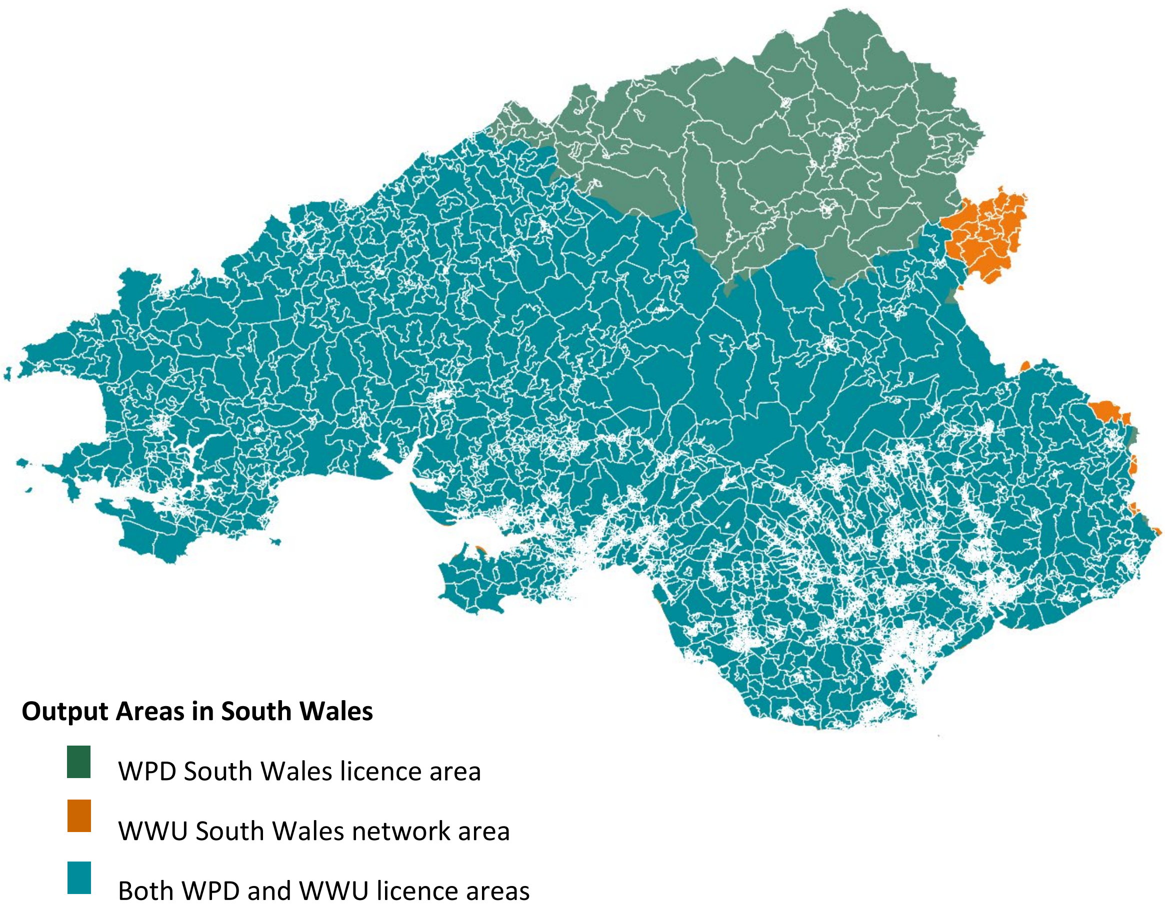
Net Zero South Wales

A combined gas and electricity distribution network future energy scenarios (DFES) assessment for South Wales to 2050

Learning report



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Contents

Introduction

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.

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 Distribution Future Energy Scenarios (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/

This Learning Report is separate innovation learning report which has been produced to focus on the methodology and innovation related to an integrated DFES analysis. The learning gained from this process will be used to improve the DFES going forward and the findings will also be disseminated to other networks.

Project innovation 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.

In particular the project had the following innovation objectives that are the focus of this Learning Report:

- 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.

Distribution Future Energy Scenarios

Regen worked with both WPD in 2018 and WWU in 2019 to undertake DFES studies for their separate electricity and gas distribution networks in South Wales. The process for DFES is outlined in Figure 1. A DFES process creates bottom-up, stakeholder led, locally relevant decarbonisation pathways for licence areas and regions. The DFES data produced is then used by the distribution networks to plan how the network might need to evolve and where and when network investment or flexibility solutions might be needed.

