WPD INNOVATION
Transforming the electricity network

Net Zero South Wales

NIA Project Closedown Report

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1. Executive Summary

The UK energy system is going through a significant transition as it moves towards a more decentralised and net-zero carbon energy system. Renewable and other low-carbon technologies are expected to dominate the future system, which will also feature widespread “smarter” new technologies.

Already the growth of decentralised electricity generation has led to local and regional network constraints, meaning electricity network operators have needed to become more proactive and sophisticated in how they plan for, and manage, future network connections.

The project aimed to develop a process and methodology by which both gas and electricity network operators can conduct local level joint scenario planning in a region or licence area. This would include identifying shared definitions and building shared operational understanding, geographical areas, approaches to assessing the evolution of energy generation and supply, along with changes in demand and flexibility. In addition, the impacts of a set of net zero carbon pathways on the distribution network, within a single licence area (South Wales) was sought to be understood.

The project successfully met its aims and developed a methodology, and an associated dataset or South Wales. The methodology was taken forward in the WPD Distributed Futures Energy Scenrios (DFES) 2020. This implementation included the recommendation for greater spatial granularity (In WPD DFES 2020 over 3,000 small areas were assessed), and based on project learnings the number of technologies assessed was expanded - multiple low carbon heating technologies were assessed, as well as a full picture of waste treatment processes, including the potential for biomethane development.

2. Project Background

Energy networks are fundamental to our energy system, delivering energy from where it originates to where it is needed. The UK's commitment to net zero by 2050 means that in 30 years' time little or no unabated fossil fuels can be burnt for energy. Removing the fuels which have been fundamental to our economy for over 100 years is a truly seismic change that will reinvent our relationship with energy.

Both the electricity and gas networks need to understand and plan for how this transformational change will impact their operations in the short, medium, and longer term. These changes include:

- The decarbonisation of heat and transport.
- The increase in renewable generation at all scales.
- The production, supply and use of low carbon gases such as hydrogen and biomethane.

However, developing a local understanding of the future decarbonisation pathway is not straight-forward. Although all regions of the UK will contribute to the net zero targets, it is clear that not all regions will support the same technologies, pathways, or degrees of change. It is therefore important to rationalise the UK's net zero targets, technology pathways and future energy demand considerations, with the realities of the network, resources, politics and geographic features within regions across the UK.

In addition, although there is some continuing uncertainty about how net zero will be delivered in the UK, it is clear that an efficient future energy system will need to be increasingly flexible and cross-vector, dynamically converting energy for use as power, heat and transport fuel as required. Therefore strategic network modelling that does not take cross vector impacts into account may overestimate the demand on each network.

A net zero system is likely to need a significant increase in technologies that are system reactive and designed to directly utilise both the gas and electricity networks. This includes gas network fuelled power generation, hydrogen electrolysis, hybrid heating systems and bio-energy.

Regen along with Wales and West Utilities (WWU) and Western Power Distribution (WPD) have completed an integrated net zero DFES analysis in South Wales. The analysis has explored three scenario pathways to 2050 to explore what the future could look like in the region and develop a methodology that can be used for future integrated DFES analysis.

The main output of the project is a DFES projection dataset provided to WPD and WWU to inform network planning and investment. The dataset covers key technologies, both demand and supply, that might be expected to connect to the gas and electricity distribution networks under three scenario pathways to 2050. This dataset is accompanied by a 'Dataset Companion Report' which explains the assumptions and explores insights into how South Wales might transition to a net zero future. These can be downloaded from: https://www.regen.co.uk/publications/net-zero-south-wales/

3. Scope and Objectives

The Net Zero South Wales 2050 innovation project was undertaken as a partnership between Regen, WPD and WWU with funding from the Network Innovation Allowance (NIA) programme.

The main objective of the project was to create integrated distribution future energy scenarios for the gas and electricity distribution networks in South Wales and, as part of this, to develop a new methodology for conducting cross-vector scenario forecasting at a regional level.

The project had the following innovation objectives:

Table 3-1: Status of project objectives

Objective	Status
Work to align and harmonise gas and electricity DFES modelling to produce new scenario processes and a clear methodology for regional cross-vector scenarios and network planning.	✓
Review how existing and single vector DFES assessments are currently produced, to allow for an improved cross-vector alignment of the results.	✓
Develop shared understanding of the increase in deployment, operation and role of disruptive technologies that affect both networks.	✓

4. Success Criteria

The project had the following success criteria:

Table 4-1: Status of project success criteria

Success Criteria	Status
The project will be successful if it produces learning about the operation and network impact of cross-vector technologies. This will be evidenced through a net-zero cross vector methodology that will be developed through the project and disseminated to other GDNOs and DNOs.	✓
The project will be successful if the results of the analysis, the dataset and companion report, are used to inform National Grid’s transmission and distribution study in South Wales.	✓

5. Details of the Work Carried Out

The main objective of the project was to create integrated Distribution Future Energy Scenarios (DFES) for the gas and electricity networks in South Wales and, as part of process, to develop a new methodology for conducting cross-vector scenario forecasting at a regional level.

The project also looked to provide insights into how South Wales might transition to a net zero future under three net zero scenario pathways:

- High Electrification,
- Core Hydrogen, and
- High Hydrogen.

The details of these scenarios are given in Figure 5-5: Summary of scenario assumptions and approaches by sector

A shared scenario approach is expected to aid understanding of the impacts of net zero on the two networks, and the local approaches and investments that might be required to achieve the scenario pathways.

The main output of the project is a DFES projection dataset provided to WPD and WWU to inform network planning and investment. The dataset covers key technologies, both demand and supply, that might be expected to connect to the gas and electricity distribution networks under the three scenario pathways. The data covers each year from 2020 to 2035 and then five yearly intervals between 2035 and 2050. Projections are provided at geographic levels relevant to each respective network, these have been defined as Electricity Supply Areas (ESAs) and Gas Supply Areas (GSAs).

Regen has been working since 2015 with WPD to produce DFES projections of short and medium-term capacity growth of new and disruptive technologies connecting in their four licence areas. The DFES projections can be viewed on an interactive map on WPD's website. This analysis has been used by the DNO to identify areas where network constraints may be triggered and therefore in need of strategic network investment or a non-network flexibility solution[1]. In 2019, Regen worked with WWU to develop equivalent gas distribution network scenarios to 2035[2].

The first step in the analysis was to merge and consolidate the approaches developed for previous single network (electricity and gas) scenarios conducted for both WPD and WWU in 2018 and 2019 respectively. It also extrapolated medium-term scenarios from 2035 to 2050 net zero outcomes for South Wales, using trajectory and milestone analysis.

In order to maximise the learning, the analysis also developed an illustrative simulated day's analysis (see section 5.6) to illustrate demand and supply over two typical summer and winter days, using typical demand profiles and design demand factors used by WWU and WPD network planners. The resulting methodology and approach are explained in more detail in the sections below.

