Community Renewables and 22% in Two Degrees. Also, from feedback at engagement workshops, there is the potential that some sites may be diversified, and a second generating technology installed behind the same connection point, such as battery storage.**
- **Demand for gas energy from power generation varies across the scenarios. The highest peak being 2,553 GWh of gas energy in Two Degrees, generating 1,276 GWh of electricity in 2035.**

A summary of the overall scenario outcomes in 2035 for gas fired electricity generation is outlined in Table 14, showing installed capacity (MW$_e$), annual generation output (MWh) and resultant annual energy demand from gas (MWh).

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[32] See Welsh Government *Power: Section Emission Pathway* report, June 2019: https://gov.wales/sites/default/files/publications/2019-06/power-sector-emission-pathway-factsheet.pdf

[33] Defined as the average percentage of a site's power capacity that they are generating at, across a given year. Also see Glossary in the Technical Companion Document.

Table 13: Breakdown of the 2018 baseline gas fired power generation in the WWU South West gas network area

Technology	Number of Sites	Capacity MW_e	% of Capacity
CCGT	2*	246*	41%*
OCGT	0	0	0%
Gas reciprocating engines	21	357	59%
Total	**23***	**603***	

** Discounting Severn Power 850MW site*

Table 14: Gas fired power generation in the WWU Wales gas network area under each scenario by 2035

		Resultant scenario outcomes by 2035		
Scenario	**Generation Technology**	**Capacity (MW_e)**	**Generation (MWh)**	**Energy demand for gas (MWh)**
Community Renewables	CCGT	0	0	0
	OCGT	0	0	0
	Reciprocating Engines	888	576,596	1,153,192
	Total	**888**	**576,596**	**1,153,192**
Two Degrees	CCGT	0	0	0
	OCGT	0	0	0
	Reciprocating Engines	676	1,276,352	2,552,703
	Total	**676**	**1,276,352**	**2,552,703**
Hybrid Accelerator	CCGT	0	0	0
	OCGT	0	0	0
	Reciprocating Engines	740	938,995	1,877,990
	Total	**740**	**938,995**	**1,877,990**
Steady Progression	CCGT	16	435	725
	OCGT	0	0	0
	Reciprocating Engines	614	1,047,578	2,095,155
	Total	**630**	**1,048,012**	**2,095,880**
Consumer Evolution	CCGT	0	0	0
	OCGT	0	0	0
	Reciprocating Engines	891	702,974	1,405,948
	Total	**891**	**702,974**	**1,405,948**

4.3.2 Summary of the approach taken

The method by which gas fired generation has been assessed, is described in Figure 55.

(1) Established 2018 capacity baseline

Reviewed installed power capacity (MWe) in Wales and analysed historic annual gas usage data (MWh). Correlated with electricity network connection data.

(2) 2019-2025 capacity pipeline

Reviewed not-yet-connected pipeline sites for planning and Capacity Market (CM) activity, assigning capacity to connect (or not) and in which year, for each scenario, based on the allocation logic outlined in Appendix 3.

(3) Projected growth in capacity to 2035

Reviewed WWU Wales gas distribution network proportion of the GB FES gas fired power projections. Assessed the comparative growth/reduction of CCGT, OCGT and reciprocating engines. Applied scenario specific percentage change to 2026 totals, decommissioning CCGT sites in some/all scenarios and projecting scenario specific growth of reciprocating engines, building on the known pipeline out to 2035.

(4) Equated to generation output

Assessed actual gas flow data for existing sites to determine 2018 capacity factors for CCGT and reciprocating engines. Derived capacity factors for decentralised CCGT and reciprocating engines in each scenario, for each year from 2025 to 2035. Interpolated capacity factors between 2019 and 2025. Annual generation then resultantly calculated.

(5) Converted to annual gas demand

Projecting conversion efficiency of CCGT and reciprocating engines in milestone years and interpolated to determine annual figures. Resultantly equated annual generation to scenario specific annual gas demand to 2035.

6) Geographically distributed into GSAs

Distributed annual, scenario specific capacity into the 37 GSAs, using weighted distribution factors, such as:

- Location of existing connected assets
- Proximity to power and gas networks
- Active Network Management zones
- Location of Capacity Market bid activity

Figure 55: High level scenario assessment stages for gas fired electricity generation in Wales

More detail on the method, assumptions and references used to inform the gas fired electricity generation analysis, is outlined in Appendix 3 of the Technical Companion Document.

4.3.3 Detailed results

The location of the current operational gas fired generation sites and the near-term pipeline of potential developments in the WWU Wales gas network area, is shown in Figure 56.

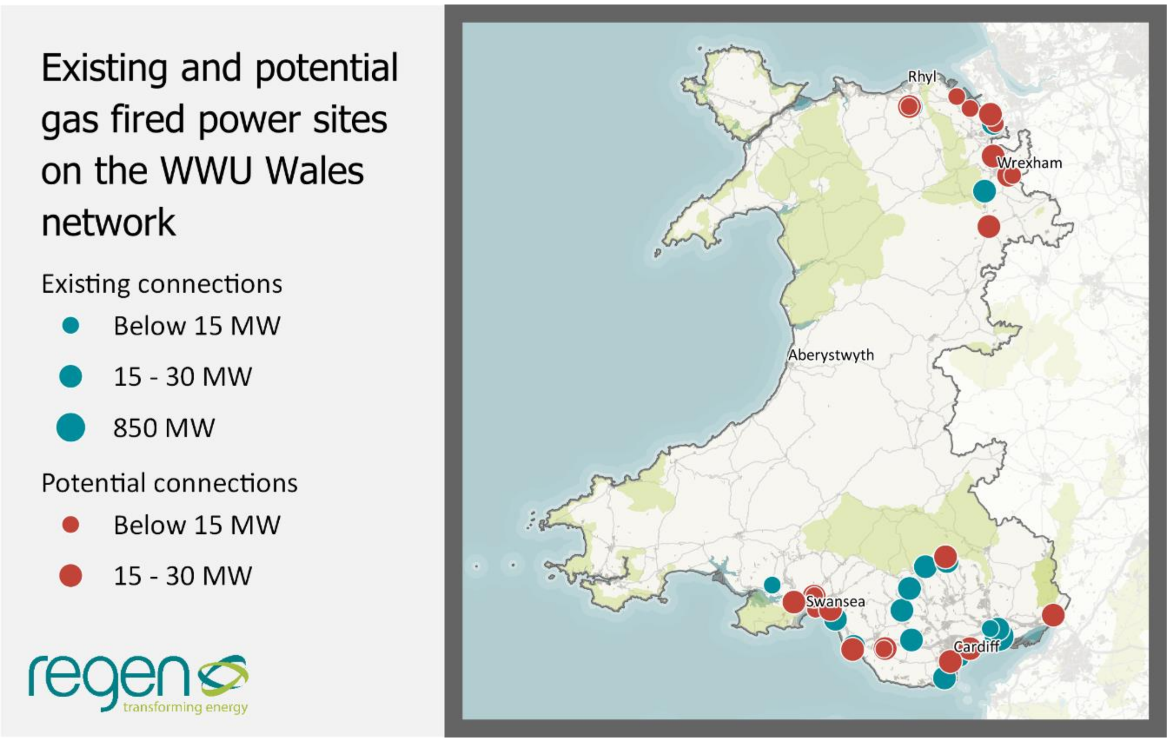

Figure 56: Map of existing and potential gas fired power generation sites connected to the WWU South West gas network

The results of the scenario analysis from 2018 to 2035 for gas fired power generation capacity are outlined in Figure 57 and Table 15.

4.3.4 Growth in installed generation capacity

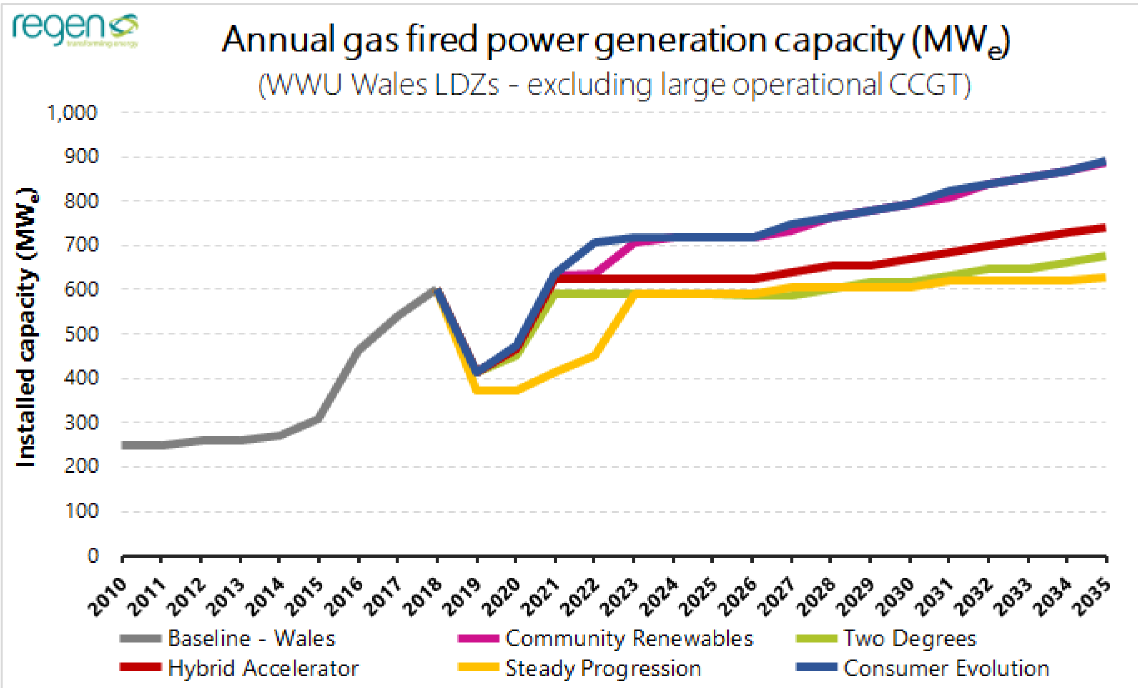

Figure 57: Scenario projections for gas fired power capacity (MW_e) in the WWU Wales LDZs, 2018 to 2035

Table 15: Table of milestone scenario projections for gas fired power generation capacity on the WWU South West gas network

Scenario	Baseline 2018 (MW_e)	By 2020 (MW_e)	By 2025 (MW_e)	By 2030 (MW_e)	By 2035 (MW_e)
Community Renewables	603 (24 sites)	468	718	792	888 (56 sites)
Two Degrees		452	589	618	676 (41 sites)
Hybrid Accelerator		468	625	669	740 (45 sites)
Consumer Evolution		473	718	792	891 (57 sites)
Steady Progression		373	589	604	630 (38 sites)

One of the large connected CCGT sites, Barry Power Station, was decommissioned in March 2019[34], and reflected in all scenarios. When assessing the 365 MW_e near-term pipeline, the modelling allocated which projects (and thus capacity) were to go through to connection and operation and the year in which they might come online, under each of the scenarios. This was based on an assessment of planning activity and Capacity Market activity. Appendix 3 in the Technical Companion Document outlines the logic chain that was applied to each pipeline project and under which scenario each project was taken forward and when.

These results show capacity increase in Wales, in all five scenarios across the analysis period, to a varying degree. The largest increase in capacity is seen in **Consumer Evolution**, with a **48% increase** from the baseline to **891 MW_e by 2035**. This is primarily due to the significant growth in the need for short duration, high power output flexible generation in this scenario in the FES, building on a strong pipeline of connection enquiries WWU has received and a positive planning approval position. The least capacity is in **Steady Progression**, with a **3% increase** from the baseline to **630 MW_e by 2035**. This is due to the projected decommissioning of existing CCGT plants on the distribution network and a lower need for additional flexible generation in this scenario.

Comparing the outcomes between the South West and Wales LDZs, shows both the higher installed baseline and the more positive planning position for the near-term pipeline sites in Wales, see Figure *58*.

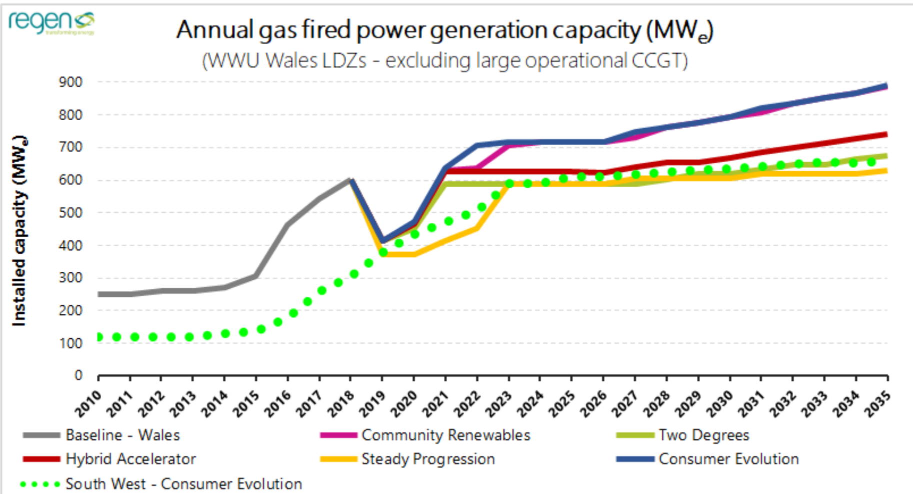

Figure 58: Annual gas fired power generation in Wales, with SW Consumer Evolution scenario overlaid

[34] See Wales Online article about closure of Barry Power Station on 31 March 2019: https://www.walesonline.co.uk/news/local-news/barry-power-station-centrica-sully-16237452

4.3.5 Growth in annual electricity generation and annual gas demand

Reviewing gas flow logger data (where available) for existing generation sites (including some equivalent sized sites in the South West LDZ) created an estimate of baseline capacity factors for existing sites. The annual output, referencing capacity factors, installed capacity and benchmark generation conversion estimates averaged by technology.