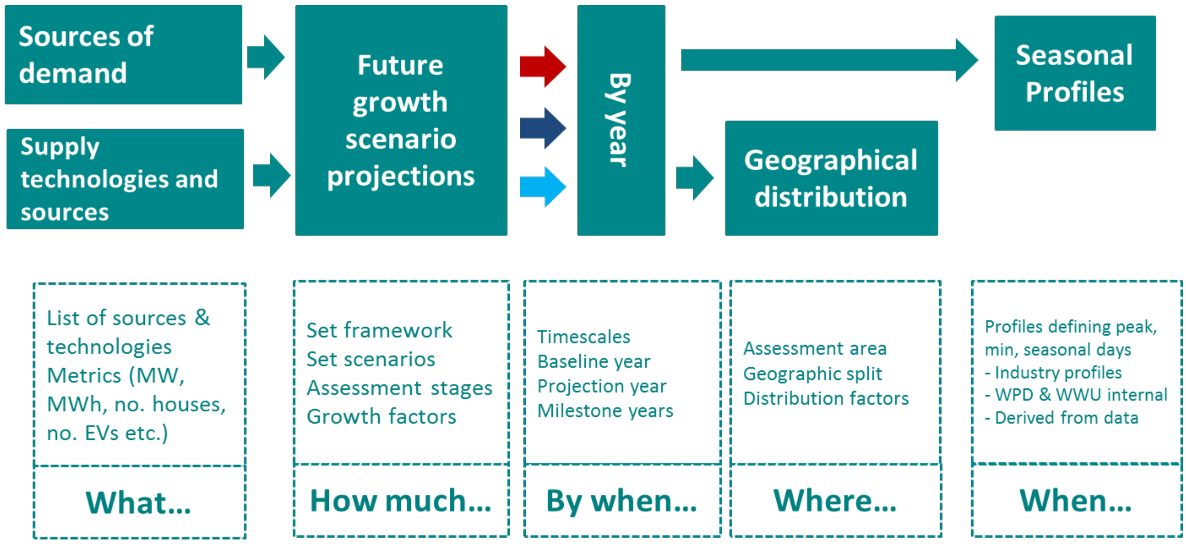


Figure 1: Illustration of the DFES process

The Net Zero South Wales 2050 project brought together the outputs and methodologies of these two earlier separate scenarios studies to create a new integrated DFES covering both networks. This involved working together with both networks to update, merge and consolidate the data, evidence and approaches developed for previous single network studies. The project also used trajectory and milestone analysis to extend the previous medium-term scenarios from 2035 to achieve a 2050 net zero outcome for South Wales.

Three net zero scenario pathways: **High Electrification**, **Core Hydrogen** and **High Hydrogen** were developed along with a hybrid heat sensitivity, to provide insights into how South Wales might transition to a net zero future with a focus on different heat decarbonisation pathways. The summary of the results by 2050 can be seen in Figure 2.

The project also produced an illustrative simulated day analysis in both summer and winter, for 2019 and scenario years 2035 and 2050. This allowed the project to explore further learnings about the separate network processes that use and process DFES data to produce network load analysis.

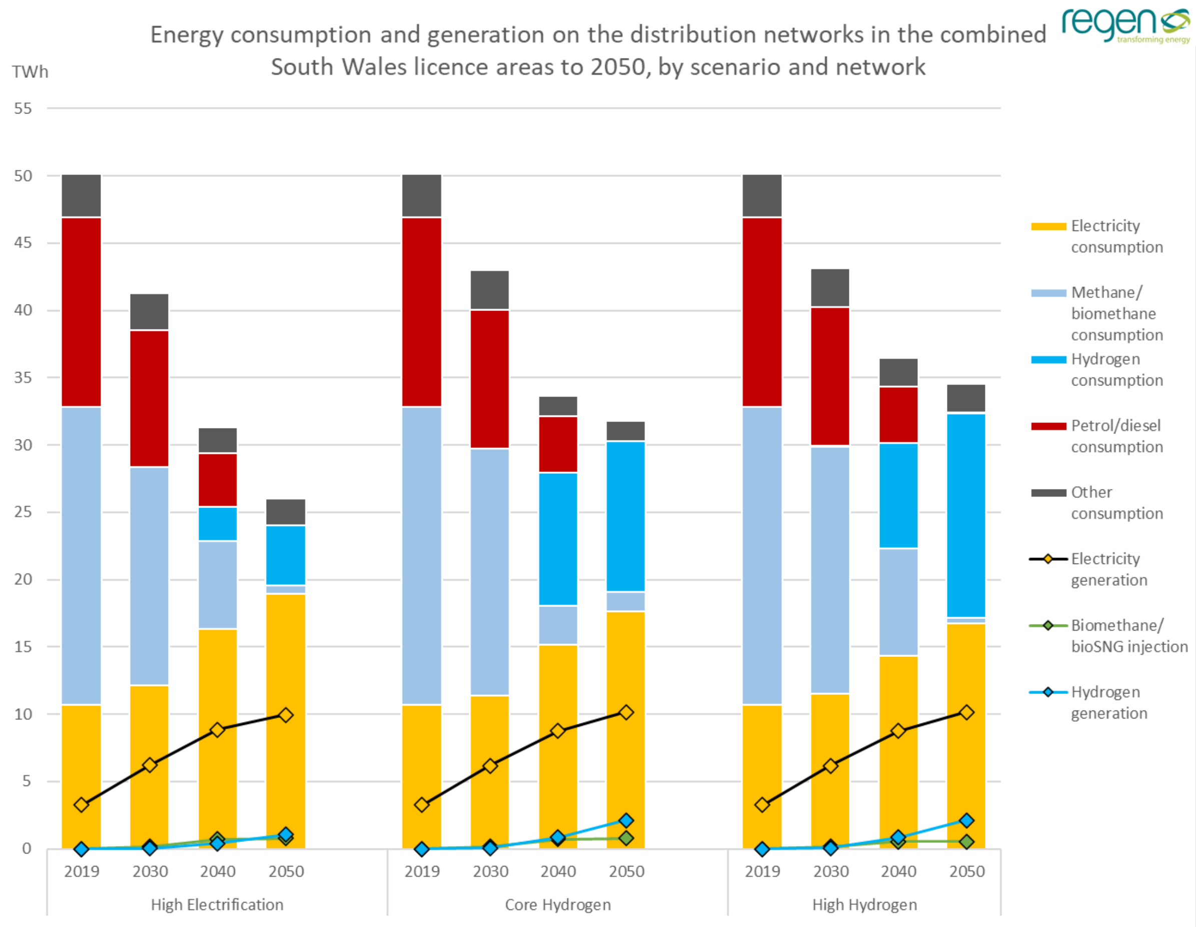


Figure 2: Overview of distribution network energy demand and supply out to 2050 by scenario

The value of integration

This innovation project was about bringing two networks together, developing insights and value from an integrated approach to gas and electricity network planning. The project involved combining and extending studies previously completed separately for both WPD and WWU into a single integrated view of future net zero scenarios for their network areas.