Table 5-1 Source DFES analysis by sector

Net zero sector models	Source DFES (to 2035)
Gas and diesel generation	WWU & WPD
Domestic and non-domestic heat	WWU
Industrial processes	WWU
Transport and electric vehicles	WPD & WWU
Waste and bioenergy technologies	WPD & WWU
Renewable energy	WPD
Electricity storage	WPD

1 https://www.westernpower.co.uk/smarter-networks/network-strategy/strategic-investment-options-shaping-subtransmission
2 https://www.regen.co.uk/project/wales-and-west-utilities-regional-growth-scenarios-for-gas/

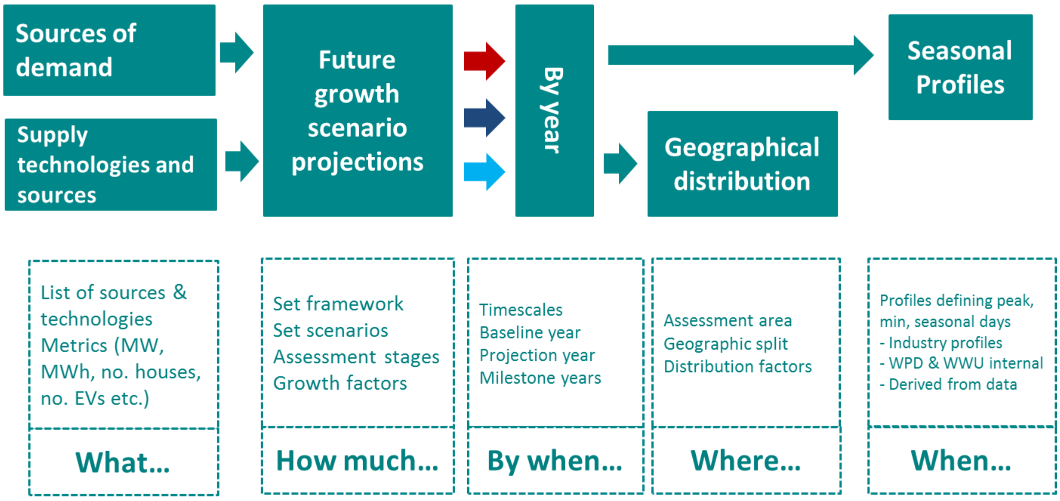


Figure 5-1 Overview of high level DFES phases

5.1. Framing the analysis outputs and inputs

Although the cross-vector approach covered both sources of distribution demand and distribution energy supply in the South Wales region, the analysis did not attempt to match demand and supply of energy in South Wales at a distribution level. The supply of energy was constrained by an assessment of likely local resource, however no constraint was put on the use of energy in whatever vector as a result of local availability. The results do however note the proportion of energy or gas use that is produced locally.

Energy use in scope

All connections to the gas and electricity distribution network were included in the scope of the projections, with the exception of electricity demand for existing domestic and non-domestic customers not related to heat or transport, such as appliances and lighting. This element was not in scope for previous DFES studies for WPD. However in order to collate the projections into a full distribution model, basic assumptions on the trajectory for underlying (non-heat) electricity demand were made using FES 2019 trajectories to 2050.

The scope of the study did not include connections at the gas and electricity transmission level such as Pembroke Power Station. It also did not include energy uses which are not on the distribution gas or electricity network, such as use of coal for industrial processes or fuel use for aviation and shipping. Where off-network energy use has been important for the modelling, such as petrol and diesel consumption for road transport, or Bio-LPG for off gas homes, this has been included.

Capacity factors

The single vector DFES studies produced outputs that were relevant for either electricity or gas distribution networks. The cross-vector analysis meant that these outputs needed to be made comparable across the energy vectors. In practice this meant an additional step in the analysis converting connection capacities usually specified in megawatt (MW) of capacity into a measure of energy generated in megawatt hours (MWh). This was particularly important for cross-vector technologies such as anaerobic digestion where the biogas could either be injected into the gas network or burnt to produce electricity.

As a result, the capacity factors for each technology became of primary importance. Where metered data was available, capacity factors were directly derived. Where actual factors were not available, the project also used FES 2019 factors for Community Renewables scenario where available. BEIS capacity factors[3] were used where the FES data was not available or insufficiently granular.

[3] BEIS source: https://www.gov.uk/government/collections/renewables-statistics

Flexible and cross-vector technologies

Technology	Gas demand	Electricity demand	Gas supply	Electricity supply
Gas fired generation	✓			✓
Hydrogen electrolysis		✓	✓	
Battery electric storage		✓		✓
Hybrid heat pumps	✓	✓		
Waste and bioenergy			✓	✓

Figure 5-2 Illustration of analysis framing with cross-vector and flexible technologies

5.2. Geographic analysis - merging gas and electricity supply areas

A key challenge for the project was to define a set of geographical areas for spatial analysis that would be relevant for both the gas and electricity networks in South Wales. In addition, the project sought to produce analysis that would also be useful for local authorities, city regions and other key stakeholders who might have a different geographical view of the data.

Though the WWU and WPD network areas predominately overlap, small sections on the east of the region are in the WWU South Wales network area but are in the WPD West Midlands licence area. There is also a larger area to the north which is part of WPD South Wales licence area but is part of WWU North Wales gas network area.

To deal with this the analysis covered the 'greater' South Wales region, but the results have been presented to the networks covering only their defined South Wales network areas.

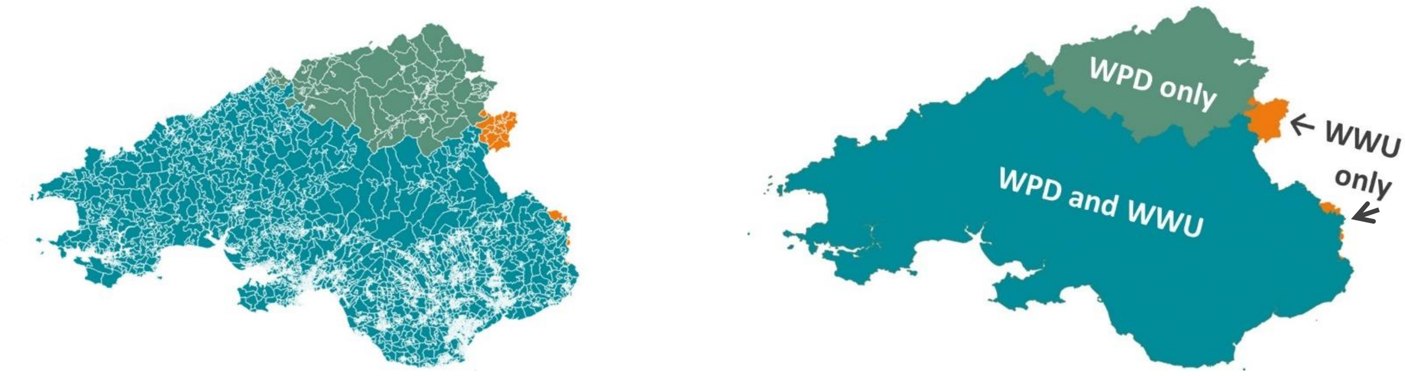


Figure 5-3 The two network areas in South Wales and output areas

The scenarios information is presented to WPD and WWU as a dataset broken down into either Electricity Supply Areas in the region or Gas Supply Areas.

These areas are defined as geographic areas served by the same network infrastructure. Regen, WPD and WWU have created these by mapping geographical data onto network points, linepack zones and local authority boundaries using Geographic Information System (GIS) software.