Future electricity generation projections have been disaggregated from the National Grid FES 2018 projections for GB. These projections are therefore relatively high level and do not represent the potential operation of specific individual assets in Wales. A notable feature of the baseline assessment, also strongly reflected in the National Grid FES 2018 projections, is the low level of generation compared to installed capacity, and therefore low implied capacity factors for distribution connected gas generation currently. This is especially true of CCGT plant.

Table 16: Table of milestone scenario projections for capacity factors for CCGT assets in the WWU Wales LDZs

Scenario	Baseline 2018	By 2020	By 2025	By 2030	By 2035
Community Renewables	7.4%	5.4%	-	-	-
Two Degrees		5.6%	0.9%	0.1%	-
Hybrid Accelerator		5.5%	0.5%	-	-
Consumer Evolution		5.6%	1.5%	1.5%	2.8%
Steady Progression		5.6%	1.3%	0.9%	0.3%

Table 17: Table of milestone scenario projections for capacity factors for reciprocating engine assets in the WWU Wales LDZs

Scenario	Baseline 2018	By 2020	By 2025	By 2030	By 2035
Community Renewables	18%	17%	13%	9%	7.4%
Two Degrees		18%	20%	203%	22%
Hybrid Accelerator		18%	16%	15%	14.5%
Consumer Evolution		17%	14%	10%	9%
Steady Progression		19%	20%	20%	20%

Table 18: Table of milestone scenario projections for annual electricity generation from gas in the WWU Wales LDZs

Scenario	Baseline 2018 (GWh)	By 2020 (GWh)	By 2025 (GWh)	By 2030 (GWh)	By 2035 (GWh)
Community Renewables	285	670	783	648	577
Two Degrees		724	996	1,097	1,276
Hybrid Accelerator		710	869	858	939
Consumer Evolution		689	846	715	703
Steady Progression		594	994	1,007	1,048

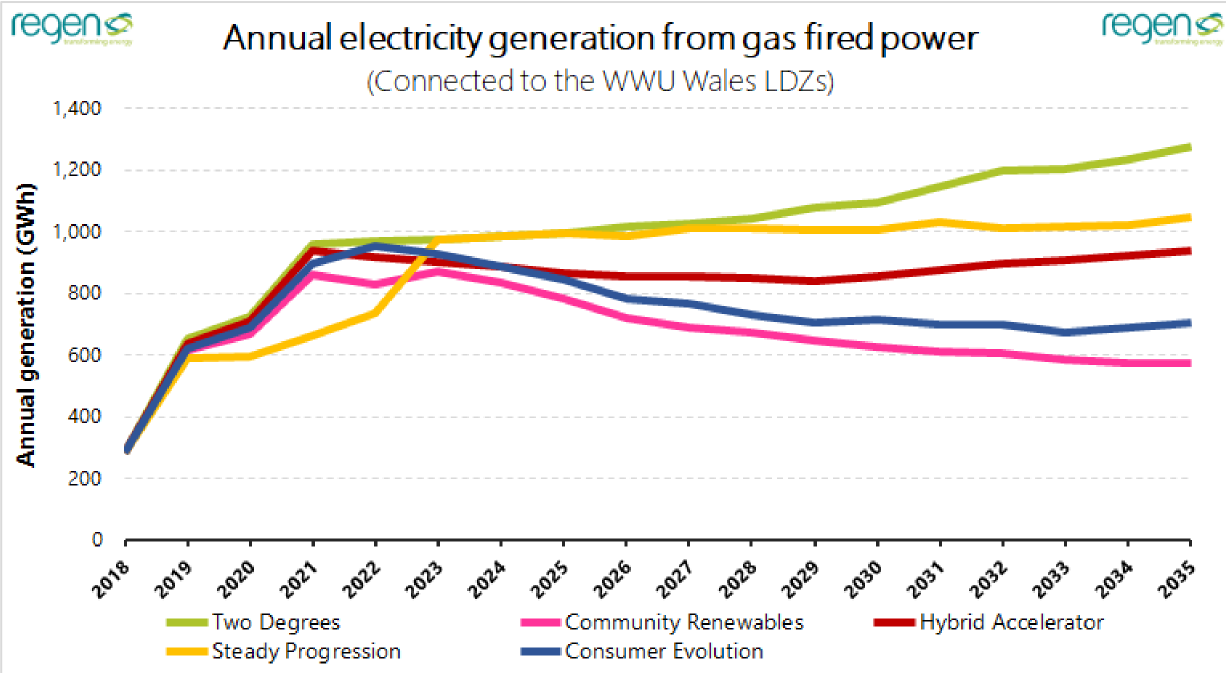

Figure 59: Scenario projections for annual electricity generation from gas fired power in the WWU Wales LDZs, 2018 to 2035

In order to convert annual electricity generation to estimated annual gas demand, the analysis used conversion efficiencies for both CCGT/OCGT and reciprocating engine assets. These conversion efficiencies are the same across all five scenarios, but increase over time, reflecting technology improvements for both gas turbines and reciprocating engines[35].

Table 19: Table of milestone conversion efficiencies for gas generation technologies used in all scenarios

Generating Technology	Baseline 2018	By 2020	By 2025	By 2030	By 2035
CCGT assets	**49%**	**51%**	**55%**	**58%**	**60%**
Reciprocating engines	**40%**	**41%**	**45%**	**48%**	**50%**

[35] References used include BEIS *Digest of UK Energy Statistics (DUKES) 2018* and the Sandbag *Coal to Clean* report: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes#2018 https://sandbag.org.uk/project/coal-to-clean/

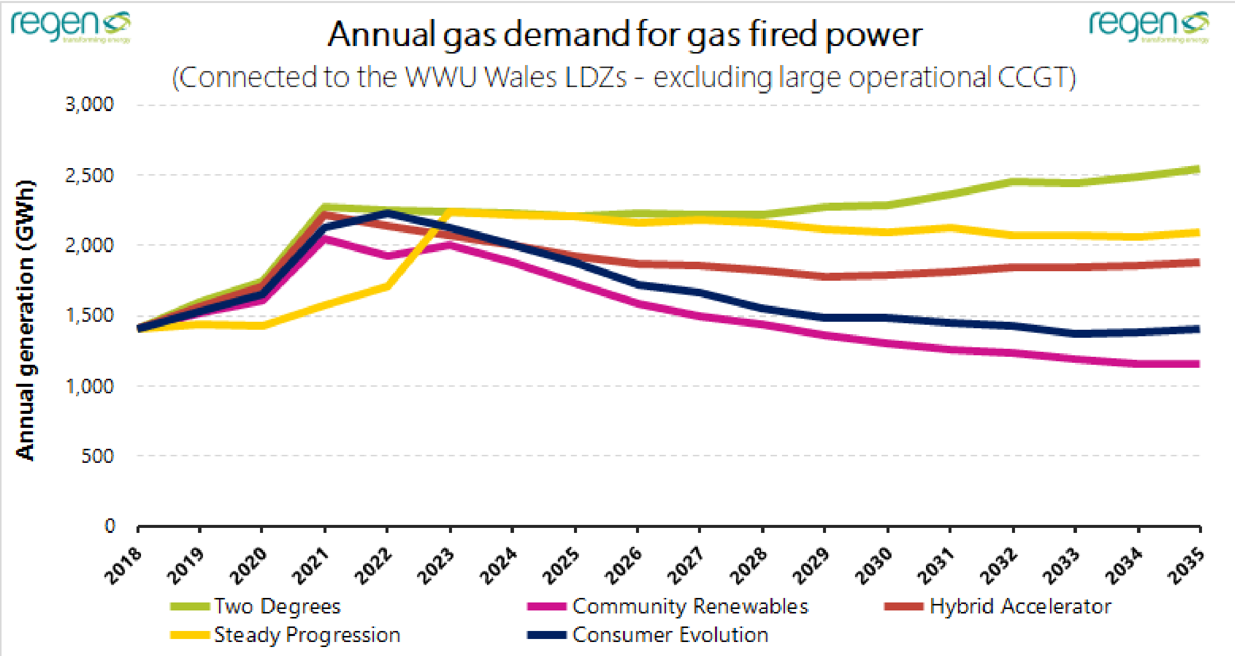

Figure 60: Scenario projections for annual energy demand on the WWU Wales gas network from electricity generation to 2035

The main trends that the scenarios describe can be summarised as:

1. There is an increase in distributed gas generation and therefore gas energy demand that peaks in the early 2020s, as flexible gas generation plays an increasing role within the energy system. In the scenarios with more centralised generation and the need for longer operating hours (**Two Degrees** and **Steady Progression**), the demand for energy on the WWU network from electricity generation increases in the 2030s. In the scenarios with more decentralised generation and more flexible operating behaviour, the demand for energy on the WWU Wales LDZs from electricity generation reduces, as other forms of flexibility including storage are likely to provide equivalent services, alongside flexible gas generators.
2. Gas reciprocating engine projects appear to have a stronger opportunity to increase over CCGT or OCGT plants, due to lower cost, smaller and modular scale and improved efficiency. This is a trend that was confirmed during all stakeholder engagement events.
3. Depending on the scenario, higher capacity does not necessarily mean higher generation. **Two Degrees** for example has a lower level of installed power capacity by 2035 (see Figure 57), yet has the highest annual electricity generation and therefore demand for gas by 2035. This reflects the role that distributed gas generation could play in **Two Degrees** as a highly centralised and high decarbonisation scenario. Similarly, **Community Renewables** and **Consumer Evolution** see by far the highest installed capacity by yet are the two scenarios with the lowest annual electricity generation and demand for gas.

The low capacity factors across the board out to the 2030s suggest a commercial environment that enables gas fired generation to operate infrequently. To some extent, relatively low capacity factors are seen from analysing the gas flows of some of the baseline connected sites, but data was only available for a handful of the baseline sites in Wales.

Capacity factors for distribution connected CCGT sites are expected to be extremely low in the 2030s, with some scenarios proposing factors of 0.1%. With Severn Power discounted from the scenario modelling and Barry Power Station decommissioned in March 2019, this capacity factor only applies to a single 16 MW CCGT site in the Wales baseline. This site has been modelled to decommission in the late 2020s in all scenarios except **Steady Progression**. Feedback from the engagement workshops, suggested that existing CCGT gas generation sites would struggle to operate under such infrequent and low annual generation output. The case for investing in new CCGT sites was highlighted as being even harder to justify in this operating environment.

The more positive outlook for gas reciprocating engines seen in the South West analysis was echoed in Wales. Feedback gained at the stakeholder workshops restated reasons around lower cost, quicker response times and smaller, more modular scalability. Stakeholders advised that some reciprocating engines are now capable of ramping to full output within 30 seconds, enabling them to be a component part of a hybrid 'rapid response' site class, perhaps being co-located with sub-second inverter-controlled battery storage assets. These types of hybrid flexibility sites are being explored right now, justifying the growth in new gas reciprocating engine capacity connecting to the network seen in the scenario projections in Figure 57.

For all distributed generation technologies there are however a number of uncertainties that could impact future growth, these include:

- Proposed significant reforms to electricity network charging
- Competition from other forms of flexibility such as standalone batteries and Demand Side Response
- Cannibalisation of higher value revenue streams (such as grid services)
- Uncertainties on future support mechanisms such as the capacity market.
- Future planning and policy positions relating to new fossil fuel generation projects in Wales
- General impacts on all forms of gas fired generation from UK net zero carbon reduction plans

The range of both installed capacity (MW_e) and annual generation/gas demand (MWh/yr) shown in the scenarios reflects many of these uncertainties. There are numerous interdependencies between future electricity demand, future national electricity generation mix, emission controls/policies and the role of gas fired generation in the system. Specifically modelling these other direct and indirect factors alongside gas fired generation is not within the scope of this assessment, but the range of 2035 outcomes reflect the various factors at play in determining what gas generation may (or may not) be connecting to WWU's gas network.

4.3.6 Geographical distribution

As gas fired power generation sites represent large point sources of demand, a granular distribution of gas fired power capacity is key for both internal WWU operational modelling and external engagement.

For the scenario analysis, projections have been distributed to 37 separate GSAs. This allows projections to be aggregated to linepack zone or local authority granularity or packaged up to approximately represent other geographical areas covered by the WWU Wales gas network.

The capacity of existing gas fired power generation and the pipeline of plants with a connection application has been allocated to GSAs according to their location. Projected capacity growth beyond the pipeline has been distributed to GSAs using the **Regen Distributor Model** based on GSA characterisation and attributes to define the likelihood of a GSA hosting gas fired power. These attributes include:

- Existing locations of gas fired power station sites
- Planned locations of pipeline developments
- Proximity to the WWU gas distribution network
- Proximity to the electricity distribution network
- Land classified as urban areas
- Active Network Management zones

For Wales consideration has been given to an active Statement of Works between National Grid ESO and Western Power Distribution (WPD), preventing the connection of new 'dispatchable generation' in South Wales (which gas generation classifies as) until the late 2020s[36].

These attributes, and the weightings of them, are informed by previous Regen work for electricity DNOs[37], stakeholder engagement workshops, and existing baseline and pipeline locations. The exact weighting of these attributes will depend on the year and scenario, based on the underlying assumptions of the National Grid FES. In addition, the decommissioning of CCGT assets in the scenarios leads to step-change capacity reductions in some GSAs during the projection years.

The six maps in Figure 61 show the resultant distribution of gas fired power generation capacity (MW_e) in 2018 and the proposed distribution of the five generation scenario capacity outcomes in 2035. The more centralised **Steady Progression** and **Two Degrees** scenarios shows limited gas fired power capacity being developed beyond existing baseline and pipeline sites currently in development. The geographic distribution of gas fired power capacity in these scenarios naturally display a similar distribution to the 2018 baseline: a relatively low capacity limited primarily to major urban areas.

In the decentralised **Community Renewables** and **Consumer Evolution** scenarios, with high growth of distribution connected gas fired flexible plant capacity in pipeline and projection years, the distribution remains focussed around city GSAs, but with a wider distribution to some of the lesser urban areas. The consideration of the Statement of Works embargo in South Wales is reflected in the dataset, but is essentially 'unlocked' by 2035, hence why an increase in capacity across north and south Wales GSAs is seen in the scenario maps.