The project involved analysis and outputs that were cognisant of the increasing cross-vector challenges faced by distribution networks. Within this, it was important to develop a shared understanding of the increase in deployment, operational modes and role of key disruptive and cross-vector technologies (such as gas-fired power and hydrogen electrolysis). These key interactions between the gas and electricity networks are mapped in Figure 3.

Map of interactions between gas and electricity distribution networks

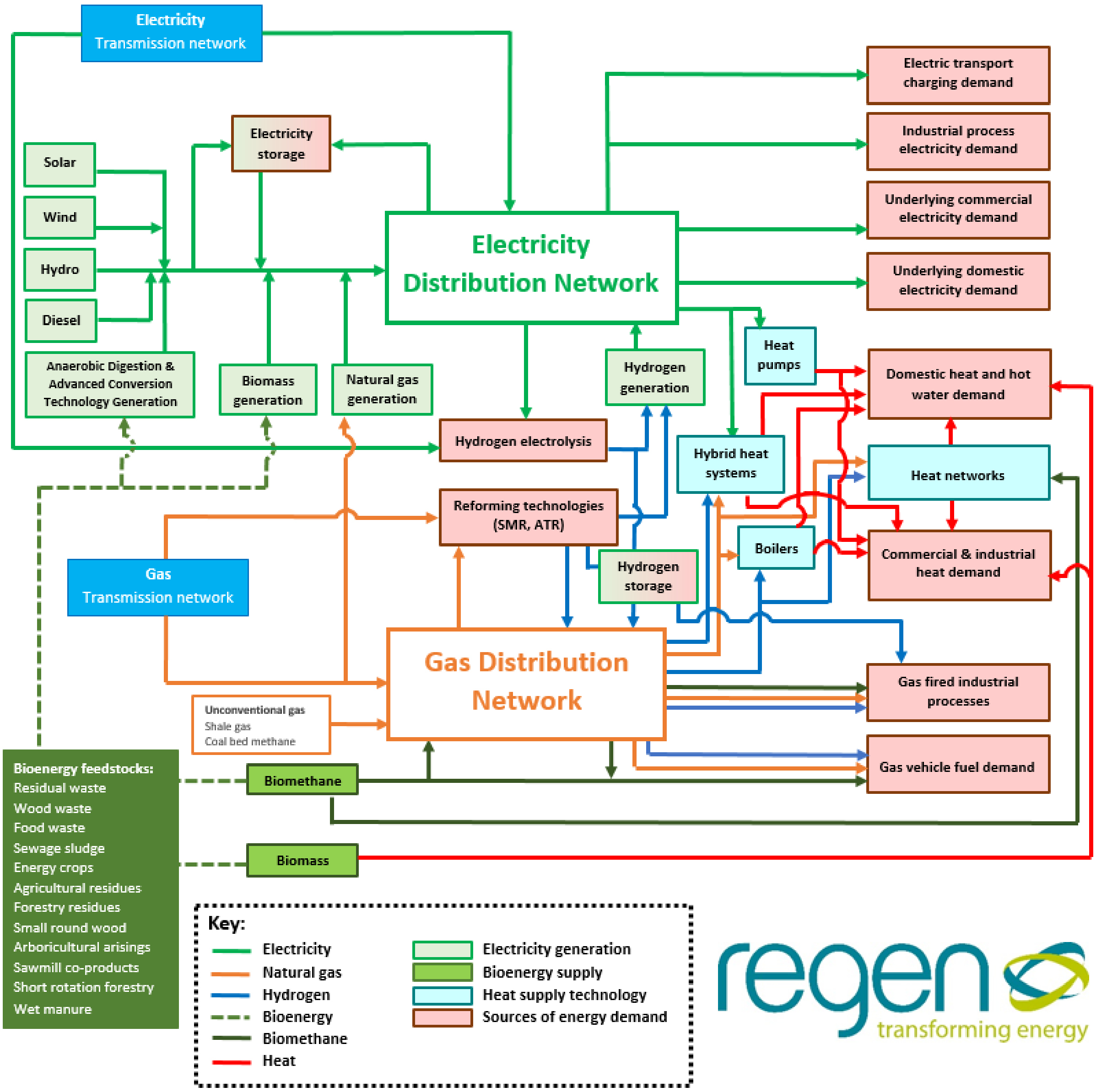
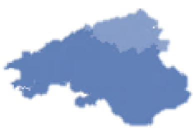
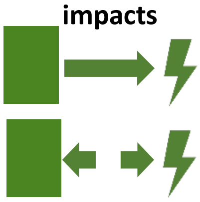


Figure 3: Mapping of gas and electricity distribution network interactions

Bringing together the datasets and combined knowledge of the two networks meant the project was able to explore South Wales's potential net zero future at an increased depth and accuracy, for example in building understanding of fossil gas peaking plant using information about both gas usage and electrical connections or merging bioenergy electrical pipeline with potential for biomethane injection.

There were many areas of commonality between the networks, partly due to the existing studies already completed by Regen, but also in some data and processes that helped with the completion of this analysis. There were also some areas of divergence and key learnings that are explored more in the sections below. This report also makes recommendations related to these for further study or development.