- There are 24 GSAs across WWU's South Wales network area which combines three gas linepack zones with local authority boundaries.
- There are 56 ESAs across WPD South Wales licence area, these are based on Bulk Supply Point substations. This has since been extended to approximately 380 ESAs based on Primary Substations

In order to produce the information at different geographic levels, the analysis has been disaggregated to Output Area Classification (OAC). These are the smallest units for census data and cover approximately 125 households. This level of granularity allows the scenarios analysis to be aggregated to either ESA, GSA, or to LSOA and local authority, as required.

Further complexities for the combined studies included situations where some connections were distribution connected for gas but connected to electricity transmission, for example CCGT plants and potentially for future technologies such as hydrogen electrolysis sites. This was dealt with by developing specific 'gas only' output areas for power station and CCGT sites, ensuring this would only be included in the gas network output data, in a similar fashion to the output areas only in one of the two network's South Wales distribution areas.

5.3. Process for developing net zero scenarios

The DFES development used a bottom-up process that prioritises stakeholder and local factors to identify an envelope of possible futures within a region. The projections are built up from;

- The existing baseline of technologies and demand sources connected to the local networks;
- Near term pipeline projections developed using the pipeline of new applications for network connections; and
- Local authority planning information such as new housing or commercial developments as well as local and regional planning applications for energy projects.

Longer term scenario projections were then developed for each scenario which incorporate factors including energy resources, geographical and land-use factors, historic growth and investment, regional policies and socio-economic factors.
The analysis undertaken for each technology and sector involved the following stages illustrated in Figure 5-4 .

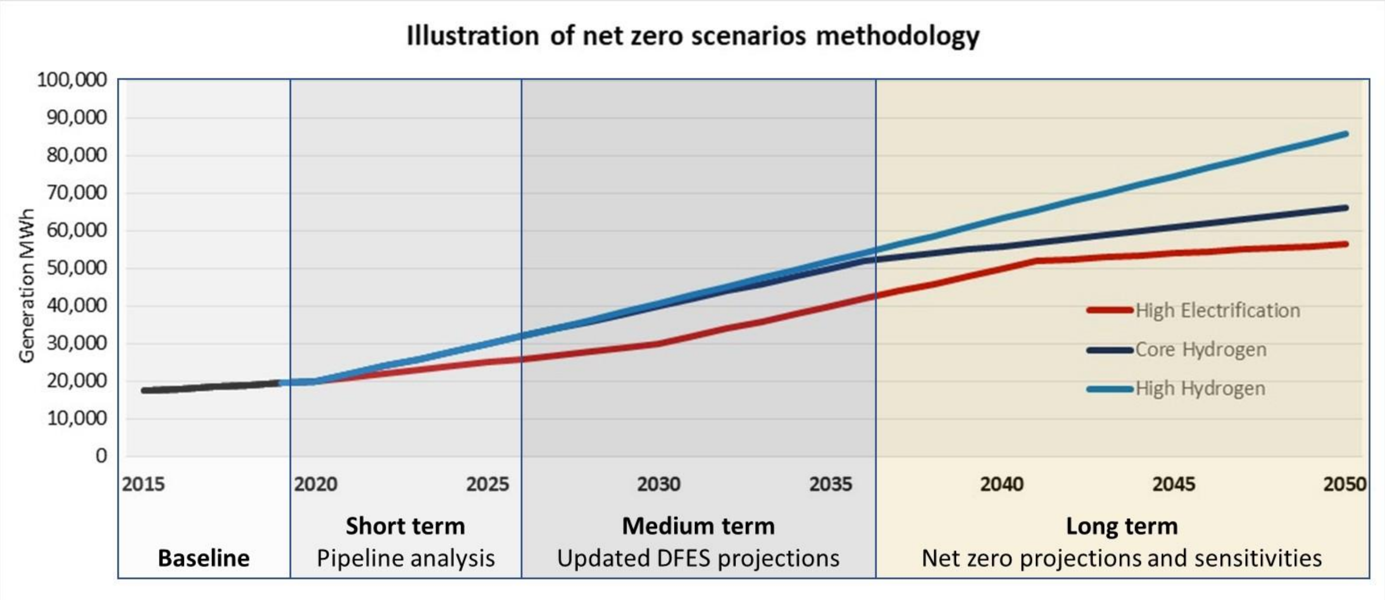


Figure 5-4 Summary of scenario methodology

Stage 1: Baseline

Technology baselines for installed electrical and injection capacity were calculated from WPD and WWUs network connection databases. This identified historic 'high' installation levels as well as historic trajectories that steer future growth.

This information was then reconciled with Regen's project database and further desktop research was undertaken to address any identified inconsistencies.

Stage 2: Short-term pipeline – 2020 to 2025

The short-term projections were driven, where possible, by projects with network connections which have been accepted by the networks but are not yet connected. The pipeline connection database from WPD and WWU was then reconciled and augmented with data from the Renewable Energy Planning Database[4], Department for Transport, ONS and other relevant data sources, along with telephone and internet research and understanding of the current market conditions and the net zero trajectories. The project also used analysis and stakeholder engagement recently undertaken for the Welsh Government and the development of regional energy strategies.

[4] See: https://data.gov.uk/dataset/a5b0ed13-c960-49ce-b1f6-3a6bbe0db1b7/renewable-energy-planning-database-repd

This allowed an assessment of which projects may go ahead and on what short term timescale. The domestic scale generation and demand technologies do not have a pipeline because they do not require a connection agreement.

Stage 3: Medium term – 2025 to 2035

The medium term projections were steered primarily by the earlier separate DFES analysis completed for WPD and WWU where stakeholder engagement helped build credible medium term trajectories. These existing projections were updated for the most recent information and then merged.

In addition, locational data from various data sources and GIS analysis was used to understand the geographical distribution, local attributes, constraints and potential for technologies to develop within the region in the next 15 years.

Stage 4: Long term – 2035 to 2050

The long term stage was an additional stage developed for this analysis as it extended 15-18 years further than the DFESs previously developed for WPD and WWU. Long term projections required a further bottom-up assessment of maximum potential of certain key technologies and sectors based on local resource, geography and other trends. For example, the amount of household waste produced provides a theoretical maximum for Energy from Waste or syngas generation and the trajectory to 2050 needs to account for significant expected declines in residual waste production over time.

A process of defining the optimum potential was calculated for each technology and steered the total generation and capacity expected by 2050. As well as referring to trajectories in FES 2019 sensitivity and Committee on Climate Change, the project also collated and reviewed stakeholder feedback from both WPD and WWU regional assessments, with specific relevance to future net zero trajectories

5.4. Technologies and sectors

This project presents credible scenarios for the potential changes in technology installations, use and take-up that have an impact on the electricity and gas distribution networks between 2020 and 2050 in the South Wales region.

Covering both electricity and gas networks within the DFES, as well as producing a representative day analysis, meant that the envelope of technologies needed to be larger than those analysed for each individual network. In order to complete a full analysis, the projections needed to cover the whole of energy use at distribution network level rather than the individual technologies that impact one network or another. For example, it was necessary to analyse the heat sector as a whole rather than covering individual heat technologies such as heat pumps or electric heat in isolation.

A 2050 scenario timeline also meant new technologies were needed to reflect the shift to hydrogen, or other low carbon gas. These included both demand from heating or peaking generation and hydrogen electrolysis.