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[36] See Western Power Distribution South Wales Statement of Works update, March 2017: https://www.westernpower.co.uk/downloads/3907

[37] See Western Power Distribution - Distribution Future Energy Scenarios :A generation and demand study Technology growth scenarios to 2032

Flexible gas fired power capacity on the WWU Wales network in 2035, by GSA, under each future scenario

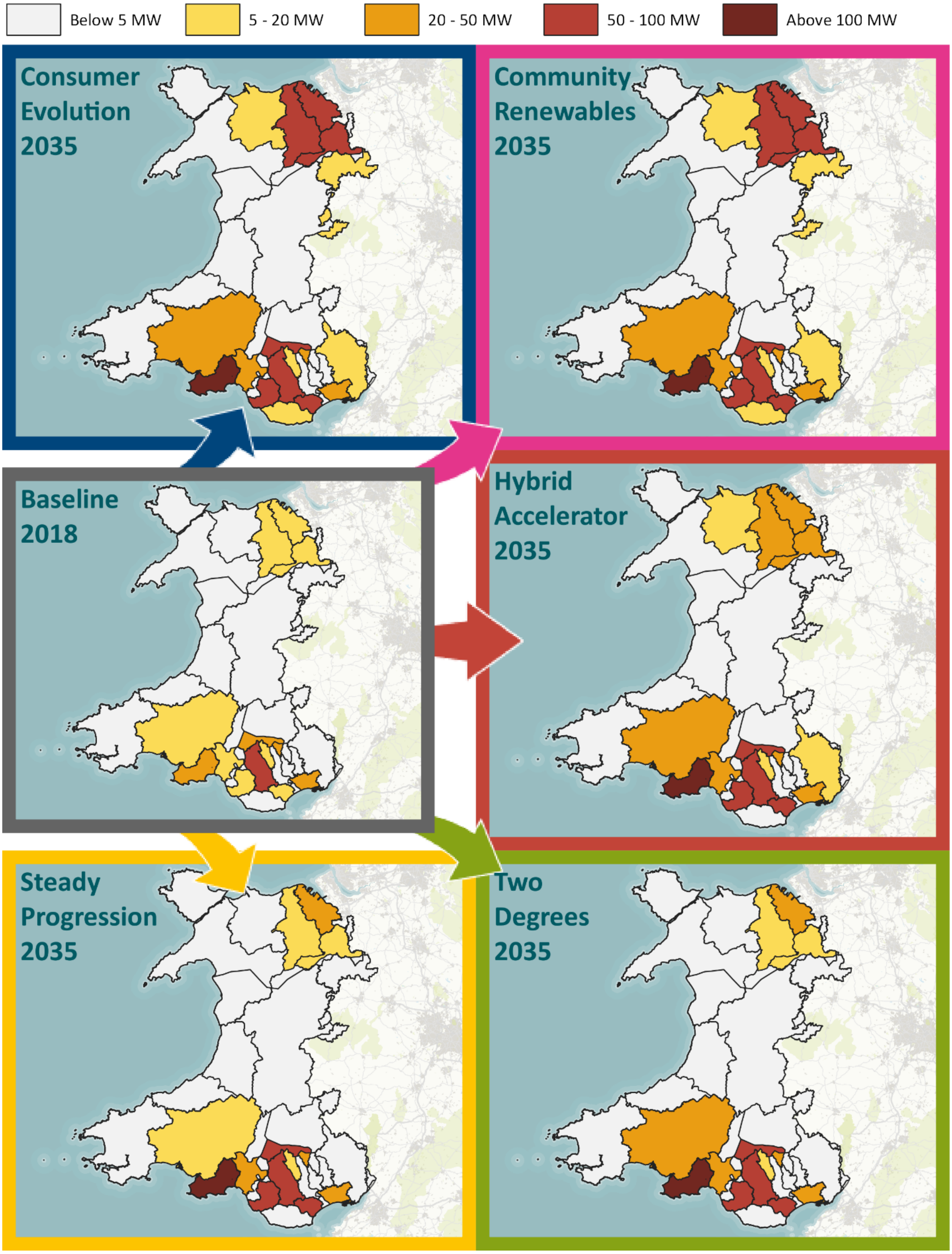

Figure 61: Projected geographical distribution of gas fired power capacity on the WWU Wales gas network in 2018 and 2035, under each scenario

4.4 Other gas fired industrial processes

In addition to gas fired power generators, WWU serves several large-scale, daily metered gas customers with high levels of gas demand for industrial processes.

Gas demand for industrial processes has steadily decreased over the last decade, reducing by 24.3% between 2007 and 2017[38].

There are currently **60** DM industrial sites[39] in the Wales LDZs, with a combined annual gas demand of **6,821 GWh** in 2018. It has been assumed that the number and location of DM sites will remain constant through the assessment period, there will however continue to be energy efficiency improvements which will vary by scenario, and a fuel switch to hydrogen for some sites in the latter years of the **Two Degrees** scenario.

4.4.1 Headlines from scenario analysis

- **There are 60 non-power generation daily metered industrial sites on the WWU Wales distribution network, with a baseline annual gas demand of 6,821 GWh.**
- **3,657 GWh (51.8%) of gas demand in 2018 related to high temperature industrial processes such as steelworks. 2,447 GWh (34.7%) of demand related to lower temperature processes such as the timber, chemical and textile industries.**
- **A small amount of demand reduction is seen in every scenario by 2035, from 2.4% by 2035 under Steady Progression to 19.6% under Community Renewables. This assumes various degrees of ambition and policy support for reducing industrial gas demand, and individual projections for particular sites of high gas demand based on future potential business decisions.**
- **Furthermore, the Two Degrees scenario sees a 70.6% reduction in gas demand for daily metered industrial sites, as hydrogen replaces natural gas for large consumers in industrial clusters in both south and north Wales.**
- **The Two Degrees scenario industrial hydrogen clusters sees 4,289 GWh of natural gas demand replaced with low carbon hydrogen by 2035. Produced by autothermal reformation of methane with associated carbon capture and storage, this would require ~5,000 GWh of methane to produce. It is expected that the methane would be sourced directly from the gas transmission network, and therefore causes a decrease in the demand on the WWU gas distribution network.**

[38] https://www.gov.uk/government/statistics/energy-consumption-in-the-uk
[39] Excluding gas fired power generators, as noted previously.

4.4.2 Summary of the approach taken

The method by which other gas fired industrial processes have been assessed is described in Figure 62:

(1) Established 2018 demand baseline

Reviewed hourly demand data from WWU to ascertain the expected annual demand in 2018 for each DM site, correlated to NTS total 2018 DM demand for the WWU Wales LDZs.

(2) Breakdown of demand by sector

DM sites are investigated and classified by sector and demand type. Examples include gas fired power, high temperature processes, food and drink production etc. Gas fired power is removed from the analysis.

(3) Comparison of WWU Wales to UK

The annual demand of each broad scale demand type in the WWU Wales LDZs is compared to a similar classification of industrial gas demand for the UK, through ECUK data.

(4) Projections by scenario

Projection of demand, as a proportion of 2018 baseline demand through stakeholder engagement and research of each broad scale industry type represented in the WWU Wales LDZs, under each future scenario conditions.

(5) Engagement with stakeholders and large consumers

Discussions with individual large consumers around potential future gas demand changes under each future scenario, to refine projections for individual sites/industries.

(6) Industrial hydrogen clusters

Modelling of hydrogen replacing natural gas energy demand for select industrial gas users, based on review of existing hydrogen projects such as Cadent's HyNet North West project.

Figure 62: High level scenario assessment stages for other gas fired industrial processes

4.4.3 Detailed results

The location and current gas demand of the existing, operational daily metered industrial sites on the WWU Wales network is shown in Figure 63. Figure 64 shows the results of the scenario analysis from 2018 to 2035 for daily metered industrial gas demand.

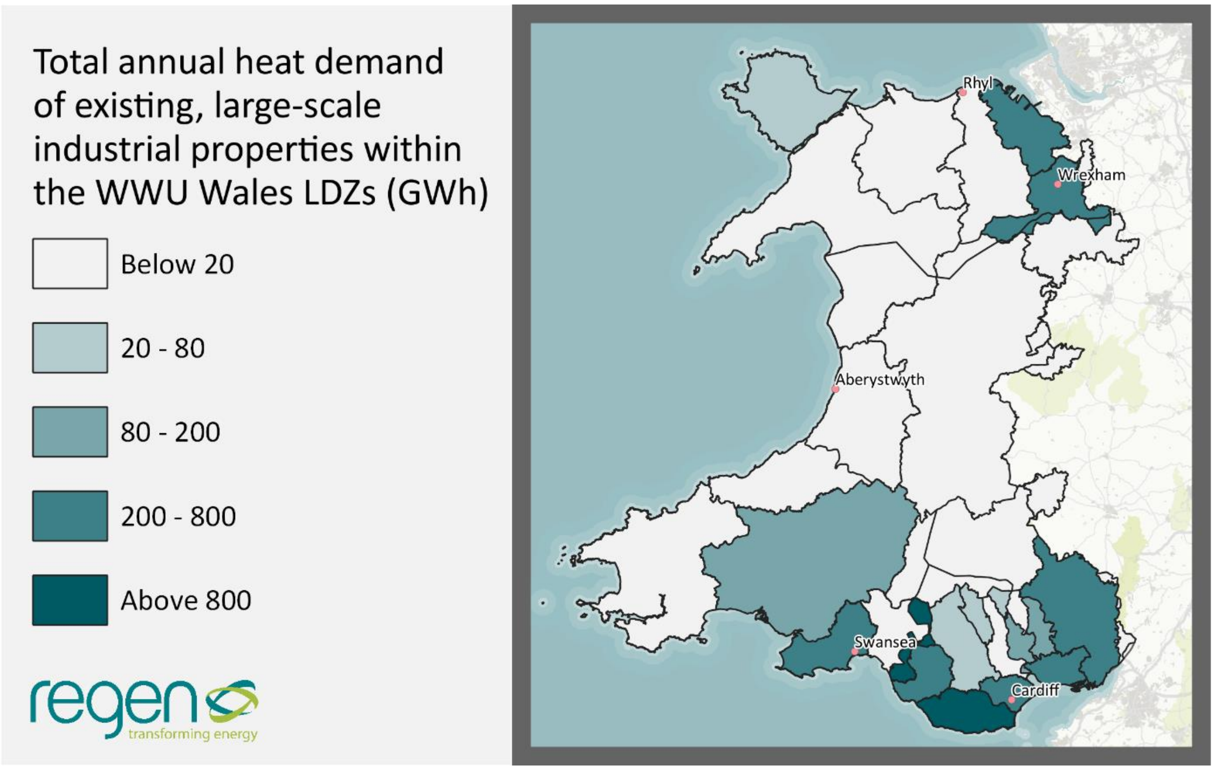

Figure 63: Modelled 2018 demand of daily metered gas customers on the WWU Wales gas network, distributed by GSA

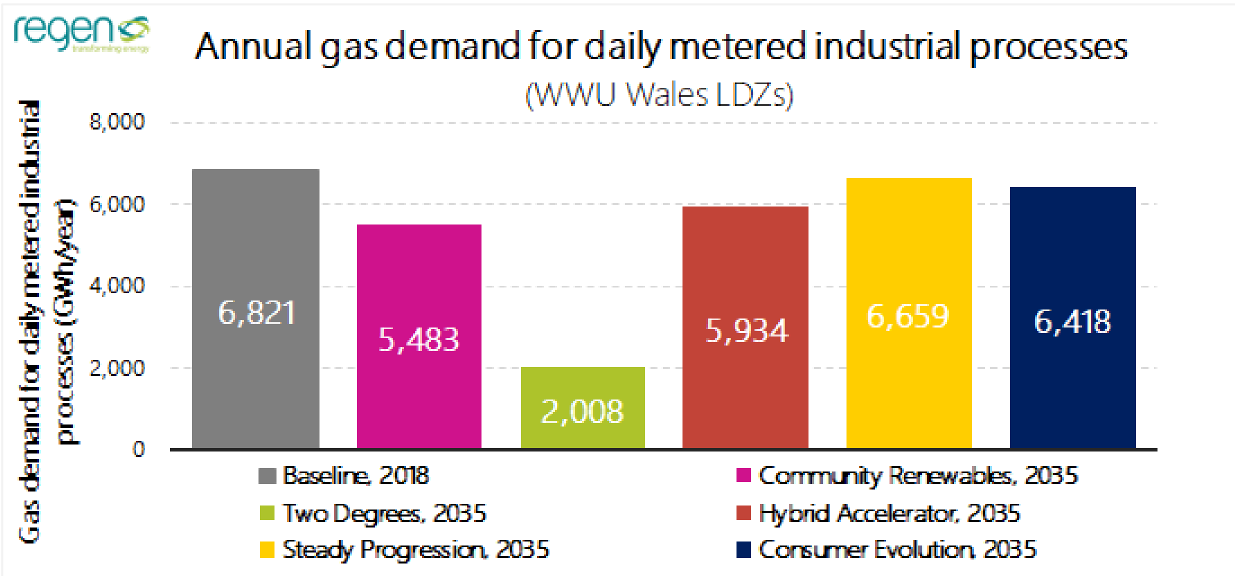

Figure 64: Projected energy demand on the WWU Wales gas network for other gas fired industrial processes in 2035 compared to the 2018 baseline demand, by scenario.

The results show a limited decrease in gas energy demand for DM industrial processes under every scenario, with the least reduction of **162 GWh** (**2.4%** of 2018 baseline demand) under **Steady Progression**, and largest reduction of **1,338 GWh** (**19.6%** of 2018 baseline demand) under **Community Renewables**. The relatively modest reductions reflect the nature of large-scale gas consumption for industrial processes, with relatively limited opportunities the improve efficiency of switch fuels, hydrogen notwithstanding. The results echo National Grid FES trajectories for industrial gas demand, adjusted to reflect the limited scope of significant demand reduction, particularly in process heat. Following conversations with specific stakeholders and large gas consumers, some individual sites have business-decision related projections under each scenario.