Theme	Learning area
Framing the scenarios 	Certainty and uncertainty in long term scenario pathways
	Supporting decision making on local heat pathways
Producing an integrated DFES 	Aligning geography for integrated network assessments
	Understanding network interactions; cross-over and cross-network technologies
	Shared definitions and aligning DFES outputs
Modelling network impacts 	Building a shared understanding of a network 'peak' day or event
	Energy profiles now and in the future
	Network forecasting in a net zero energy system

Theme 1. Framing the scenarios

Scenarios are an important tool to explore the implications of a variety of different futures. A scenarios process helps distribution networks manage risk and plan future investment in the context of rapid energy decarbonisation. Scenarios are not forecasts, and therefore how they are framed, and the decisions on the fixed and variable factors within them, are fundamental. Scenario parameters ultimately dictate what the results will show, and whether these will be credible and useful.

The DFES is a bottom up scenarios process which typically uses the annual National Grid Future Energy Scenarios (FES) as a structure for scenario framing and as a guide for longer term technology trajectories. However, the latest available version, FES 2019, was not based on net zero carbon reduction targets and did not contain all the data and information needed for this analysis. A key challenge for this project was to develop a scenarios framework without being guided by FES.

An additional challenge was to produce an integrated scenario that covered a period beyond 2035 where there are increasingly divergent options for decarbonisation, all of which had very significant implications for the futures of both networks involved in the study. Although the net zero analysis started by combining two pre-existing separate scenario outputs completed for the two networks, these provided results only into the early 2030s which was before some of the more fundamental changes that would be needed to achieve a net zero energy system.

1.1. Certainty and uncertainty in long term scenario pathways

This integrated project involved working with two partners with a range of interests and views about the future decarbonisation pathways, all of which had significant and diverse implications for the development of their respective networks by 2050. This meant that the process for agreeing these scenarios was critical and it was important to develop scenarios that would provide a useful envelope of results for both gas and electricity distribution networks.

A scenario based approach itself is critical to delivering a cross-vector DFES as it allows the two networks to agree on a set of possible futures.

The project used a number of different sources to set parameters and steer the projection framework. These included:

- The FES 2019 net zero sensitivity[1].
- Early information from National Grid about the future FES 2020 scenario structure.
- The Committee on Climate Change (CCC) Further Ambition scenario[2].

The projections for many technologies were also informed by, and compared with, data from the FES 2019 Community Renewables and Two Degrees scenarios at both a national and Grid Supply Point (GSP) level. These scenarios were compliant with the earlier 80% carbon reduction target and therefore assumed to be below a net zero trajectory.

The analysis did not cover transmission related technologies, which were expected to be covered by the Zero 2050 South Wales project[3]. However, the analysis revealed that the transmission context and interaction with distribution became increasingly important when conducting DFES over the longer term, particular for new technologies such as hydrogen and continued fossil gas supply.

Producing a combined DFES emphasised the key role of the National Grid FES in setting credible envelopes for future energy scenarios, providing frameworks and assumption consistency for regional analysis.

Reviewing the available information from FES and CCC on UK net zero pathways, it was clear that in some areas, the decarbonisation pathway is becoming more consistent and certain, for example domestic vehicles are expected to be mainly electrified and renewable energy (wind and solar) capacity in South Wales optimised. However, in other sectors, such as heat, there remains significant uncertainty about future technology routes.

The project aimed to reflect these varying levels of certainty within the scenarios and therefore projected the more certain 'core factors' to have the same net zero trajectory across the scenarios. These included sectors with a clearer decarbonisation pathway and those technologies which only directly impacted one network (such as the level of renewable generation or electrification of domestic vehicles).

[1] http://fes.nationalgrid.com/
[2] https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/
[3] This analysis is feeding into a National Grid whole system study of net zero by 2050 in South Wales. The National Grid process will covers both distribution and transmission. More information can be found here: https://www.zero2050.co.uk/

By keeping these variables fixed the analysis was then able to focus the scenarios, learnings and insights on ‘cross vector uncertainties’ such as heat, industrial processes and heavy transport. Three different pathways were developed for these areas which were combined with core factors to create three discrete scenario pathways. A workshop was then held in January 2020 with the project partners to discuss and agree these scenario pathways as well as the modelling approach by sector and technology.

This analysis approach to net zero is outlined in Figure 4.