Figure 5-5 summarises the sectors and technologies covered in the analysis and modelling along with assumptions made in the three scenarios. This illustrates that there are a number of shared assumptions across the scenarios, such as renewable generation and some waste technologies.

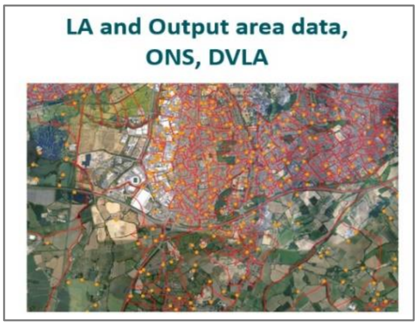
Sector	Sub-sector	High Electrification	Core Hydrogen	High Hydrogen
Renewable generation	Onshore wind, solar and hydropower	Distribution resource potential is maximised as per Welsh Energy Strategy. Broadly aligned to FES 2019 Community Renewables.		
Heat	Existing off gas grid - Domestic and commercial	Majority electrified earlier than on gas. By 2025 low carbon alternatives are more attractive than off-gas fossil fuels		
Heat	Existing on gas grid - Domestic and commercial	Majority electrified with higher number of heat networks and small domestic biomethane networks. By 2030 low carbon alternatives are more attractive than gas and boilers are replaced at an increasing rate due to incentives.	A hydrogen network replaces gas network in core urban areas between 2040 and 2045 covering c. 57% of existing connections. Properties outside the hydrogen network are mainly electrified with a small number of domestic biomethane neworks	Hydrogen replaces the majority of the gas network between 2045 and 2050. The majority of heating is provided by hydrogen boilers with a small number of hydrogen hybrid systems installed.
Gas fired power	Natural gas generation	Small number of industrial sites have natural gas supply with CCUS by 2050.	No fossil fuels generation at distribution network level by 2050 (all hydrogen & green gas).	
Gas fired power	Distribution gas fired capacity trajectory	Investment and replacement slows from 2035	Investment and replacement slows from 2030.	
Gas fired power	Future of CCGT (electricity transmission but gas distribution)	CCGT plant remains generating using natural gas with CCUS.		
Gas fired power	Flexibility and peaking	No unabated fossil peaking generation at distribution by 2050. A few gas fired peaking with CCUs at industrial sites.	No unabated fossil peaking generation at distribution by 2045. Small hydrogen peaking plant growth at industrial sites.	
Industrial usage	Large-scale industrial cluster sites	Largest consumers and sites that cannot be electrified switch to hydrogen, remainder are electrified or install carbon capture and storage.	Majority of gas-fired processes switch to hydrogen, combined with process efficiencies to mitigate increased cost.	
Industrial usage		Cluster begins to develop in late-2030s and is limited to the largest consumers of natural gas.	Cluster begins to develop in mid-2030s around core anchor loads, expanding throughout the 2040s.	
Hydrogen electrolysis	Hydrogen manufacturing	Electrolysis produces hydrogen in industrial cluster areas using 16% of renewable generation. SMR assumed to be gas transmission connected.	Electrolysis produces hydrogen in industrial cluster areas using 32% of renewable generation SMR assumed to be gas transmission connected.	
Transport	Light and domestic vehicles	Fully electrified		
	Light goods vehicles	Near-fully electrified	Mainly electric, ~10% hydrogen	
Transport	Heavy goods vehicles	~70/10/20 hydrogen/green gas/electrified	~80/10/10 hydrogen/green gas/electrified	
Transport	Buses and coaches	~15/5/80 hydrogen/green gas/electrified	~25/5/70 hydrogen/green gas/electrified	
Bio Energy	Anaerobic digestion	Capacity is higher than High Hydrogen due to higher value of biomethane. Three additional plants provide biomethane for local networks.		Capacity increases over time and maximise export of biomethane with network injection where possible.
Bio Energy	Biomass	No new capacity on distribution network in south Wales. Existing sites remain generating electricity		
Waste	Energy from Waste (incineration)	Incineration capacity reduces to zero by 2050.		
Waste	Energy from Waste (ACT)	Sites run to maximise export of syngas and injection where possible.		
Waste	Landfill gas	Capacity reduces over time linked to the reduction seen in FES 2019.		
Waste	Sewage	Maximise biomethane export over electricity		
Battery storage	Storage capacity	More required due to more peaking required due to heat electrification.	Less required at distribution due to hydrogen heating and industrial demand served by hydrogen.	
Battery storage	Technology type	Batteries only – alternative technologies not viable on distribution network in South Wales. Energy to power ratio taken from FES 2019		

Figure 5-5: Summary of scenario assumptions and approaches by sector

NB: This work was carried out before the legal changes banning new gas boilers in new build homes after 2025.

5.5. Geographical distribution

Once regional projections were made for increased capacity or installation numbers, these projections were then distributed to Output Area Classification (OAC) level. Each relevant technology was analysed to understand the factors impacting likely future deployment locations, through:



- **Baseline geography** – where existing capacity or currently installations were expected to have a greater impact in the short and medium term. For example, electric vehicle registrations are correlated with affluent households with off-street parking.
- **Pipeline trends** – pipeline location is used mainly for generation technologies that have sites identified by WPD that were expected to connect in the short term.
- **Planning evidence and portals** – Planning information is analysed for potential sites and locations for generation technologies. This includes current sites in planning that may not yet be in WPD's connection data but also previous rejected or abandoned sites which are likely to have good resource and potential for growth in the medium and long term.
- **Previous stakeholder engagement events** – evidence gained from stakeholder engagement events for both WPD and WWU DFES was used to understand locational drivers and geographical constraints in South Wales network areas.
- **Direct engagement with stakeholders** – this includes both conversations with developers for pipeline generation sites or sites in planning and other relevant stakeholders such as Welsh Water for plans for sewage plants and industrial cluster members for decarbonisation plans for Port Talbot for example.
- **Local plan data** – to understand locations for new developments for commercial and domestic sites, consultation is undertaken with local authorities directly as well as local plan information and supporting documents. These sites are expected to be higher for new technology installations.
- **Datasets** – demographic, socio economic and geographical data by OAC is used including MCS, census, AddressBase, GIS and others.