Under the **Two Degrees** scenario, some of the largest consumers of natural gas for industrial process heat convert to hydrogen in the 2030s. This change has been included following research and discussions around the potential for hydrogen clusters to decarbonise heavy industry in Wales. Aspects of this scenario are based on Cadent's HyNet North West project[40] and the multi-body FLEXIS project[41], both of which envisage a role for hydrogen in decarbonising Welsh industry. By 2035, **17** industrial sites are converted to hydrogen in clusters of industrial premises (Figure 65), representing **68%** of the energy demand for large-scale industrial processes in the WWU Wales LDZs, fuelled by low carbon hydrogen produced by autothermal reformation of natural gas sourced from the gas transmission system coupled with carbon capture and storage.

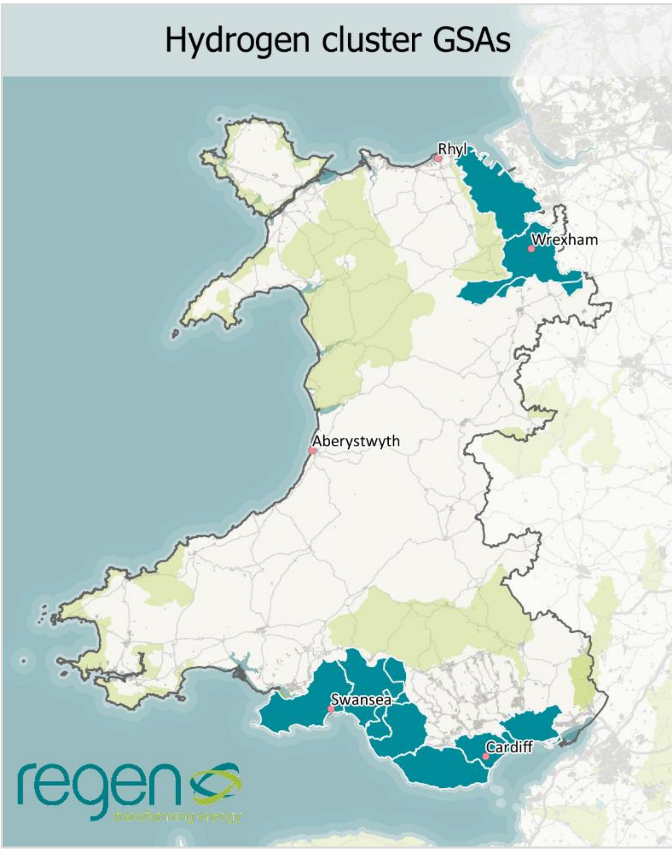

Figure 65: GSAs considered as part of south Wales and north Wales industrial clusters, highlighted in blue.
Note: There is not necessarily a hydrogen conversion in every GSA, and not every industrial gas customer in a hydrogen cluster GSA is modelled to convert to hydrogen.

[40] https://hynet.co.uk/app/uploads/2018/05/14368_CADENT_PROJECT_REPORT_AMENDED_v22105.pdf
[41] http://www.flexis.wales/

4.5 Gas fuelled vehicles and electric vehicles

Transport is expected to undergo a radical transformation in the coming decades, with a wholesale shift from petrol and diesel fuelled vehicles to alternative low carbon and low emission vehicles.

Cars, light goods vehicles (LGVs), smaller Heavy Goods Vehicles (HGVs) and buses used in urban areas are expected to see electric drives (rather than internal combustion engines) become the primary new motive technology. However, for larger HGVs, agricultural and construction vehicles, marine transport and potentially some classes of buses, other fuels could be adopted. Alternative vehicle fuels could include natural gas, biogas and/or hydrogen.

The **Regen Regional Transport Model** has been used to disaggregate the national transport growth projections contained in the FES 2018 dataset, in order to create a transport growth projection for the Wales LDZs. The resulting scenario projections provide annual and cumulative growth projections by vehicle and fuel type including cars, LGVs, vans, HGVs, motorcycles, buses and coaches. Fuel types include full battery electric, hybrid electric, diesel, petrol, hydrogen, biogas and Compressed Natural Gas (CNG).

The full model allows the distribution of the number of vehicles (by type) and mileage at local authority level. In order to keep the scope of this assessment focussing on elements that will have material impact on WWU's long term network planning, only those vehicle types and vehicle fuel categories that have the potential to be a noteworthy source of new demand for energy from the gas network have been considered.

Therefore, for the purposes of this assessment, the following vehicle types have been analysed:

- Electric Vehicles (EVs)
- Compressed Natural Gas (CNG) and/or biogas fuelled buses and HGVs
- Hydrogen fuelled buses and HGVs

CNG and biogas buses and HGV vehicles have been assessed as one category of vehicle as, at this stage it is difficult to split out their growth projections, and it is very likely that vehicles will adopt a duel fuel approach and may use a blend of gases.

The increase in numbers of EVs[42] is expected to result in a significant increase in electricity demand. EVs have therefore featured as a key growth driver in the analysis that Regen has undertaken for WPD and other electricity DNOs, when undertaking scenario assessments for electricity network licence areas[43].

The growth in electricity demand for transport will have an indirect impact on the demand for gas fired power generation discussed in Section 4.3. If EV electricity demand results in an increase in peak demand and/or demand volatility at a national or local level, then the opportunities for flexible plants such as gas reciprocating engines may be increased. Conversely if EV demand is more effectively managed using smart charging technology, then the opportunities may be more limited as better use is made of off-peak electricity generation. In some scenarios the energy storage potential of EVs may become a source of flexibility using vehicle-to-grid or vehicle-to-home technology.

[42] Regen's modelling in 2018 concluded that 2 million battery EVs could be sold in 2035, equating to 85% of new vehicles being sold in the UK. See *Harnessing the Electric Vehicle Revolution*, April 2018: https://www.regen.co.uk/publications/harnessing-the-electric-vehicle-revolution/

[43] See Section 1 of Regen's latest WPD scenarios assessment, *Distribution Future Energy Scenarios – A generation and demand study technology growth scenarios to 2032, South West licence area*, July 2018: https://www.regen.co.uk/wp-content/uploads/Distributed-generation-demand-and-storage-study-South-West-2018.pdf

The wide range of scenario outcomes presented in section 4.3 reflect the uncertainty about the long-term impacts of an increased uptake of EVs on the demand for electricity and gas fired generation.

Annual scenario projections for the uptake of EVs have been produced for the Wales LDZs, but have not been geographically distributed to GSAs, as the impact of EVs on gas fired power is not geographically linked to a GSA level.

4.5.1 Headlines from scenario analysis

The key outcomes of the scenario analysis for CNG/biogas and hydrogen fuelled vehicles is as follows:

- **There are currently no CNG, biogas or hydrogen fuelling stations in the WWU Wales LDZs. This is expected to increase, with enquiries being seen in the neighbouring South West region.**
- **There is a moderate increase in the uptake of gas and hydrogen fuelled HGVs in all scenarios. The largest growth in the uptake of these vehicle types is seen in Two Degrees with 7,615 registered vehicles by 2035. The lowest increase in the uptake of these vehicle types is seen in Consumer Evolution with 2,832 registered vehicles by 2035.**
- **There is similarly moderate growth in the uptake of gas and hydrogen fuelled buses in all scenarios. The largest increase in the uptake of these vehicle types is seen in Two Degrees with 1,902 registered vehicles by 2035. The smallest increase in the uptake of these vehicle types is seen in Steady Progression with 938 registered vehicles by 2035.**

The key outcomes of the scenario analysis for EVs is as follows:

- **There are currently 4,507 EVs registered in the WWU Wales gas network area, equating to an estimated annual electricity demand of 5.0 GWh.**
- **There is significant increase in the uptake of EVs across all scenarios. The largest increase in EV uptake is in Community Renewables with 1,245,047 EVs registered by 2035, a 276x increase. The lowest increase (an 84x increase) is in Consumer Evolution, with 379,311 EVs registered by 2035. This results in an equivalent annual electricity demand of 2,563 GWh and 794 GWh within 2035 respectively.**

4.5.2 Summary of the approach taken

The Regen Transport Model uses several variables to project future growth scenarios. The main variables are:

- **Scale Factor**, which is based on the current level of transport activity within the region measured in vehicles registered and annual mileage.
- **Uptake Factor**, which is a measure of the current propensity to adopt EVs and gas vehicles, based on the rate of uptake to date.

The determination for both factors for the WWU Wales gas network area is based on Department for Transport vehicle registration data for 2018, categorised by local authority. Both these factors have been altered over time to reflect different regional variances and factors that could potentially influence the rate of uptake of EVs, natural gas, biogas and hydrogen vehicles.

More information about the process to model vehicle uptake is outlined in Appendix 4 of the Technical Companion Document.

4.5.3 Detailed results

Baseline position

The baseline analysis of transport activity[44] shows that 5.0% of all GB registered vehicles and 5.6% of the GB miles driven are in the WWU Wales gas network area. With 4,507 EV vehicles registered, the WWU Wales area has had a slower uptake of EVs to date, compared to the national average. There are currently very few CNG, biogas and hydrogen HGVs and buses registered in GB (5,822). At the baseline, **270** of these (4.6%) are registered in the WWU Wales area, however, there are currently no refuelling sites in the WWU Wales area.

Future transport trends and potential growth of EVs and gas fuelled vehicles

Overall the scenario projections for EV and Ultra Low Emission Vehicles in FES 2018 are higher than in previous FES scenario analysis. This reflects a significant shift towards higher EV adoption supported by UK government's commitment to ban sales of diesel and petrol vehicles from 2040, the policy initiatives set out in the Road to Zero strategy paper[45], plus the ongoing pressure to reduce emissions which is being driven by cities and other stakeholders.

Although the current proportion of EVs is still quite low, the uptake of EVs has begun to increase and the consensus across analysts and government departments is that EVs will dominate the market for cars in the medium to long term. The outstanding question is whether this transformation will happen very quickly over the next decade (as outlined in the **Two Degrees**, **Community Renewables** and **Hybrid Accelerator** scenarios), or more slowly out to 2035 (as outlined in the **Steady Progression** and **Consumer Evolution** scenarios).

The technology solution for HGVs, buses and coaches is less certain. Electric batteries will certainly play a notable role, and there are a number of electric buses already in fleets both in the UK and overseas, but cases have also been made for hydrogen vehicles, biogas and potentially CNG.

[44] See Department for Transport (DfT) Vehicle Licencing statistics and mileage data from Q4 2018: https://www.gov.uk/government/statistics/vehicle-licensing-statistics-2018
[45] See Office for Low Emission Vehicles 'Road to Zero Strategy' paper, July 2018: https://www.gov.uk/government/publications/reducing-emissions-from-road-transport-road-to-zero-strategy

The role that CNG could play is based on its lower NOx emissions and its potentially lower CO_2 emissions. Government analysis, presented in the *Road to Zero* strategy[46] has suggested that the CO_2 reduction case is still to be evidenced and that a period of technology development, including the development of more efficient CNG engines is required.

The UK Government Road to Zero 2018 strategy document recognises the potential of CNG vehicles as a road transport solution but highlights a number of issues and challenges that are to be overcome. The report highlights that while *"Natural gas typically has lower greenhouse gas emissions per unit of energy than petrol or diesel. However, gas vehicles tend to have relatively inefficient engines (when compared to diesel) which affects the overall greenhouse gas impact of a gas vehicle."*

The analysis conducted as part of the strategy development suggested that current HGVs using CNG or LNG may have a carbon footprint between 4% and 20% higher than an equivalent diesel vehicle. While for buses in an urban or mixed urban drive cycle the greenhouse gas emissions may be 12-24% higher.[47] The paper acknowledges that gas powered vehicle efficiencies are improving, and that the industry is claiming that the newest most efficient vehicles can now deliver greenhouse gas emission savings of 15%. The paper suggests that more technology development and evidence gathering is now needed.

The Committee on Climate Change has argued that by the late 2030s[48], all new HGVs and buses sold must be zero emission. In the meantime, they have suggested that natural gas HGVs are best suited for long duty cycles with continuous speeds, so long-haul motorway journeys, and not urban transport, are likely to represent the largest opportunity for reduced emissions. They also argue that natural gas refuelling infrastructure should connect to the grid where there are minimal energy losses from compressing the gas to refuel vehicles using the high and intermediate pressure distribution networks.

There is therefore uncertainty regarding the long-term growth for CNG vehicles and resulting demand for gas. There is however a potential scenario where CNG does play a significant role for larger HGVs (and other specialist vehicles) associated with long haul transport. This would tend to support the case for a relatively small number of fuelling stations at major transport hubs connected to the gas network.

WWU is seeing interest for such fuelling stations and has received grid connection applications/ agreements for three sites within the South West LDZ, but none in the Wales LDZs as of 2018.

The FES 2018 suggests that under the **Community Renewables** scenario there could be **243,130 natural gas fuelled vehicles** operating across GB by 2035.

EV and gas vehicle projection results

- Gas/biogas and hydrogen HGVs in the WWU Wales LDZs, see Table 20 and Figure 66.
- Gas/biogas and hydrogen buses in the WWU Wales LDZs, see Table 21 and Figure 67.
- Total annual energy demand for gas fuelled vehicles in the WWU Wales LDZs, see Table 22.
- EV registrations (assuming mainly cars) in the WWU Wales LDZs, see Table 23 and Figure 68.