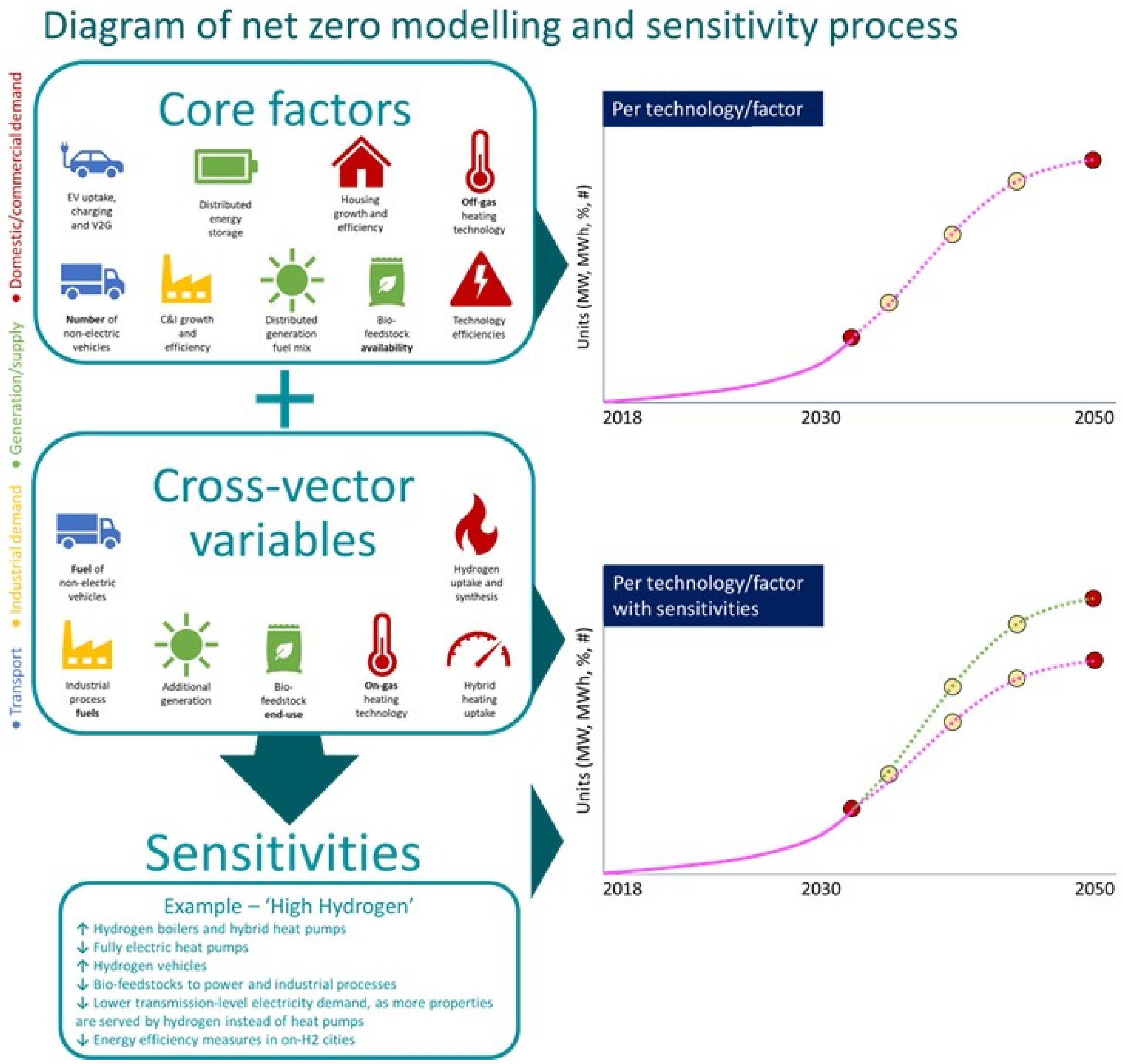
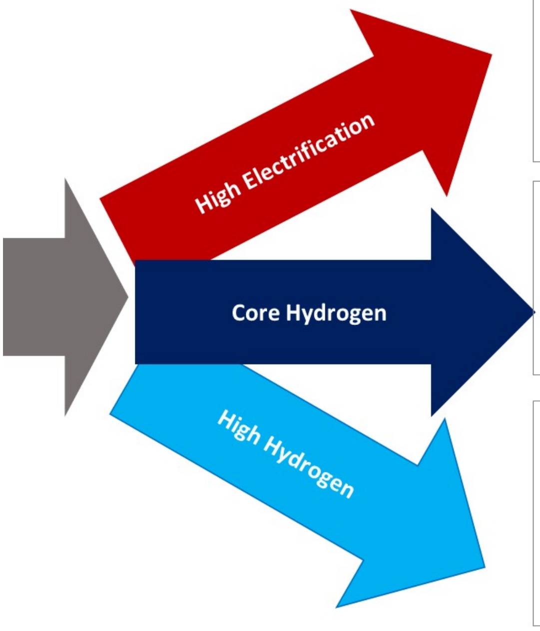


Figure 4 Core scenario factors and cross-vector uncertainties

It was agreed with the partners that the key factor in each scenario would be the different ways that the region might choose to decarbonise domestic and commercial heat, either through electrification, or with a full system switch-over to hydrogen. In addition to the two 'extreme' approaches, the project included a scenario 'Core Hydrogen' that took a middle way between hydrogen and electrification based on rural urban split. This approach was also guided by the Consumer Transformation and System Transformation scenarios expected in FES 2020[4].

The three scenarios are outlined in Figure 5.



In **High Electrification**, electrification is prioritised as the solution for heat. The majority of domestic and commercial heat needs are electrified, use low carbon heat networks or shared source heat pumps. Hydrogen use is focused on some high value sectors including heavy transport and for decarbonising the South Wales industrial clusters. This scenario is similar to the FES 2020 Consumer Transformation scenario.

In **Core Hydrogen**, a hydrogen network replaces the fossil gas network from 2035 in c. 57% of existing South Wales connections related to the densest areas of domestic and commercial demand. The remaining gas customers are electrified along with existing off gas areas during 2030s. Hydrogen also fuels industrial clusters, heavy transport and some peaking generation.

In **High Hydrogen**, the majority of the current gas network is converted to hydrogen from 2035 and users install a hydrogen boiler. Existing off-gas areas are electrified for heat. Hydrogen also fuels industrial clusters, heavy transport and some peaking electricity generation. This is similar to the FES 2020 System Transformation scenario. A **hybrid sensitivity** also explores the impact of hybrid heating systems replacing hydrogen boilers.