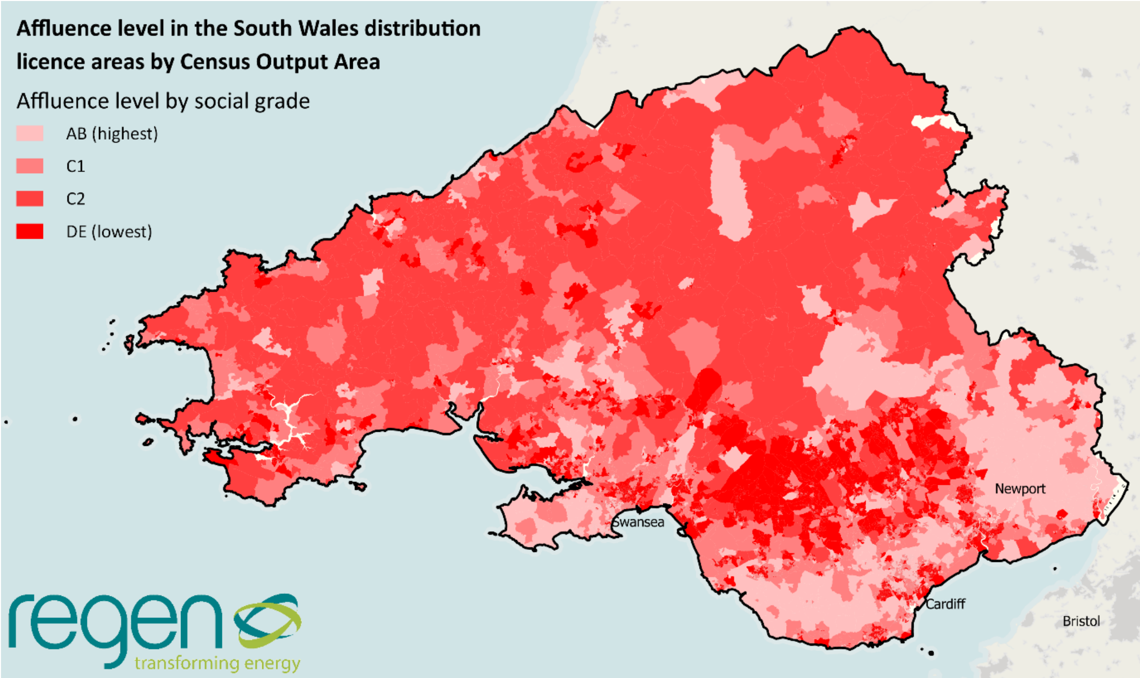


Figure 5-6: Affluence, based on NRS Social Grade, in South Wales at Output Area Classification level

- **Assumptions detailed in the National Grid FES** – modelling assumptions that are detailed in the National Grid FES, such as the types of housing most suited for different low carbon heating technologies.

The above factors, along with desk based research was used to characterise each geographical area. This was then inputted into Regen's Distributor model to calculate the potential uptake of each technology in each area by scenario pathway.

This was then collated by GSA and ESA to create scenarios for analysis by the distribution networks.

Figure 5-7 Example of Address base data

5.6. Seasonal day methodology

A simulated day analysis was completed as part of the study to build further understanding and learning on how the scenarios might impact the electricity and gas distribution networks in South Wales. For this, demand and generation (e.g. distributed electricity generation and distributed gas entry) was modelled on a simulated baseline summer and winter day and equivalent seasonal days in 2035 and 2050, for each scenario. The methodology for this analysis is outlined below.

An initial consideration was that each network has their own methodology to model and identify potential stress periods on their networks. These methodologies and approaches differ as a result of the very different nature of the energy vectors and infrastructure involved. This project did not attempt to replicate the critical planning processes for either network. Instead the project worked to define two simulated seasonal days on the energy networks using a combined set of existing demand and generation profiles including those used by WPD and WWU network planners to build a shared understanding between the networks.

The modelling sought to illustrate what future seasonal day energy demand and distributed generation would look like on the gas and electricity networks, with known existing profiles applied. The modelling therefore simulated future demand without future behaviour change, time of use tariffs, smart EV charging or more sophisticated heating control systems applied to the profiles. How the two seasonal days were defined is outlined in Table 5-2.

Table 5-2 Energy characteristics of simulated seasonal days

Simulated summer day	Simulated winter day
High solar generation	Low solar generation
Medium/Low wind generation	High wind generation
Gas generation variable / flexible operation	
Other thermal generation assumed to have flat 100% output	
Heating demand assumed to be zero (some underlying hot water demand)	Heating demand assumed to be high (moderately higher hot water demand)
Fairly generic diversified EV charging profile (not reflecting smart charging)	
Seasonally reflective industrial demand	

By modelling these two seasonal days on the networks, it was possible to assess the potential intra-day flows of energy (distributed supply and demand), as well as determining illustrative intra-day supply and demand maximum periods on both networks. Note that the demand from distribution connected CCGT plant was not included in the gas demand profiles, as this site exports to the electricity transmission network and was therefore deemed out of scope for the purpose of this as a distribution network assessment.

The scenario projections of growth in connected capacity of generation technologies, electricity storage and various sources of gas and electricity demand were applied their equivalent seasonal day profiles shown in

Table 5-3.

Whilst some profiles were adjusted for 2035 and 2050 (e.g. fuel conversion efficiency improvements for heating technologies or increased capacity factors etc.), the majority of the load profiles remained unchanged, and thus did not reflect more significant changes in behaviour or incentives that may shift demand or generation into different times of day. Developing more reflective future profiles for sources of demand, storage and flexible generation technologies that can be applied to DFES projections, is an area that would benefit from further analysis, engagement, and development. Some work in this area has taken place as part of the EPIC NIA project which is building on the learning from this project.

5.6.1. Detailed seasonal day methodology

The method outlined in Figure 5-8 was adopted to assess and model seasonal days on the networks:

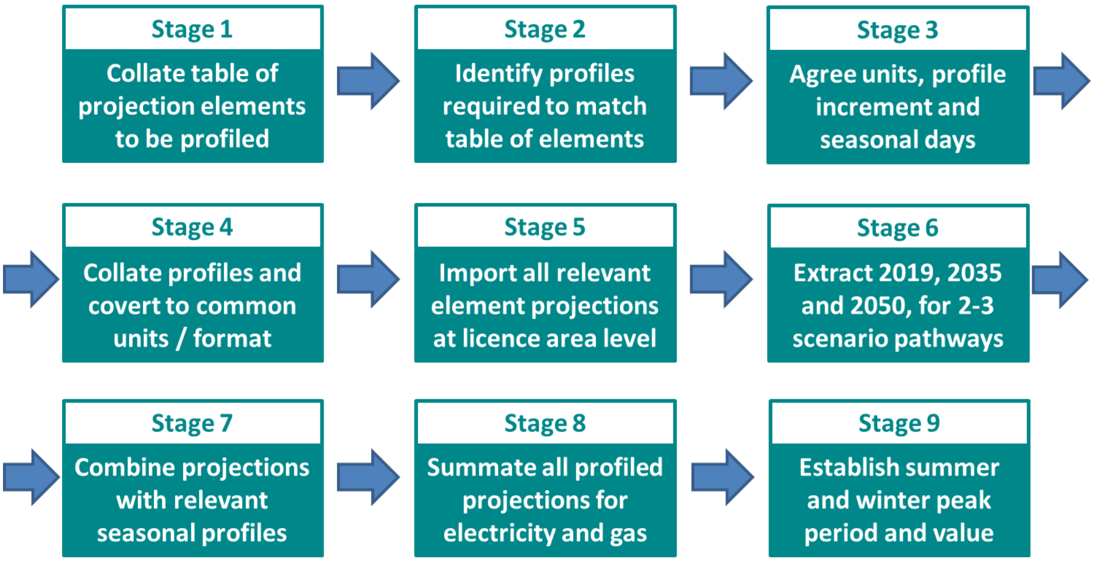
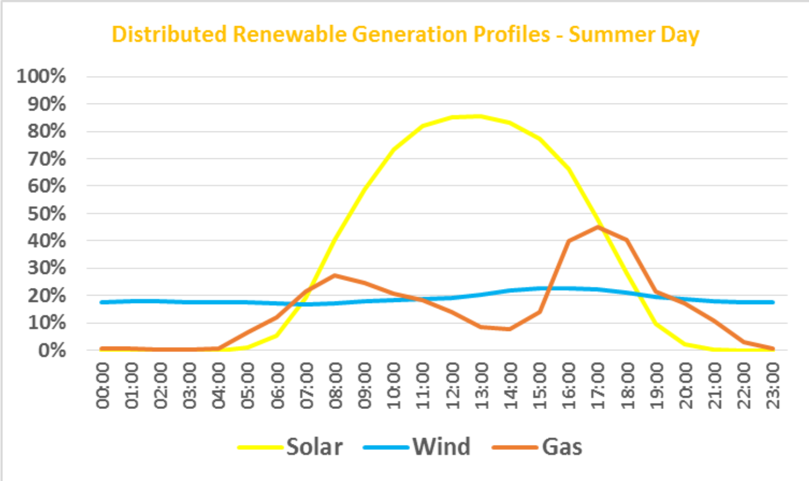
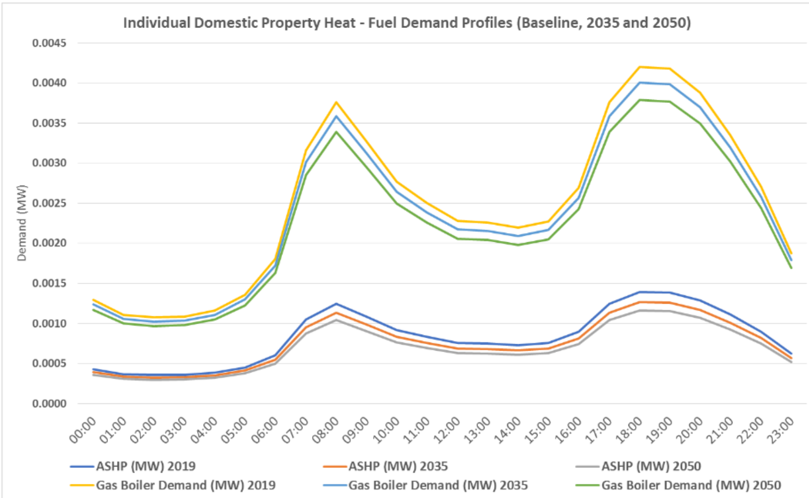