[46] See Office for Low Emission Vehicles 'Road to Zero Strategy' paper, July 2018: https://www.gov.uk/government/publications/reducing-emissions-from-road-transport-road-to-zero-strategy
[47] UK Government Road to Zero Industrial Strategy Paper Page 126
[48] See CCC report, *Net Zero – The UK's contribution to stopping global warming*, May 2019: https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

Table 20: Table of milestone projections for gas, biogas and hydrogen fuelled HGVs in the WWU Wales LDZs

Scenario	Baseline 2018 (#)	By 2020 (#)	By 2025 (#)	By 2030 (#)	By 2035 (#)
Community Renewables	0	290	2,121	4,207	7,092
Two Degrees		299	2,251	4,519	7,615
Hybrid Accelerator		294	2,186	4,363	7,353
Consumer Evolution		198	1,151	1,983	2,832
Steady Progression		198	1,151	1,983	2,832

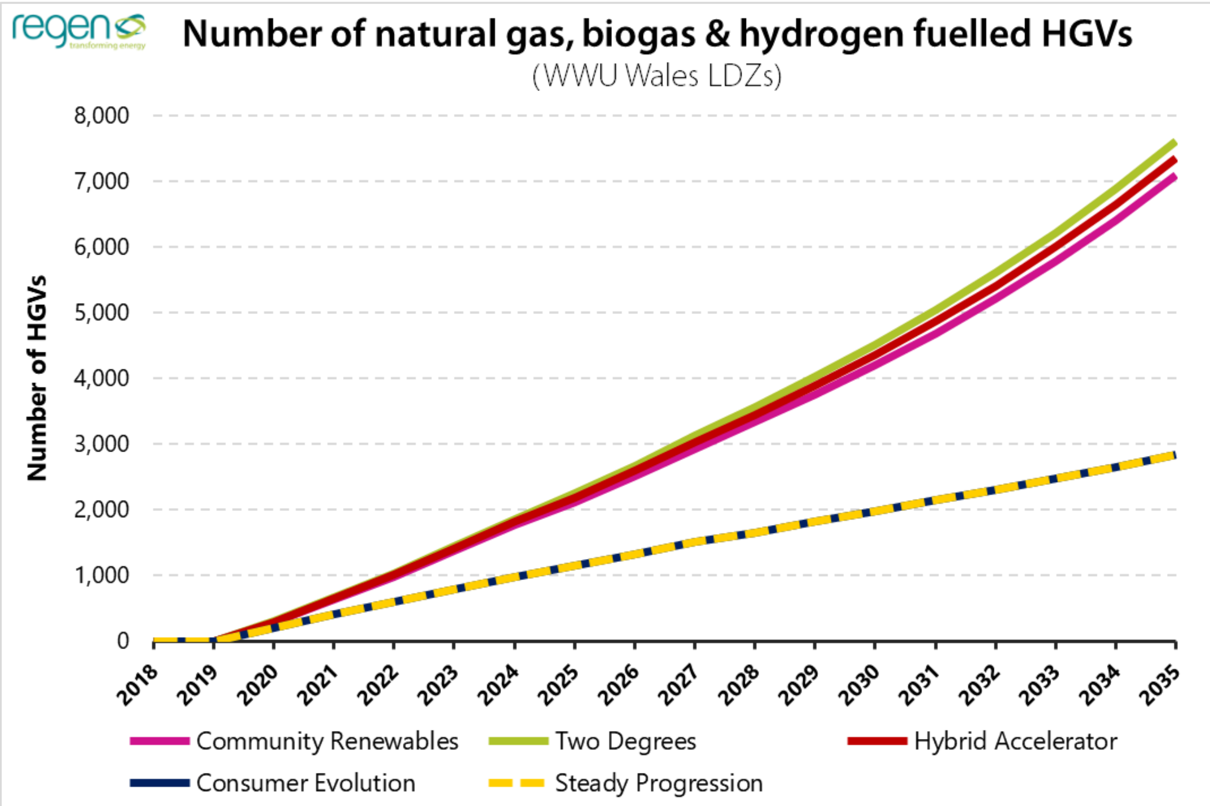

Figure 66: Scenario projections for the number of gas, biogas and hydrogen fuelled HGVs in the WWU Wales LDZs

Table 21: Table of milestone projections for gas, biogas and hydrogen fuelled buses in the WWU Wales LDZs

Scenario	Baseline 2018 (#)	By 2020 (#)	By 2025 (#)	By 2030 (#)	By 2035 (#)
Community Renewables	0	17	152	576	1,867
Two Degrees		17	151	577	1,902
Hybrid Accelerator		17	152	576	1,885
Consumer Evolution		15	111	346	945
Steady Progression		15	111	345	938

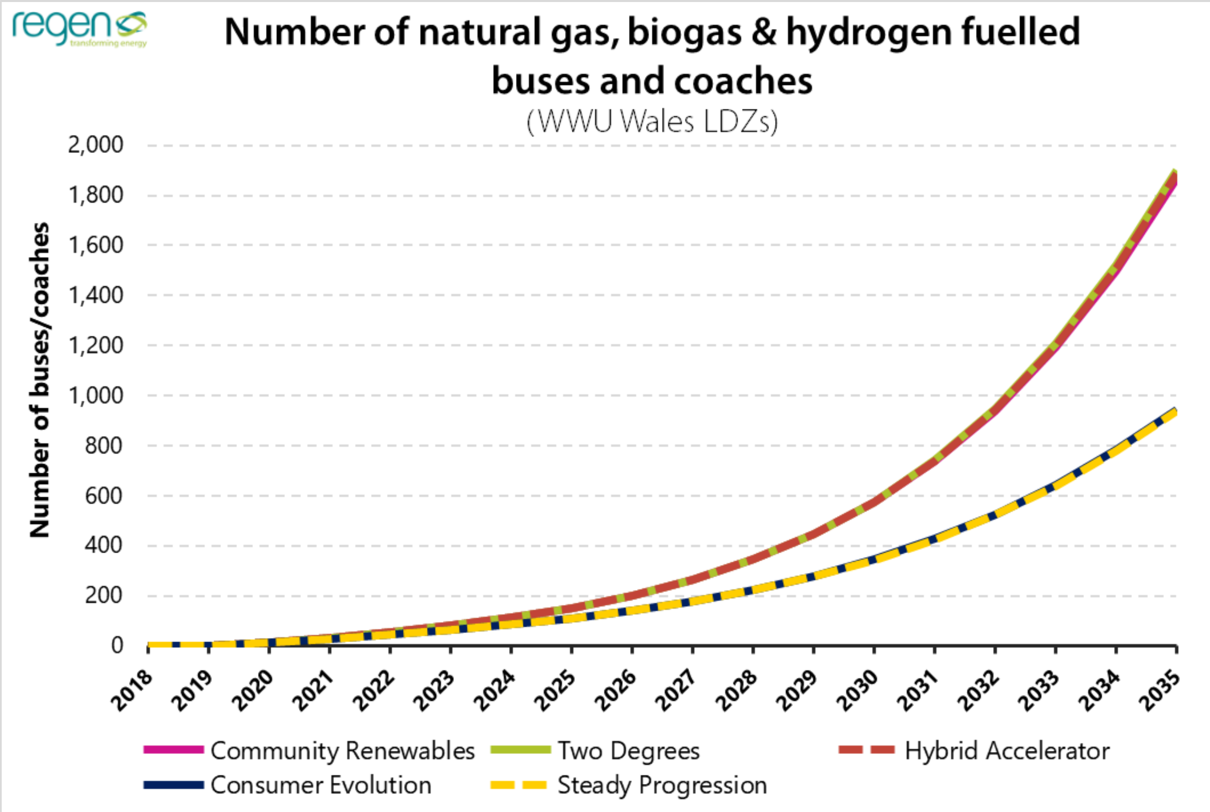

Figure 67: Scenario projections for the number of gas, biogas and hydrogen fuelled buses in the WWU Wales LDZs

The **Regen Regional Transport Model** converts vehicle number projections for gas/biogas, hydrogen and electricity types into annual mileage projections and resultantly annual fuel demand. The annual vehicle energy demand on the WWU Wales gas distribution network is shown in Table 22.

Table 22: Table of milestone projections for annual energy demand from gas fuelled vehicles in the WWU Wales LDZs

Scenario	Baseline 2018 (GWh)	By 2020 (GWh)	By 2025 (GWh)	By 2030 (GWh)	By 2035 (GWh)
Community Renewables	0	42	285	540	871
Two Degrees		44	301	580	940
Hybrid Accelerator		43	294	560	905
Consumer Evolution		29	157	268	398
Steady Progression		29	157	268	397

Table 23: Table of milestone projections for EVs in the WWU Wales LDZs

Scenario	Baseline 2018 (#)	By 2020 (#)	By 2025 (#)	By 2030 (#)	By 2035 (#)
Community Renewables	4,507	22,551	128,271	481,148	1,245,047
Two Degrees		19,788	111,891	457,168	1,225,395
Hybrid Accelerator		21,169	120,081	469,158	1,235,221
Consumer Evolution		8,551	31,982	112,509	379,311
Steady Progression		8,469	31,930	115,003	390,372

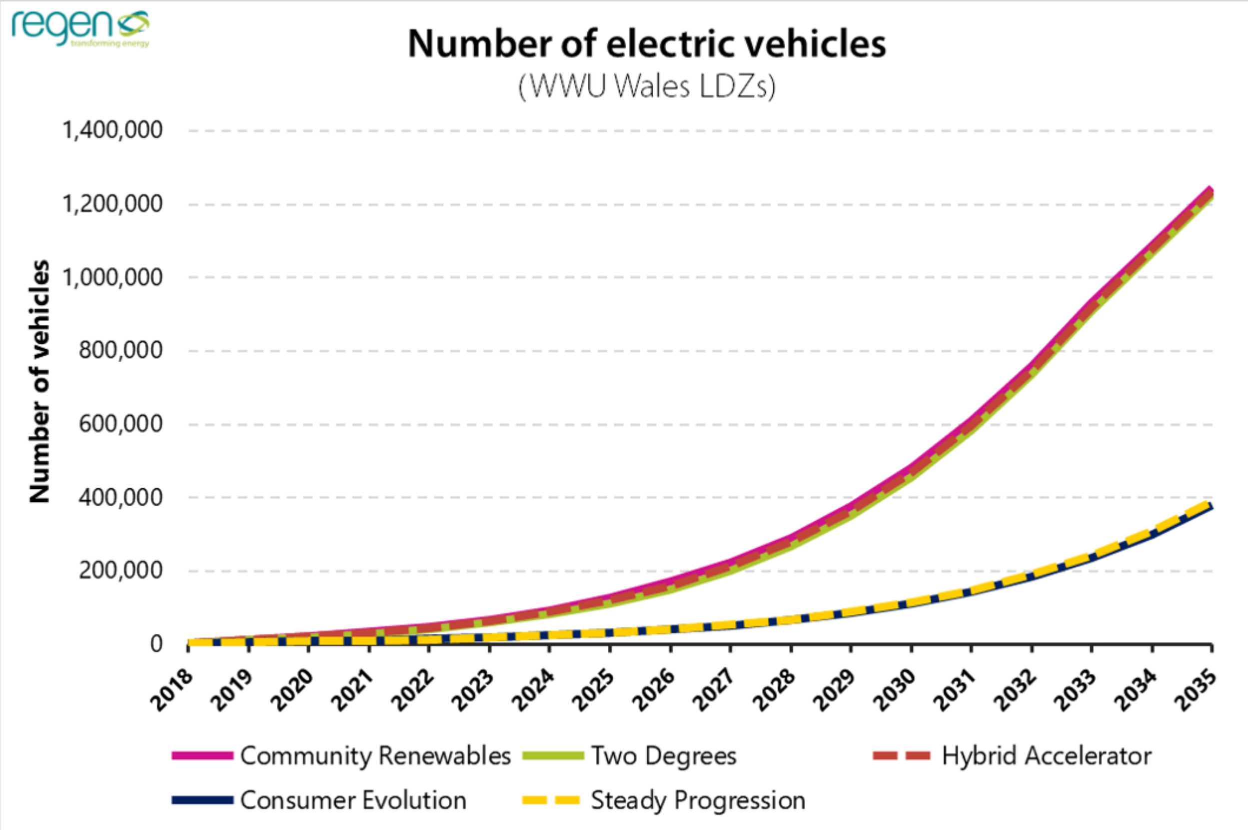

Figure 68: Scenario projections for the number of electric vehicles in the WWU Wales LDZs

4.5.4 Geographical distribution

HGVs and buses/coaches, the gas fuelled vehicles distributed in this analysis, are currently fuelled almost exclusively by petroleum fuels. In every scenario, a number of these vehicles are expected to be replaced by vehicles fuelled by gas delivered by the WWU Wales gas distribution network. Naturally, distribution of this gas demand is predicated on the distribution of existing petroleum HGVs and buses/coaches, with the additional constraint of gas network proximity. As a result, the spatial distribution of the overall Wales LDZs projections does not overly vary by scenario.

HGVs are distributed using the following GSA factors:

- Major roads (motorways and low-numbered A-roads)
- HGV registrations
- Large urban areas
- Proximity to the gas distribution network

The resultant distribution of gas fuelled HGVs (Figure 69) shows a high volume of energy demand around the industrial areas of the Wales LDZs, particularly the Swansea Bay City Region in South Wales and Flintshire/Wrexham in North Wales. In the compliant scenarios, only the west coast of Mid Wales and the Brecon Beacons area show limited gas HGV uptake, as these areas are strongly off-gas.

Buses and coaches are distributed using the following GSA factors:

- Bus registrations
- Number of urban households
- Major roads (motorways and low-numbered A-roads)
- Proximity to the gas distribution network

The resultant distribution of gas fuelled buses and coaches (Figure 70) reflects the current distribution of petroleum buses and coaches, with epicentres of demand on and around the Cardiff and Swansea GSAs. In the non-compliant scenarios, gas vehicles are mostly restricted to these two areas. In the compliant scenarios, gas fuelled buses and coaches are more widespread and in greater numbers, with many on-gas GSAs across the gas network area showing some uptake.