Figure 5: Overview of the three analysis scenarios and heat pathways

Although the National Grid FES analysis provides a valuable national context, the bottom up DFES analysis allows more geographic and regional analysis that reflects actual expected pathways (for example specific locations for heat networks or in the future a biomethane or hydrogen network). Increasing certainty in regions, will then need to be reflected back into national scenarios to allow ranges within the National Grid FES to narrow into a clearer and agreed pathway.

[4] http://fes.nationalgrid.com/media/1460/introducing-the-fes-2020-scenarios.pdf

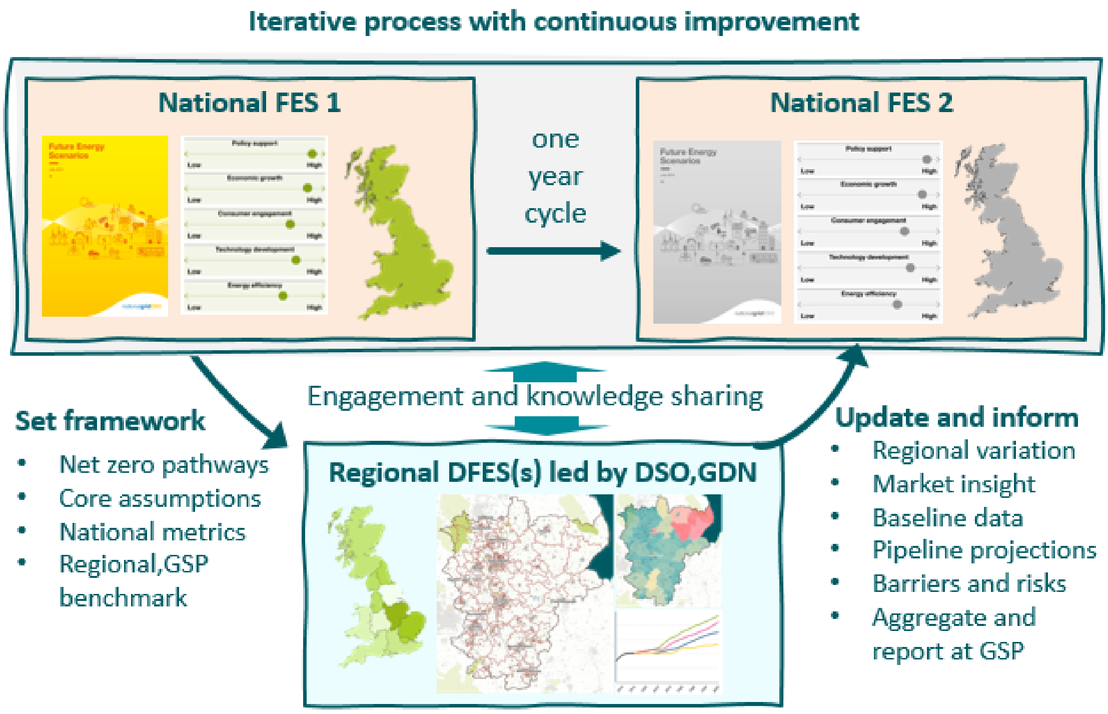
Recommendation 1: National Grid FES and DFES synergy and coordination

The Open Networks[5] have started investigating whether regional DFES (both single and integrated) could be part of an annual iterative process to help the National Grid FES include more regional and local perspectives in their analysis.

Key inputs would be the DFES investigation of short and medium term pipeline projects in a particular licence area, along with the findings of local authority and stakeholder research to identify areas for renewable generation or energy and heat pathways in localities. This information would then feedback into the national process to improve analysis and reduce uncertainty overtime.

The National Grid FES outputs could also be better tailored towards supporting the delivery and consistency of regional DFES processes led by the distribution networks. For example, providing additional FES data, including:

- Breakdowns of assumed heat technologies by region or by housing type (e.g. off gas areas).
- Data for both gas and electricity demand and supply related to cross-vector technologies such as anaerobic digestion and electrolysis.
- Transmission level gas and electrical regional results.
- Additional detail on assumed capacity factors by projected technology.



[5] https://www.energynetworks.org/electricity/futures/open-networks-project/

1.2. Supporting decision making on local heat pathways

The integrated DFES study outlined three possible pathways for how various sectors and low carbon technologies **could** develop to 2050. How they **will** develop is likely to depend primarily on cost and relative cost of one solution compared with the alternative. Although direct solution cost was not considered in this analysis, the relative cost of the solutions were implicit in the framing of the scenarios.

In some technologies such as EV's the pathway is likely to be cost or market-led however a net zero heat pathway will require explicit, likely political, decisions. These decisions will be different in different parts of the UK, potentially from one town to the next, and in South Wales and beyond will have a profound impact on people and businesses. The implications will be particularly acute in a scenario such as the Core Hydrogen where some areas retain a gas connection and others do not. There will also be very different implications for the development of, and investment needed in, both the gas and electricity networks.

Making local decisions on decarbonised heat pathways will require a thorough, transparent, and consultative process, starting from a clear national heat strategy and then involving gas and electricity networks, local councils, local authorities, and many other stakeholders.

A basic assumption made in the scenarios was that a heat transition needed to commence by 2035 to allow a 15 year period for the changeover ahead of the net zero target date. This would imply that consultation processes and decisions on heat pathways would need to be made significantly ahead of this point, and that investments to support the heat transition should be the focus of the ED3 network price control period.

The sooner these decisions about heat pathways are made the better, for carbon and cost, for networks, people, and the whole energy system.