Figure 5-8 Seasonal day profiling methodology at a high level

For each stage, a summary of the approach can be described as follows:

Profiling method stage		Summary of approach / outcome
1	**Collate table of projection elements to be profiled**	The first stage of the analysis was to understand what projections needed to be profiled and what metrics to use. These were: **Electricity network elements:** • All distributed electricity generation technologies • All electricity storage asset classes (import and export) • Underlying domestic electricity demand • Electricity fuelled domestic heat demand • Underlying non-domestic (C&I) electricity demand • Electricity fuelled non-domestic heat demand • Electric vehicle charging demand **Gas network elements** • Distributed biomethane gas injection • Gas fuelled domestic heat demand • Gas fuelled non-domestic heat demand • Gas demand for gas fired electricity generation (not including distribution connected CCGT) • Gas fuelled industrial process demand • Gas vehicle fuelling demand
2	**Identify profiles required to match table of elements**	Regen was provided with a number of pre-defined typical profiles from WPD and WWU, ranging from seasonal renewables profiles, diversified EV and heat demand profiles, heat technology profiles (boiler and heat pumps) and underlying domestic and commercial demand. A number of other profiles were also derived based on operational data provided by WWU, including industrial gas use (categorised by industry sectors), hybrid heating 'switching' profiles, as well as samples of biomethane injection and gas fired generation operational data.

<table>
<tr><td>3</td><td>Agree units, profile increment and days</td><td>The profiles were unified to be 24 x hourly increments.
The profile units were also unified to be % if the element projections were in MW or equated to MW if the element projections were dimensionless (e.g. no. properties or no. EVs etc.)</td></tr>
<tr><td>4</td><td>Collate profiles and covert to common units / format</td><td>A modelling spreadsheet was developed to capture all key demand, storage charge/discharge and generation profiles, examples below:



</td></tr>
<tr><td>5</td><td>Import all relevant element projections at licence area level</td><td rowspan="2">The cumulative total licence area level projections for all elements listed in stage 1 were collated for the three snapshot years, 2019, 2035 and 2050 and under all three scenarios (High Electrification, Core Hydrogen and High Hydrogen), totalling some 620 snapshot projections used in the seasonal day profiling.</td></tr>
<tr><td>6</td><td>Extract 2019, 2035 and 2050 projections for 2-3 scenario pathways</td></tr>
<tr><td>7</td><td>Combine projections with relevant seasonal profiles</td><td>In order to combine the profiles identified in stage 4 with the projections, some elements first required future efficiency gains to be applied e.g. generation technology conversion efficiency, industrial process efficiencies or heat technology fuel efficiency. Once these were applied, the projections in each snapshot year, for each scenario, were multiplied by their equivalent summer</td></tr>
</table>

8	**Summate all profiled projections for electricity and gas**	and winter seasonal profiles to create a set of 72 individual aggregated profiles. These aggregated profiles were collated into 4 categories: • Distributed electricity generation • Distribution network electricity demand • Distribution network gas injection • Distribution network gas demand
9	**Establish the winter and summer maximum periods on both networks**	Analysis was undertaken to determine the maximum period (hour) and maximum value (MW) on both networks in all years and scenarios, for the four aggregated categories identified in stage 8. The variance between the two networks and between the years was assessed, to determine an energy vector balance in the region. The summation of the seasonal maximum values on both networks was also identified to provide an indication of total seasonal day demand across the energy system at distribution network level.

5.6.2. Seasonal day profiling sources

Developing profiles that could provide a valuable indicative seasonal day analysis has been a challenging area for the project. Though there were profiles available that described technology behaviours seen on the networks today, a key issue is that some of these profiles will likely become less representative of 2035 and 2050 behaviours. As the seasonal days were intended to be an illustrative of the capacity growth projection results, rather than the focus of the study. A further issue was whether the profiles provided were comparable both in metrics, units, intended use and geography.

The nature of gas molecules and electrons has produced a different set of priorities and focus for peak day load analysis. For gas network planners, the key objective is to maintain a daily gas pressure, using the inherent energy storage within the network as an intra-day balancing mechanism, thus gas networks are particularly interested in the peak hour or peak 6 mins within a peak day, with regards to extremity pressures and governor capacity. Whereas electricity network planners are concerned with the instantaneous peak demand (within a time period) that must be balanced by instantaneous generation. Gas profiles therefore tend to focus more on a worst case peak demand day, whereas electricity profiles focus on the worst case, or more accurately the 90th percentile, design demand required for each individual demand period.

As an example, gas network planners would not assume that gas electricity generation peaking plant would be running at full capacity for a full day (48 concurrent half hour periods). Electricity network planners however have to assume that, during a peak day, gas generators could be running at full capacity during any of the 48 half hour periods within the day.

Table 5-3 summarises the source and method to determine the indicative profiles used in the analysis.