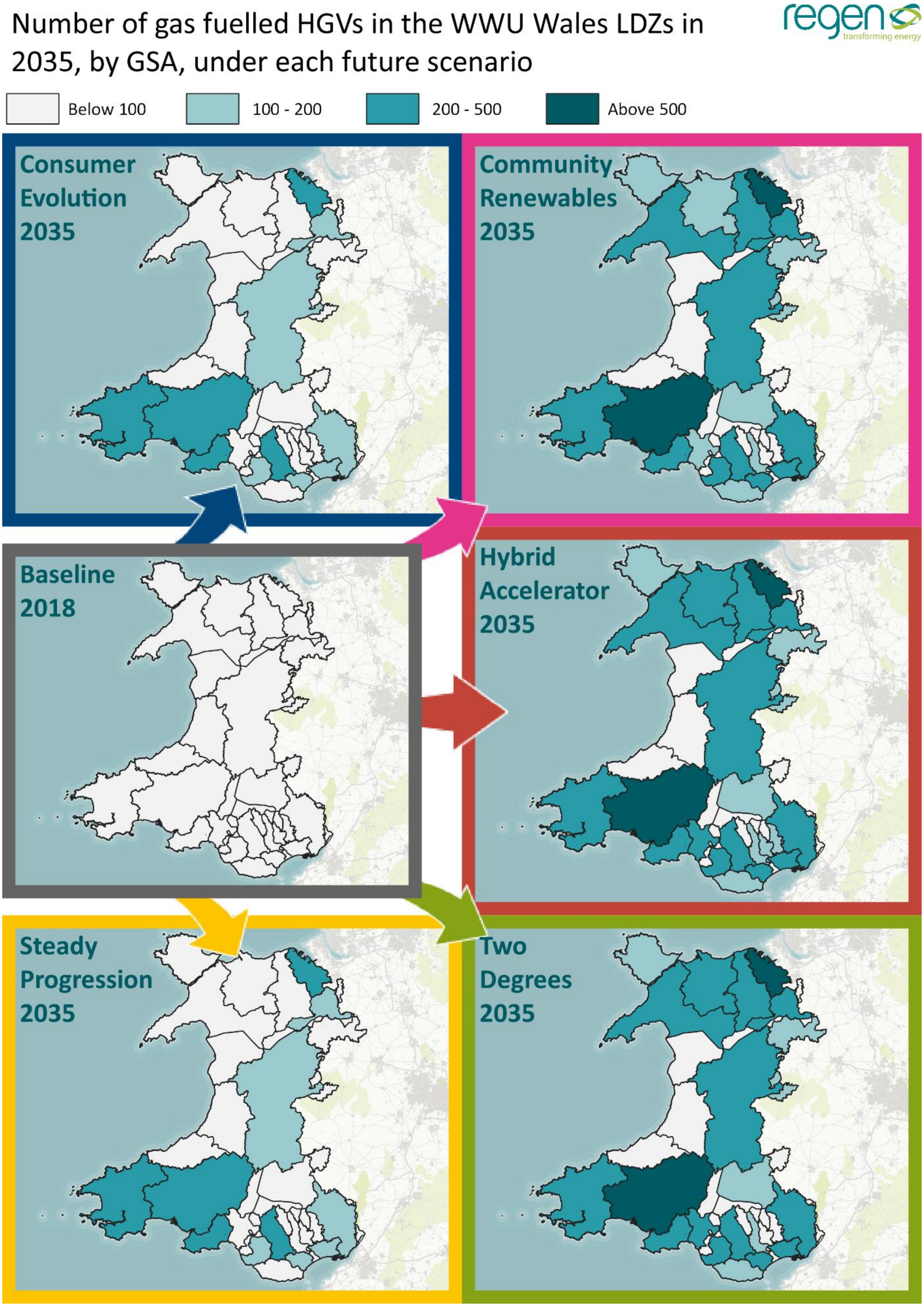

Figure 69: Annual energy demand for gas fuelled HGVs in the Wales LDZs, in 2018 and 2035, by GSA and scenario

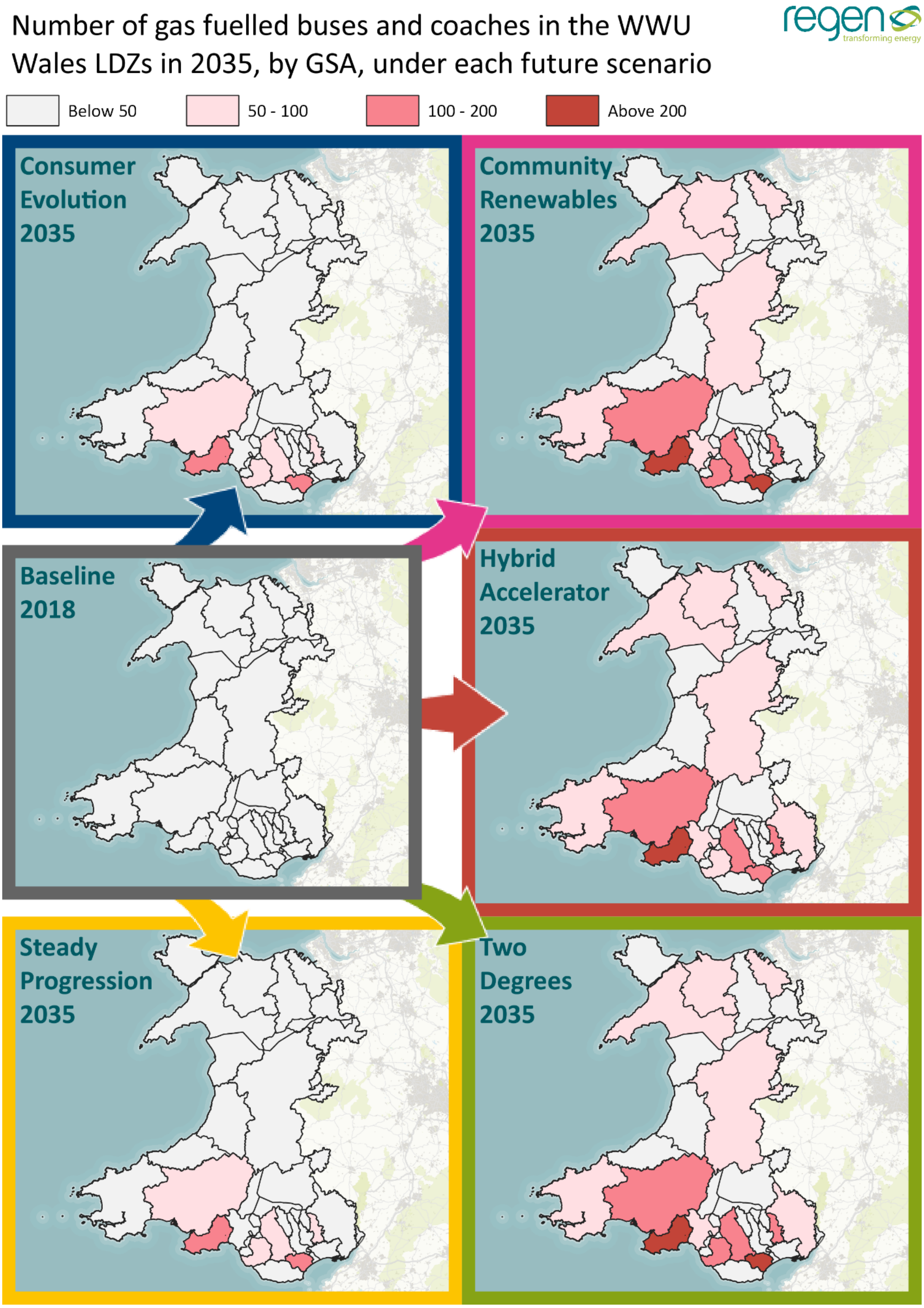

Figure 70: Annual energy demand for gas fuelled buses and coaches in the Wales LDZs, in 2018 and 2035, by GSA and scenario

4.6 Green gas supply

The WWU South West LDZ has a number of biomethane injection sites currently operating, or in the near-term pipeline to come online. In contrast to this, the Wales LDZs currently have only one operational biomethane injection site, located at a Five Fords Sewage Treatment Works in Wrexham, operated by Dwr Cymru (Welsh Water), with one site in the near-term pipeline.

The disparity in biomethane injection uptake between the two network regions was a core topic of discussion at the stakeholder engagement events. Reasons behind this were outlined as:

- The nature and scale of farming, with there being more remote hill farms in Wales
- Food waste collection is more centrally coordinated in Wales, with more central contracts with AD/CHP plants, so not as much surplus food waste available for injection
- There is less food processing currently in Wales
- The nature of a lack of gas network coverage in some rural areas where some waste feedstocks are located. The use of these feedstocks is predominantly for more standalone AD
- There is a minimal amount of energy crops Wales, related to Welsh Agriculture Policy[49]
- The opportunity for sewage gas is very locational. Dwr Cymru has five strategic sludge digestion centres and the use of sewage gas for injection through the non-domestic RHI, is weighed up against AD and Advanced AD paired with power generation, heat recovery and self-use.
- There are also a number of location factors to consider, essentially a trade-off between feedstocks, transport location of the gas network, where:
    - Food waste is available in urban areas but difficult/expensive to transport digestate
    - Agricultural waste is available in rural areas but potentially too far from the gas network

Some of these factors could be temporary barriers to market growth, but the potential for more biomethane injection in Wales will be lower overall by 2035 than the South West, in all scenarios.

The analysis has considered the number and distribution of individual projects/injection sites, their booked gas injection capacity (scm/h) and their future injection rates (%), to estimate the potential annual injection volume (both in scm and MWh), determined also as a proportion of the overall gas demand/volume.

Whilst less of an issue, due to the lower uptake in Wales, introducing more green gas injection brings challenges for WWU and their network operation management. In locations where increasing volumes of green gas may enter the system and the demand for gas reduces or develops a 'peakier' profile (i.e. due to an uptake in gas power generation discussed 4.3), network pressure could become difficult to manage in certain areas. As discussed in the South West results report, WWU and other gas network operators are already looking into potential solutions such as smart pressure controls, compression to higher pressure tiers and additional gas storage through innovation projects such as OptiNet[50].

There is the potential for green gas to be used for onsite heat, power generation or in the future as a fuel for transport or in heat networks. Wales currently has 27 MW of AD capacity[51]. Starting from a low base and pipeline and with conflicting future usages, the amount of green gas injection in Wales could vary over the timeframe of this assessment.

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[49] See https://gov.wales/support-welsh-farming-after-brexit

[50] See collaborative NIA project between Cadent and WWU, project OptiNet: https://www.smarternetworks.org/project/nia_wwu_052/documents

[51] See Regen's report for Welsh Government, *Energy Generation in Wales 2017*: https://gweddill.gov.wales/docs/desh/publications/181212-energy-generation-in-wales-2017-en.pdf

4.6.1 Headlines from scenario analysis

The outcome of scenario analysis for green gas injection in Wales shows the following:

- **There is only one operational green gas injection site in Wales, located at a Sewage Treatment Works in Wrexham, with a booked capacity of 700 scm/h.**
- **The volume of green gas entering the WWU South West gas distribution network in 2018 was 9.3 GWh, equating to 0.03% of the total energy supplied by the Wales gas distribution network. This proportion is lower than the national average of 0.4% and significantly lower than the current position in South West of 1.4%.**
- **There is one (notably larger) known injection project in the pipeline (1,700 scm/h) of provisionally booked capacity. This project is modelled to come online in the three compliant scenarios (Community Renewables, Two Degrees and Hybrid Accelerator).**
- **There is then a subsequent increase in new green gas to 2035, in terms of both capacity and green gas volume entering the network in Wales, in all scenarios.**
- **The largest capacity growth by 2035 is seen in Community Renewables with an increase to 18 sites totalling 14,400 scm/h. This roughly equates to a new 750 scm/h project connecting every year from 2019 to 2035. The lowest growth is seen in Steady Progression, with an increase to only 4 sites by 2035, totalling 2,950 scm/h.**
- **The highest annual volume of green gas by 2035 in Community Renewables totals 965 GWh and equates to 4.2% of overall Wales LDZs energy demand in 2035. The lowest annual volume of green gas by 2035 in Steady Progression totals 1,494 GWh, equating to 0.5% of overall Wales LDZs energy demand in 2035.**
- **It is estimated that in the high and low growth scenarios, green gas volumes would require between 0.6% (in a Steady Progression scenario) and 3.5% (in a Community Renewables scenario) of the estimated total GB potential feedstocks for biomethane production from Anaerobic Digestion available in 2035.**

4.6.2 Summary of the approach taken

The method by which green gas injection has been assessed is described in Figure 71:

(1) Established 2018 capacity baseline

Reviewed operational injection capacity (scm/h) up to 2018. Correlated connections with BEIS RHI and ADBA biogas map data. Reviewed annual green gas flow data for one operational site to establish current injection rates (%). Calculated proportion of demand delivered by green gas in 2018 (%).

(2) Established 2019-2025 pipeline

Reviewed accepted network entry pipeline site for RHI, planning activity and dialogue with developers. Assigned capacity to compliant scenarios. Added a small number of additional sites in the near-term out to 2025 in the compliant scenarios, modelling additional injection development in Wales, reflecting newly adopted decarbonisation objectives in Wales.

(3) Projected growth out to 2035

Analysed the UK annual proportion of green gas in each FES scenario in 2035 and the incremental increase in preceding milestone years back to 2025. Derived an equivalent number of projects and booked injection capacity, using typical 750 scm/h project size, to meet expected capacity year, to 2035, for each scenario.

(4) Equated to green gas volumes

Referenced the existing injection rates established in Stage 1, RHI estimated injection rates over the first two years of operation and the projected capacity figures calculated in stage 3. Established a 'within year' injection rate for capacity connecting in each year, in each scenario. Resultantly calculated annual green gas volume in scm and MWh in each scenario to

(5) Equated proportion of gas demand and assessed feedstock availability

Used WWU proportion of FES gas demand figures to 2035 and the calculated green gas volume from Stage 4, to determine the proportion of gas demand that is met by green gas production. Calculated available UK biomethane from AD in 2035 and compared to the 2035 results seen in stage 4 as a percentage.