Local areas and regions are not yet in the position to make clear decisions on heat but there are still areas where early action can be taken for example on energy efficiency and new homes. This analysis also suggests that there could be a key role for the distribution networks to support local areas in understanding the options and implications of different heat pathways including district heat, electrification, hydrogen networks, hybrid heating systems and biomethane networks.

Recommendation 2: Integrated DFES supporting local energy planning
Although all regions of the UK will contribute to the net zero targets, it is clear that not all regions, and the areas within them, will support the same technologies, pathways, or degrees of change. **With the energy networks at the core of the net zero transition, this suggests an important role for distribution networks to work with local stakeholders, local authorities, and regions to support local energy planning for net zero. Both the Open Networks and the Energy Systems Catapult have been exploring how networks might be able to do this in a transparent and constructive way.** **This analysis suggests that a key area would be integrated DFES along with a joint electricity and gas network analysis that will help engaging local and regional stakeholders with the options and implications of heat pathways ahead of the development and roll out of a national strategy. A regular integrated DFES process can be used to support and capture the results of this engagement and feeding results back into the National Grid FES process.**

Theme 2. Producing an integrated DFES

Combining DFES for electricity and gas distribution networks produced an array of benefits that would not be possible in a single-network DFES, through the ability to compare, contrast and collate the cross-vector outputs of the study. The process to achieve this posed a number of challenges and produced some important learnings.

The previous separate DFES studies conducted for both WPD and WWU focused on the potential changes in energy supply and demand that impacted their networks only. For example, the WPD analysis examined the potential for generation from anaerobic digestion but did not have projection about associated biomethane injection that was projected for WWU. Therefore, a starting point for the integrated analysis was to develop understanding of different cross-vector technologies and sectors and define how they might interact with both networks.

Aligning the geographies of the two different gas and electricity network areas in South Wales was another challenge for the project. The two South Wales network areas themselves do not fully align, however the key challenge was that the existing DFES geographical definitions (and earlier DFES studies) had Electricity Supply Areas (ESAs) and Gas Supply Areas (GSAs) related to the separate electricity and gas networks. These project analysis areas also did not align.

A further issue was to align the study outputs. The previous DFES studies were able to produce projections outputs that were relevant for each network and their subsequent analysis. The electrical DFES focused on installation numbers or electrical capacity (MW) and the gas analysis provided some elements in different units (e.g. square cubic metre per hour (scm/h) of biomethane injection) as well as focussing on annual gas energy consumption and injection potential. The disparities in outputs were rooted in the physical differences in the energy vectors and their associated network forecasting processes. In order to merge the studies effectively, common currencies had to be developed across the two networks.

2.1. Understanding network interactions; cross-over and cross-network technologies

The project worked to merge the modelling for the two existing single vector DFES studies. For some technologies this was straight forward as they impacted only one network, however others required a new approach as they interfaced with both networks in a number of different ways, either as a source of gas or electricity demand or distributed supply.

The project therefore grouped DFES elements into four distinct categories related to how the interacted, these were:

1. Elements directly connecting to the electricity distribution network
2. Elements directly connecting to the gas distribution network.
3. Cross-over technologies such as hydrogen electrolysis or gas power which are a source of demand on one network and supply on the other.
4. Cross-network technologies such as anaerobic digestion or hybrid heating systems that could operate to interact with both networks.

Understanding different cross-vector categories and how they interact with both networks, is an important element in undertaking an integrated DFES assessment. The key assumptions related to

the operation of these technologies has significant implications for both electricity and gas network planning.

More information on these categories are detailed below:

1. Elements directly connecting only to the electricity distribution network

Energy source	Element	Specific examples
Demand	Underlying domestic and commercial electricity demand	Lighting, electrical appliances, devices, IT equipment
	Industrial electricity demand	Electrical machinery and heavy plant
	Electrified transport	Electric vehicle charging equipment or other electrified transport
	Purely electrified heating technologies	Standalone heat pumps radiant electric heaters, ground source heat pump fired heat networks
Demand and supply	Electricity storage	Large grid-scale or domestic batteries, compressed air, pumped hydro etc.
Supply	Non-bioresource renewable electricity generation	Solar, wind and hydro
	Non-gas fossil fuel electricity generation	Diesel generators

2. Elements directly connecting to the gas distribution network

Energy source	Element	Specific examples
Demand	Underlying domestic and commercial gas demand	Gas fuelled heat, hot water and gas cooking appliances
	Industrial gas demand	High temperature plant, furnaces
	Gas fuelled transport	Gas fuelling stations
Demand and supply	Steam Methane Reformation and Auto-Thermal Reformation	More likely to be connected at gas transmission level
Supply	Distributed gas injection	Biomethane and bio-synthetic natural gas

3. Cross-over technologies

Sources of demand on one network that supplies distributed energy into the other network:

Cross-over element	Interaction
Gas fuelled electricity generation (natural gas or hydrogen peaking)	Source of gas demand converting to distributed electricity generation **e.g. Gas-to-power**
Hydrogen electrolysers	Source of electricity demand converting to distributed hydrogen supply **e.g. Power-to-gas**

4. Cross-network technologies

Shared sources of demand or supply that could interact with either (or both) networks:

Cross-network element	Electricity network interaction	Gas network interaction
Waste, anaerobic digestion and bioenergy	Distributed thermal electricity generation	Distributed biomethane and bioSNG injection
Hybrid heating systems	Demand from air source heat pump component	Demand from gas or hydrogen boiler component

2.2. Aligning geography for integrated network assessments

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, gas network 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.