Table 5-3 Method to determine indicative seasonal profiles for all key elements

Element	Network	Source of seasonal profiles	
		Baseline (2019)	Future (2035 & 2050)
Renewable generation	Electricity	WPD subtransmission profiles	WPD subtransmission profiles
Thermal generation	Electricity & Gas	WPD subtransmission profiles WWU gas flow data	WPD subtransmission profiles
Battery storage	Electricity	WPD & Regen energy storage operating mode profiles	
Underlying domestic electricity demand	Electricity	WPD subtransmission profiles	WPD subtransmission profiles
Underlying C&I electricity demand	Electricity	WPD subtransmission profiles, augmented by floorspace	WPD subtransmission profiles, augmented by floorspace
Electrically fuelled domestic and non-domestic space heating	Electricity	Base diversified heat demand per property (sourced from WWU pathfinder gas boiler demand), converted to heat technology-specific demand using current conversion efficiencies	Base diversified heat demand per property (sourced from WWU pathfinder gas boiler demand), converted to heat technology-specific demand using future conversion efficiencies projected in 2035 and 2050
Electric vehicle charging	Electricity	WPD ‘Electric Nation’ diversified profile for 7kW battery EVs	

Biomethane injection	Gas	WWU operational flow data (specific to summer and winter)	WWU operational flow data uplifted to higher 'post-commissioning' injection rates
Gas fuelled domestic and non-domestic space heating	Gas	WWU Pathfinder diversified heat demand, converted to gas demand using known average gas boiler efficiency	WWU Pathfinder diversified heat demand, converted to gas demand using future gas / hydrogen boiler conversion efficiencies projected in 2035 and 2050
Gas fired industrial processes	Gas	WWU gas flow data for key industrial sectors	WWU gas flow data for key industrial sectors, augmented with future industrial process efficiencies projected in 2035 and 2050
Gas vehicle fuelling demand	Gas	WWU CNG filling station gas flow data converted to a per vehicle demand using current numbers of gas vehicle classes	

5.6.3. Limitations of the seasonal day modelling

Some of the key limitations of the seasonal day profiling are outlined below. All of these areas would benefit from further analysis and development.

- The project used detailed solar and wind generation profiles, however there were no equivalent dynamic profiles for other low carbon technologies such as hydro, biomass, and electricity from anaerobic digestion. Therefore, these technologies have been assumed to be at 0% or 100% for all periods during the simulated day.
- Battery storage profiles were not adjusted to reflect the longer battery storage duration (e.g. MWh storage capacity) that will evolve out to 2050. Shorter duration battery profiles were therefore used for all three snapshot years.
- Heat technology profiles in 2035 and 2050 were flexed based on an assumed efficiency improvement on 2019 diversified heat demand profiles, in reality smarter controlled heat technologies may affect the profile shape across a winter day in later years. Similarly the impact of energy efficiency measures on the heat demand was not separately applied.
- Non-domestic heat technology profiles were not available, therefore a generic assumption of multiplying the domestic heat technology profiles by ten was applied.
- Underlying electricity demand (domestic and non) profiles reflect a Bulk Supply Point (BSP) level of demand diversification. Licence area level diversity could potentially be different.
- Underlying non-domestic electricity demand profiles includes some direct transmission demand sites that are connected/fed via WPD's distribution network.
- Domestic summer time cooling load from Air Conditioning was applied using an assumed 1% of homes having Air Conditioning taken from the FES 2019 data workbook.
- Non-domestic summer cooling from Air Conditioning was applied using an assumed 12% of commercial properties having Air Conditioning from Regen's analysis of EPC and DEC data.
- Distributed gas fired power generation was only profiled for 2019, as a system reactive technology, the profile for generation behaviour in 2035 and 2050 was felt to be too uncertain. Also the distribution connected CCGT site was not included in the gas fired power generation profiles either as a source of gas demand or electricity generation export.
- The EV charging profiles do not consider significant smart charging adoption in 2035 or 2050.
- The demand and supply from hydrogen electrolysis is not included in this analysis due to lack of available profiles.
- Hybrid heating technologies are treated as a dual-fuel technology, but essentially have two individual heating technology components that are fuelled from each network. The demand for electricity and gas on a winter's day is however highly dependent on a number of key factors that were external to this analysis.
    - The sizing of the heat pump and boiler components of the hybrid heating system
    - The control philosophy that determines when each technology cuts in and out

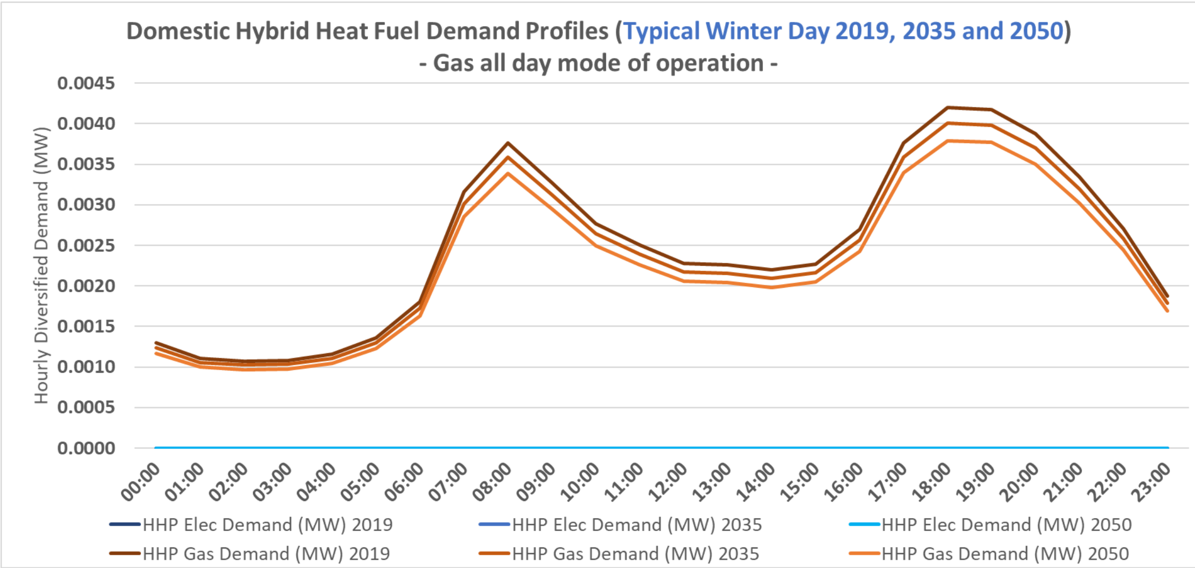
- The thermal efficiency of the home/property with the hybrid heating installed

Two basic diversified profiles were therefore adopted in the seasonal day profile modelling, to provide an indicative view of seasonal day demand on the networks from hybrid heat. These hybrid heat profiles are summarised in Table 5-4 and shown in

Figure 5-9.