6) Geographically distributed into GSAs

Distributed annual, scenario specific green gas injection capacity into the 37 GSAs, using weighted distribution factors, such as:

- Location of existing connected assets
- Proximity to gas networks
- Rural and urban land classifications

Figure 71: High level scenario assessment stages for green gas injection

4.6.3 Detailed results

The results of the scenario analysis from 2018 to 2035 for green gas injection capacity is outlined in Figure 72 and Table 24.

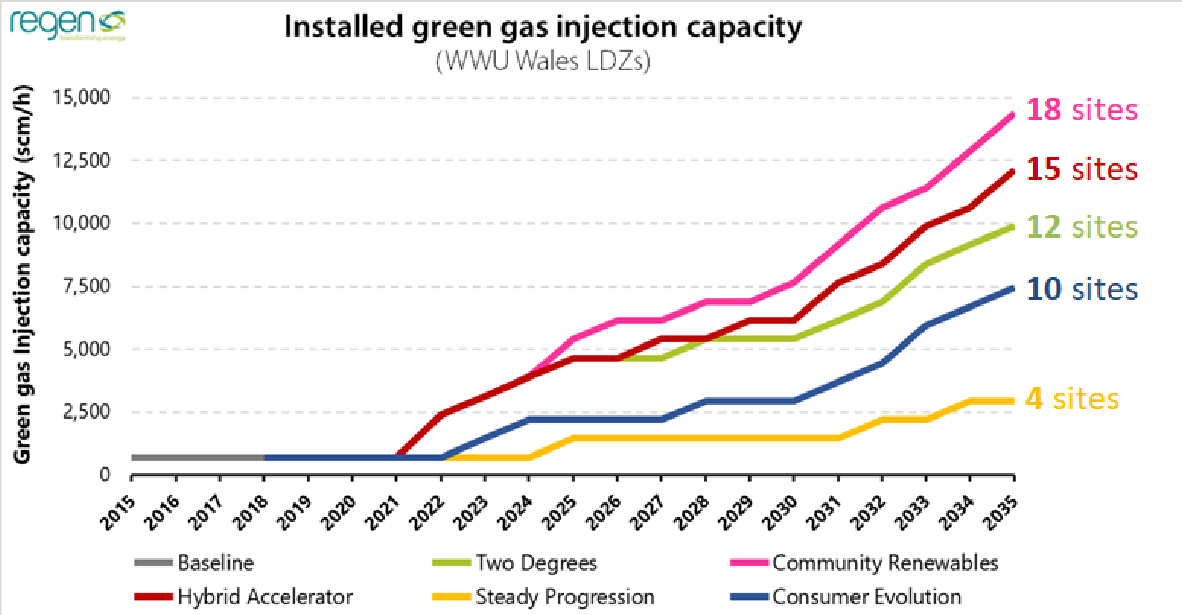

Figure 72: Scenario projections for green gas injection capacity (scm/h) into the Wales LDZs, 2018 to 2035

Table 24: Table of milestone scenario projections for green gas injection capacity (scm/h) for the Wales LDZs

Scenario	Baseline 2018 (scm/h)	By 2020 (scm/h)	By 2025 (scm/h)	By 2030 (scm/h)	By 2035 (scm/h)
Community Renewables	700	700	5,400	7,650	14,400
Two Degrees		700	4,650	5,400	9,900
Hybrid Accelerator		700	4,650	6,150	12,150
Consumer Evolution		700	2,200	2,950	7,450
Steady Progression		700	1,450	1,450	2,950

The results show growth in both the number of green gas injection sites and resultant injection capacity across all scenarios by 2035. The most capacity is seen in **Community Renewables**, with an increase from one to 18 projects by 2035. This is primarily due to **Community Renewables** being a scenario where distributed and decarbonised solutions are highest of all the scenarios. This level of growth in the development can be attributed to strong policy support to decarbonise both heat and emissions from power generation in Wales, as well as connection potential, commercial viability and feedstock availability for green gas digestion and injection sites.

The least green gas injection capacity is seen in **Steady Progression**, with a moderate increase from one to four projects by 2035. This maintains the current trend of limited interest in connecting green gas injection sites in the Wales LDZs out to 2035 and reflecting **Steady Progression** as a scenario where there is minimal policy or subsidy support beyond the closure of the current RHI programme.

In order to project the volume of green gas being injected by scenario, gas flow data for the one existing operational site was analysed and compared to the ramp-up injection rates used to estimate budgets in RHI tariff guarantees[52].

The modelling for new projects moving forward assumes a three-year ramp-up of injection rates for all new connecting injection sites from 40% in year one, 70% in year two and 80% from year three onwards. See extract from the injection rate model in Figure 73. A caveat to this generally positive outlook for network injection is the potential that biomethane is used for other purposes such as direct/district heating, power generation and transport.

Injection Rates in-year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
	40%	70%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
		40%	70%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
			40%	70%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
				40%	70%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
					40%	70%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
						40%	70%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
							40%	70%	80%	80%	80%	80%	80%	80%	80%	80%	80%
								40%	70%	80%	80%	80%	80%	80%	80%	80%	80%
									40%	70%	80%	80%	80%	80%	80%	80%	80%
										40%	70%	80%	80%	80%	80%	80%	80%
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															40%	70%	80%
																40%	70%
																	40%

		These numbers are taken from Top Down driven															
Community Renewables		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Year online	Plants online	2,700	2750	1750	4250	1500	750	750	2250	2250	3000	2250	2250	2250	1500	2250	1500	2250
2019	Production	9,460,800	16,556,400	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600	18,921,600
2020			9,636,000	16,863,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000	19,272,000
2021				6,132,000	10,731,000	12,264,000	12,264,000	12,264,000	12,264,000	12,264,000	12,264,000	12,264,000	12,264,000	12,264,000	12,264,000	12,264,000	12,264,000	12,264,000
2022					14,892,000	26,061,000	29,784,000	29,784,000	29,784,000	29,784,000	29,784,000	29,784,000	29,784,000	29,784,000	29,784,000	29,784,000	29,784,000	29,784,000
2023						5,256,000	9,198,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000
2024							2,628,000	4,599,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000
2025								2,628,000	4,599,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000	5,256,000
2026									0	0	0	0	0	0	0	0	0	0
2027										7,884,000	13,797,000	15,768,000	15,768,000	15,768,000	15,768,000	15,768,000	15,768,000	15,768,000
2028											10,512,000	18,396,000	21,024,000	21,024,000	21,024,000	21,024,000	21,024,000	21,024,000
2029												7,884,000	13,797,000	15,768,000	15,768,000	15,768,000	15,768,000	15,768,000
2030													7,884,000	13,797,000	15,768,000	15,768,000	15,768,000	15,768,000
2031														7,884,000	13,797,000	15,768,000	15,768,000	15,768,000
2032															5,256,000	9,198,000	10,512,000	10,512,000
2033																7,884,000	13,797,000	15,768,000
2034																	5,256,000	9,198,000
2035																		7,884,000
	Total annual pr	9,460,800	26,192,400	41,916,600	63,816,600	81,774,600	92,067,600	97,980,600	100,608,600	109,149,600	125,574,600	143,313,600	159,738,600	175,506,600	188,646,600	202,443,600	214,926,600	228,723,600

Figure 73: Extract of in-year injection rates used to model green gas injection figures

The highest growth in green gas energy[53] entering the network is seen in **Community Renewables**, with an increase in annual green gas energy entering the network to **965 GWh in 2035**. This represents an estimated **4.2%** of total gas network energy supply in 2035 in this scenario[54] in the Wales LDZs. The lowest growth is in **Steady Progression**, with an increase in annual green gas energy entering the network to **171 GWh in 2035**. This represents an estimated **0.5%** of total gas energy supply in 2035 in this scenario in the Wales LDZs.

Table 25: Table of milestone scenario projections for annual green gas injection into the Wales LDZs

Scenario	Baseline 2018 (GWh)	By 2020 (GWh)	By 2025 (GWh)	By 2030 (GWh)	By 2035 (GWh)
Community Renewables	9.3	**9.3**	**297**	**501**	**965**
Two Degrees		**9.3**	**270**	**361**	**663**
Hybrid Accelerator		**9.3**	**270**	**410**	**803**
Consumer Evolution		**9.3**	**115**	**178**	**479**
Steady Progression		**9.3**	**37**	**65**	**171**

[52] See BEIS RHI Budget Caps report, Feb 2019, Table 5: RHI_budget_cap_publication_data_to_end_of_February_2019.pdf
[53] From combining the scenario projections for injection capacity and the proposed injection rates, scenario projections for annual green gas volumes were produced, in scm. Using a conversion calculation (referencing a Calorific Value of 37.6), these figures were then converted into GWh of energy.
[54] Referencing the total demand on the WWU Wales gas network modelled in this assessment in 2035

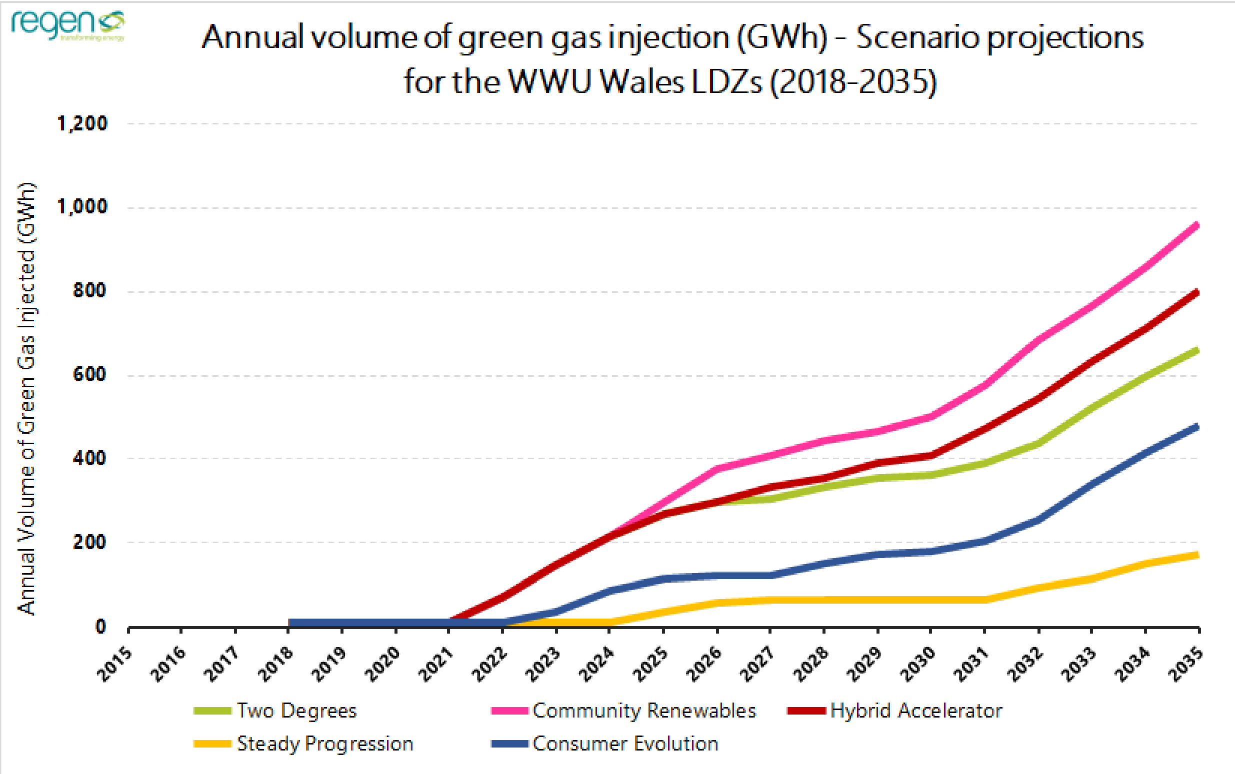

Figure 74: Scenario projections for annual green gas (GWh) injected into the WWU Wales gas network, 2018 to 2035

The projections shown in Figure 74, were compared to national green gas feedstock availability[55] to validate the feasibility of the data. The results of the highest and lowest annual green gas projections in 2035 for the Wales LDZs, were compared to the total UK biomethane potential from Anaerobic Digestion (AD) in the same year. This data was interpolated using the 2030 and 2040 figures produced in the Cadent dataset. The results were as follows:

- The **965 GWh** seen in 2035 in **Community Renewables** equates to **3.5%** of the total UK biomethane potential from AD.
- The **171 GWh** seen in 2035 in **Steady Progression**, equates to **0.6%** of the total UK biomethane potential from AD.

No specific assessment of feedstocks available in Wales has been made as part of this assessment however, at a high level and based on stakeholder feedback, the amount of biomethane required does not seem unfeasible given the relatively low amount, compared to national average and the SW analysis.

The required proportion of the UK land space, agricultural land and population that the Wales LDZs cover is more than sufficient to align with the moderate 2035 projections modelled in Figure 74. More detail around the method, assumptions and references used to inform this analysis can be found in Appendix 5 of the Technical Companion Document.

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[55] Data sourced from Cadent Gas' *Renewable gas potential in the UK* study completed in 2017: https://cadentgas.com/innovation/projects/the-future-role-of-gas

4.6.4 Geographical distribution

The minimal baseline and pipeline of green gas injection in Wales does not provided sufficient evidence in inform the potential distribution of projected sites coming online. As a result, the distribution of green gas injection to GSA level has been based on other factors, modelled using the **Regen Distributor Model**. These factors include:

- Population centres for sewage, food and commercial waste
- Agricultural land classifications for crop and animal waste
- Proximity of the WWU Wales network, with transportation of feedstocks more than a few miles greatly reducing the feasibility of a prospective green gas injection site (Figure 75).

Evidence gathered from engagement events regarding potential for co-digestion and waste-based policy drivers, alongside the farm-orientated baseline and pipeline, suggest that future green gas sites could be located in a mix of urban and rural areas.

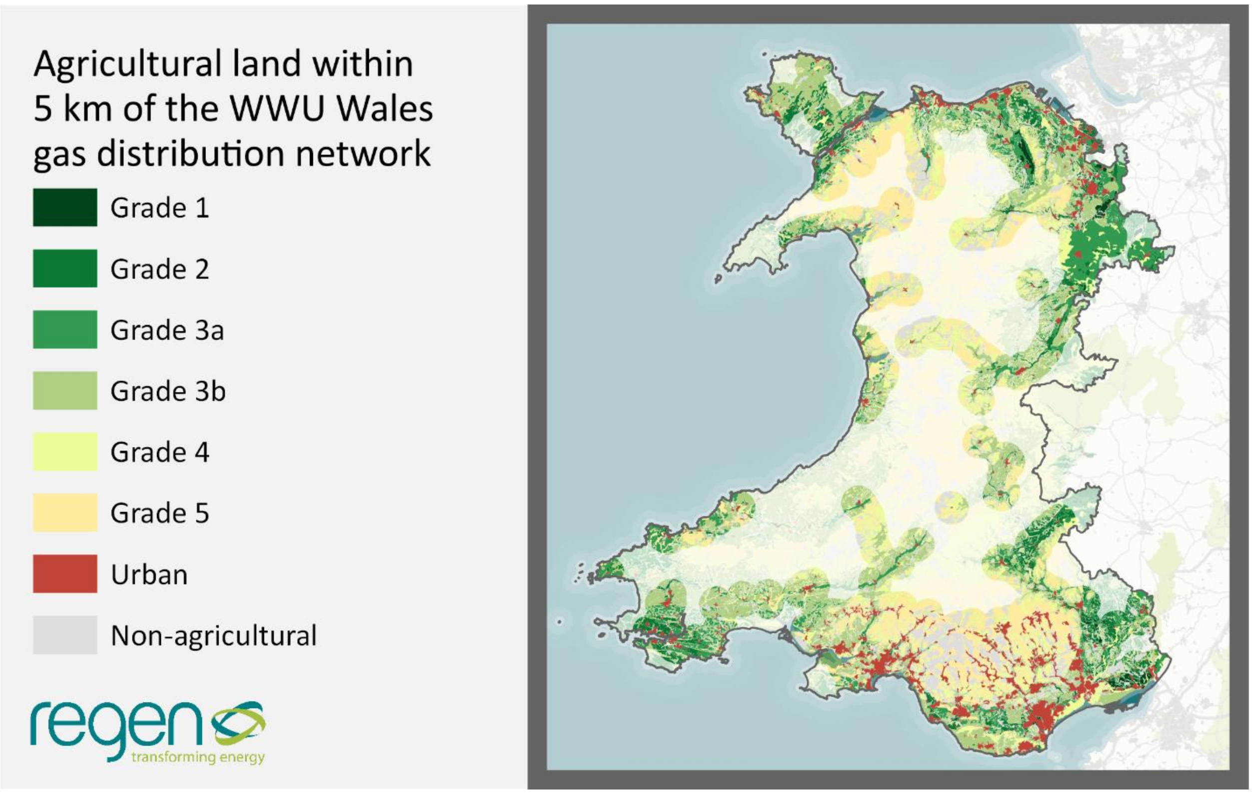

Figure 75: Map of agricultural and urban land within 5 km of the Wales LDZs, indicating potential feedstock areas for green gas production

The results shown in Figure 76 illustrate the distribution of green gas injection in 2035 under each of the five scenarios, compared to the 2018 baseline position. The non-compliant and more centralised **Steady Progression** scenario shows the least green gas, with distribution restricted mainly to existing and expected connections. The **Community Renewables** scenario displays moderate more green gas sites across a wider range of GSAs. In the **Community Renewables** and **Hybrid Accelerator** scenarios, the high levels of green gas in some areas of the network may require management to disperse injected volumes to other areas of the network, during periods of low demand.

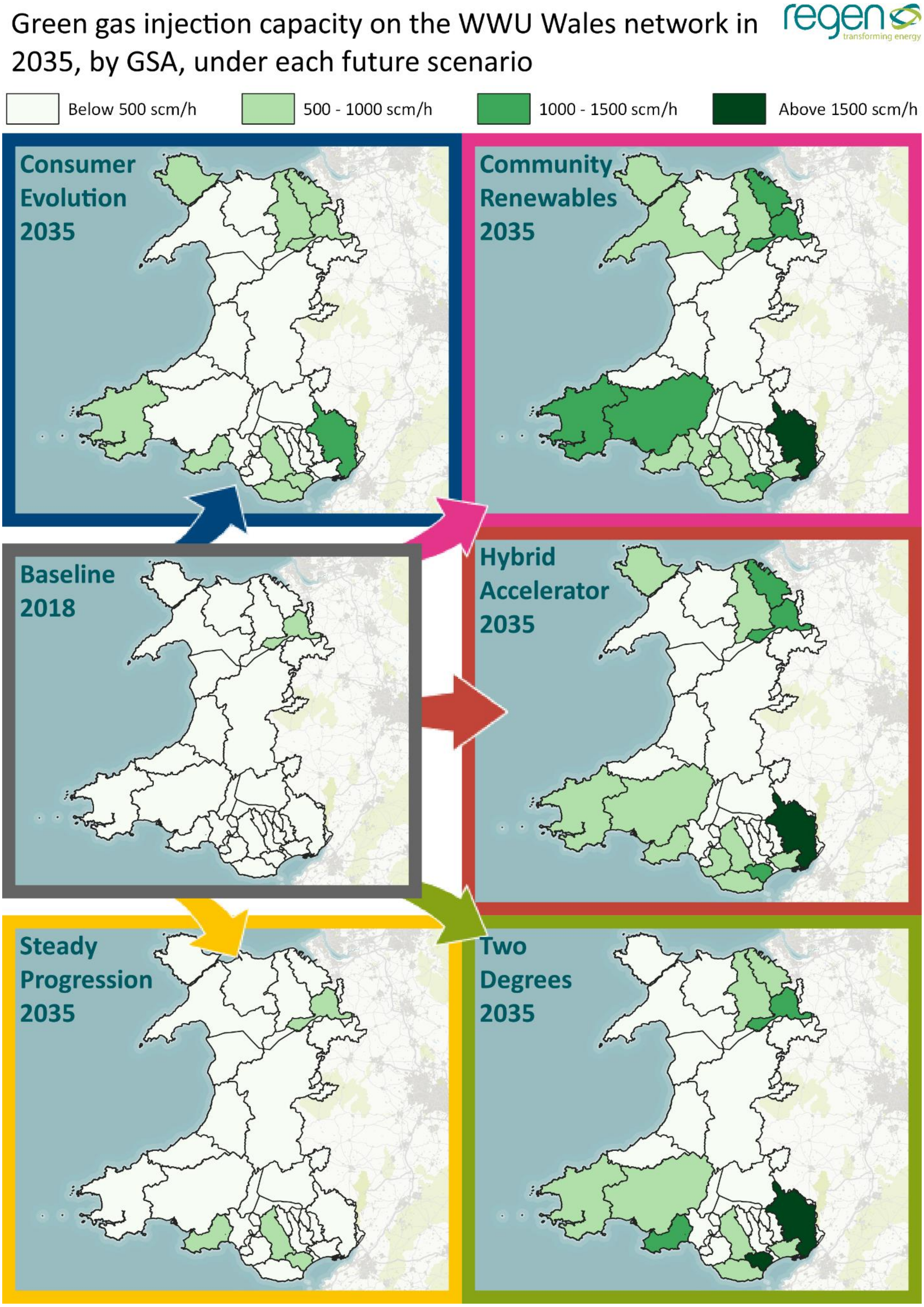

Figure 76: Projected distribution of green gas injection capacity in the Wales LDZs in 2035, under all scenarios

4.7 Hydrogen

The analysis of hydrogen for heat has considered two potential means of hydrogen distribution:

- **Hydrogen blending** – injection of low levels of hydrogen within the existing distribution network.
- **Hydrogen networks** – creation of specific hydrogen networks supplying 100% hydrogen, which may replace the existing natural gas network, or serve a small number of high-demand gas consumers in "hydrogen industrial clusters".

To produce large volumes of low carbon hydrogen, as would be required for 100% hydrogen networks, it is likely that hydrogen would be produced through reformation of methane combined with carbon capture and storage. As there is no suitable offshore carbon storage off the south coast of Wales, captured carbon would have to be shipped and piped to more distant carbon storage facilities. Smaller volumes of hydrogen, used for transport and blending, could be produced through electrolysis which would not result in the issue of storing captured carbon.

4.7.1 Hydrogen blending

There is no projected hydrogen blending within the gas distribution network in any of the four National Grid FES 2018 scenarios by 2035.

In the **Hybrid Accelerator** scenario, a modest amount of low-carbon hydrogen blending is projected within a limited number of urban GSAs within the Wales LDZs. In this scenario, 12-20% blending by volume (4-7% by energy) has been projected in the major urban areas of Wales, mirroring the potential areas for hydrogen conversion detailed within the H21 North of England[56] and HyNet[57] projects. This scenario anticipates the deployment of some hydrogen compliant infrastructure in larger urban areas leading to more widespread hydrogen conversion post-2035. In the **Two Degrees** scenario, a small amount of blending occurs in the industrial cluster areas. In terms of total energy, this level of local injection represents 2% of the total energy delivered by the WWU Wales distribution network in 2035 under the **Hybrid Accelerator** scenario, and 1% of energy delivered under **Two Degrees**.

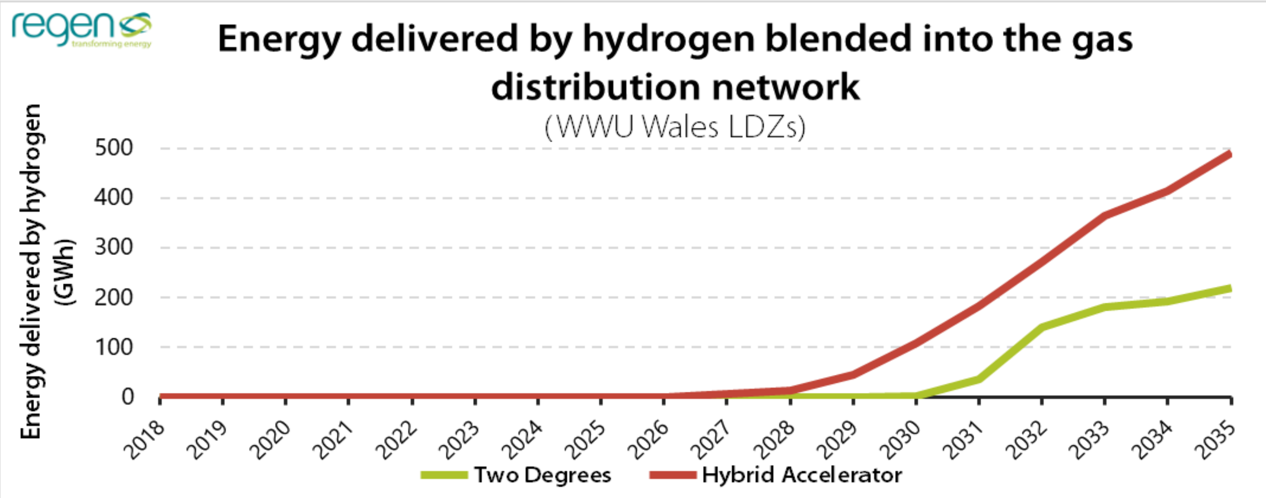

Figure 77: Blended hydrogen energy delivered by the WWU Wales gas distribution network out to 2035 by scenario

[56] H21 North of England report: https://northerngasnetworks.co.uk/h21-noe/H21-NoE-23Nov18-v1.0.pdf
[57] HyNet North West project report: https://hynet.co.uk/app/uploads/2018/05/14368_CADENT_PROJECT_REPORT_AMENDED_v22105.pdf

4.7.2 Hydrogen networks

Networks of 100% low-carbon hydrogen replacing the existing mains gas network could become a significant energy vector for the decarbonisation of heat, as explored in the **Two Degrees** FES scenario in the period beyond 2030.

The timeframe outlined by existing projects, such as H21 and HyNet, envisage a region-by-region conversion to hydrogen networks starting in the north of England from in the late 2020s and early 2030s. Conversion of regions in Wales such as the Cardiff metropolitan area would be expected to occur in the late 2030s and early 2040s under the **Two Degrees** scenario. Therefore, the WWU Wales gas network area analysis has not projected to contain any significant domestic hydrogen networks under any of the five scenarios, in the assessment timeframe of 2018 to 2035. However, as detailed in Section 4.4, a small number of high-demand industrial gas users have been modelled as converting to hydrogen under the **Two Degrees** scenario.

4.7.3 Demand for gas for the production of hydrogen

Production of hydrogen through reformation of methane is a potential source of demand in the Wales LDZs. There are two tiers of natural gas demand for hydrogen: small-scale hydrogen production for chemical processes, and large-scale hydrogen production for 100% hydrogen gas networks, such as industrial clusters. The hydrogen industrial clusters detailed in Section 4.4 are likely to see autothermal reformation of methane sourced directly from the gas transmission network, and as such do not represent a demand on the gas distribution network. Small-scale operation of SMR for chemical processes is assumed to be included within the demand projections of commercial and industrial gas demand.

4.8 Unconventional natural gas supply

Unconventional sources of natural gas, such as shale gas and coal bed methane, have potential to inject into the WWU gas distribution network. There are currently no unconventional natural gas connections in the Wales LDZs.

In terms of potential future supply, no unconventional natural gas injection connections have been projected under any of the five scenarios. While there are 13 active Petroleum Exploration and Development Licences (PEDLs) Wales, the lack of evidenced resource assessment, planning activity or firm customer connection enquiries suggests that it is unlikely that distribution-level injection will result from these PEDLs under any scenario within the assessment timeframe. Furthermore, emphatic Welsh Government policy on fossil fuel extraction denies any new petroleum licencing in Wales, and subjects existing licences to Welsh planning policy, which “has placed fossil fuels as the least favoured fuel in the energy hierarchy”.[58]

[58] https://gov.wales/written-statement-petroleum-extraction-policy-statement