Table 5-4 Generic hybrid heating profiles used in seasonal day modelling

Profile	Mode of operation	Description
Hybrid Heat Profile 1	**Gas all day**	The boiler component of the hybrid system provides heat all day due to temperature
Hybrid Heat Profile 2	**Hybrid switcher**	Using a 2kW heat demand threshold, the heat pump component provides any hourly demand below 2kW and the boiler component cuts in to supply heat at 2kW or above



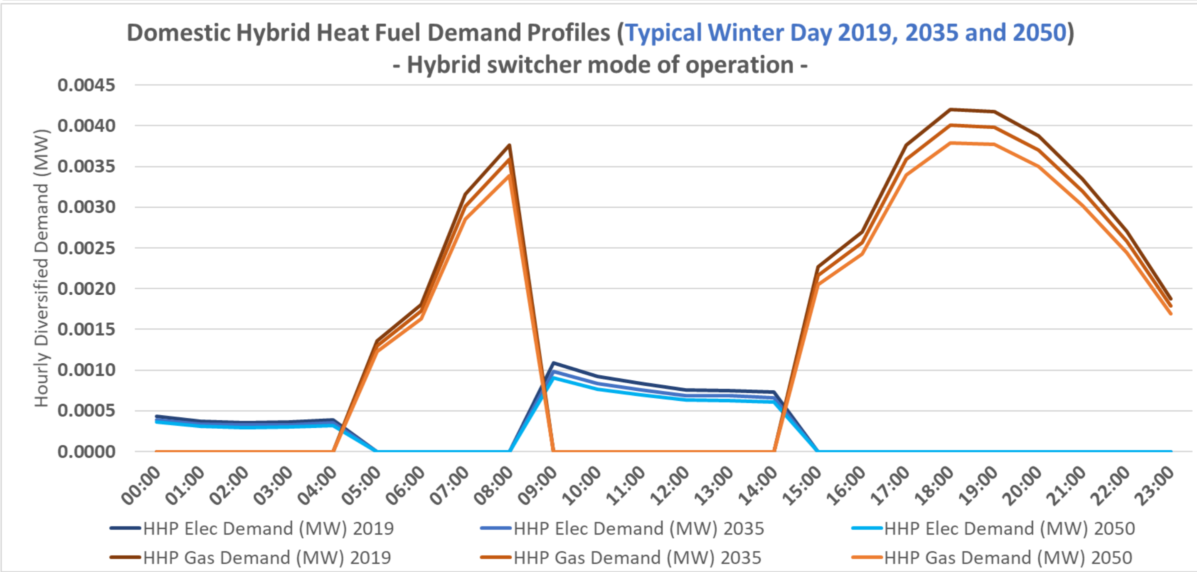


Figure 5-9 Diversified hybrid heat fuel demand profiles used in seasonal day modelling, reflecting several aggregated properties and converted to a single house profile

6. Compared to Original Aims, Objectives and Success Criteria

1. **Production of learning about the operation and network impact of cross-vector technologies. This will be evidenced through a net-zero cross vector methodology that will be developed through the project and disseminated to other GDNOs and DNOs**

   The project produced a 28-page Learning Report[5] containing insights and recommendations on the continued development of whole system energy scenarios. This learning was disseminated to other network operators and wider industry stakeholders over a few online sessions in June and July 2020.

2. **Results of the analysis, the dataset and companion report, are used to inform National Grid's transmission and distribution study in South Wales.**

   The project produced a spreadsheet dataset detailing results of the South Wales 2050 analysis and an 86-page Companion Report[6] which comprehensively details the developed methodology and results. Both of which were used by National Grid's Zero 2050 NIA Project.

[5] See: https://www.westernpower.co.uk/downloads-view/153937
[6] See: https://www.westernpower.co.uk/downloads-view/153943

7. Required Modifications to the Planned Approach during the Course of the Project

There was some disparity between project partner's views on the degree that hydrogen boilers were used in the hydrogen scenario in an early draft of the project learning reports. As such, an additional scenario was created so that there were three: High Electrification Scenario, Core Hydrogen, and a High Hydrogen. The major difference between Core Hydrogen and High Hydrogen is the relative use of hydrogen boilers and hybrid heat pumps.

8. Project Costs

The below are WPD budgets and spends for the Net Zero South Wales project

Table 8-1: Project Spend

Activity	Budget	Actual
NZS - WPD PROJECT MANAGEMENT	£17,752	£14,167
NZS – W&W PROJECT MANAGEMENT	£17,752	£17,166
NZS – WPD CONTRACTOR COSTS	£51,500	£51,500
NZS – W&W CONTRACTOR COSTS	£51,500	£51,500

Comments on variance: WPD Project Management was minorly underspent as less time was required that forecasted.

9. Lessons Learnt for Future Projects

Below are ten key learning insights generated throughout the project. These can be viewing in more detail in the Data Companion Report:

1. There is significant evolution on both networks by 2050.
2. Decentralised energy supply meets an increasing proportion of annual demand.
3. The pathway for decarbonising heat is the most significant variable in distribution net zero analysis.
4. The scenarios have a wider range for distributed gas than distributed electricity.
5. Carbon emissions from heat decline at different times in different scenarios.
6. Distributed hydrogen production via electrolysis is likely to meet only a proportion of hydrogen demand. Further supply will require a strategy for large-scale hydrogen production, storage and transmission in South Wales. This is being investigated by the South Wales Industrial Cluster project.[7]
7. Electricity demand and supply variance increases in both summer and winter, in all scenarios. Local and national balancing is likely to be increasingly important.
8. Biomethane has many valuable uses in a net zero scenario, not least in negative emissions. But with a limited supply, its role needs careful consideration.
9. By 2050, winter day electricity demand doubles in High Electrification, though High Hydrogen has highest total energy demand across both networks.
10. A High Hydrogen hybrid sensitivity has similar levels of hydrogen demand by 2050 as Core Hydrogen. Though winter day demand looks similar to High Hydrogen.

[7] https://www.swic/cymru

10. The Outcomes of the Project

The project had three distinct outcomes:

- The production of a 28-page learning report containing insights and recommendations on the continued development of whole system energy scenarios.
- A spreadsheet dataset detailing results of the South Wales 2050 analysis.
- An 86-page data set Companion Report which comprehensively details the developed methodology and results. Both of which were used by National Grid's Zero 2050 NIA Project.

11. Data Access Details

The dataset generated throughout this project is on the WPD Innovation website[8]
The latest DFES data is available to view and download via the WPD DFES Map[9]

[8] see: https://www.westernpower.co.uk/downloads-view/153946
[9] see: https://www.westernpower.co.uk/smarter-networks/network-strategy/distribution-future-energy-scenarios

12. Foreground IPR

IP generated during this project includes:

- Net Zero South Wales Companion Report
- Net Zero South Wales Learning Report
- Net Zero South Wales Dataset

13. Planned Implementation

Learnings from the NZSW project have been taken forward in the WPD DFES 2020. In WPD DFES 2020 over 3,000 small areas were assessed, incorporating a key recommendation from the innovation study for greater spatial granularity i.e. moving from ESAs based on Bulk Supply Points to Primary Substations.

The WPD DFES results can be directly aggregated up to local authority areas, so that stakeholders or other networks can view results most relevant to them.

The number of technologies assessed was expanded based on learnings from the innovation study. Multiple low carbon heating technologies were assessed, as well as a full picture of waste treatment processes, including the potential for biomethane development.

14. Contact

Further details on this project can be made available from the following points of contact:

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Glossary

Abbreviation	Term
CCGT	Combined Cycle Gas Turbine
CCUS	Carbon Capture, Usage and Storage
DEC	Display Energy Certificates
DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
EPC	Energy Perfromance Certificates
ESA	Electricity Supply Area
EV	Electric Vehicle
GDNO	Gas Distribution Network Operator
GIS	Geographic Information System
GSA	Gas Supply Area
MW	Megawatt
MWh	Megawatt hour
OAC	Output Area Classification
SPF	Seasonal Performance Factor
WPD	Western Power Distribution
WWU	Wales and West Utilities

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