In order to align the geography for the study, and produce results of value to both networks, a more granular analysis was used in this project to produce results to a high enough resolution to enable collation to ESA, GSA and local authority level without significant loss of accuracy.

The double benefit of a more granular approach was that it met the needs of both networks as well as wider stakeholders. For example the data will be in the right format to be able to produce outputs by Lower Super Output Area (LSOA)[6], local or regional authority area. Furthermore, where ESA and GSA boundaries may change in future DFES studies, the data can be collated to these new areas to allow earlier projections to be directly compared to the new study.

In order to produce output data to ESA, GSA and local authority level, modelling was undertaken at an Output Area Classification level[7]. The geography of South Wales, which contains a broad range of population densities from heavily rural areas in the north of the licence area to dense urban areas of Cardiff and Swansea, required the use of Output Areas to accurately represent relevent electricity and gas management areas for both distribution networks.

[6] Lower Super Output Area is a geographical area covering c. 650 households.

[7] Output Area Classification is the most granular areas as defined by 2011 Census Data, containing an average of 125 households in 2011.

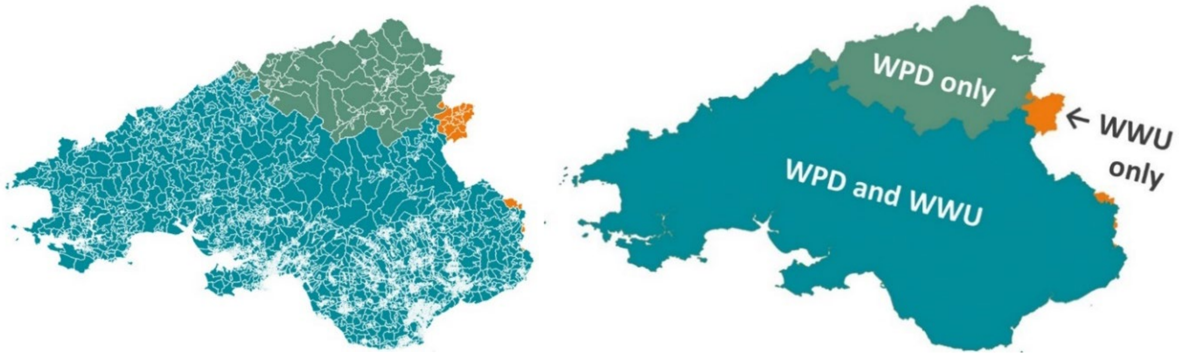


Figure 6 The two network areas in South Wales and Output Areas used for analysis.

In other regions, where population density (and therefore Census geographic area sizes) may be less varied, producing outputs to LSOA level may prove sufficient. If the study were completed to LSOA level, the number of geographic areas would reduce by 80%. However, by using LSOAs as the minimum geographic unit, the resolution of the output data would reduce to areas covering around 650 homes which, in more rural areas of South Wales, can cover several hundred square kilometres. This is an insufficient resolution to accurately produce collated outputs to ESA and GSA level.

LSOA areas are of insufficient resolution for an integrated DFES analysis particularly in rural areas. Output area level modelling provides additional benefits allowing analysis to package outputs to other geographic areas such as local authorities or city regions

Compared to previous DFES studies undertaken by Regen for WPD and WWU, the transition from modelling at an ESA or GSA level to modelling at an Output Area level resulted in a much-increased volume of data modelling and processing. Previous DFES studies typically produced projections for less than one hundred geographic areas whereas in this analysis of the combined South Wales licence areas, there are nearly 7,454 output areas.

Recommendation 3: Increased granularity of DFES analysis
There are clear benefits of producing data for a high number of smaller areas in cross-vector studies, and this should be encouraged in all DFES analysis. However, this will result in a considerable increase in data produced and modelling required. **Factors that broadly impact one network over another, such as renewable generation for the electricity DNO, could be distributed only to an ESA level. However, this may remove the auxiliary benefits of high-resolution modelling of all factors.**

2.3. Shared definitions and aligning DFES outputs

The project also needed to make sure that with all the modelling, particularly for the cross-vector analysis, there was a common currency between the networks. Though there were many areas that were directly comparable, in most cases a number of further assumptions needed to be made for comparability. For example, the project needed to convert any capacity and energy figures to MW and MWh respectively, and expanded the annual energy analysis from WWU into the WPD elements of the assessment. This allowed scenario projections to be directly compared across both vectors, which had previously not been undertaken in the independent DFES studies.

The process is illustrated in Figure 7.

For most distributed generation technologies, the project produced annual consumption and generation figures using BEIS or FES capacity factors. These capacity factors ended up being an important uncertainty.

FES datasets did not have full granularity of capacity factors[8] used in their analysis for the smaller technologies such as anaerobic digestion, and BEIS capacity factors, which were more granular, did not have forward projections to 2050.

An additional challenge was that some superficially common terms like connection capacity (either MW or scm/h) had in reality very different implications across the networks. Gas connection capacities in South Wales are more likely to have headroom for possible future capacity increases and therefore we referenced actual gas flow data and identified maximum hourly values to identify a proxy to connection capacity in some cases.

Recommendation 4: Continue development of shared definitions in DFES analyses
The distribution networks are already working together to share data and assumptions around DFES analysis and this integrated process highlights the value of continuing to build on this Open Networks process[9]. **Key areas would be shared definitions, common currencies and standardised terms and units across electricity and gas networks. A particular focus should be the 'connection' value for cross-vector and flexible technologies.** **There would also be value in developing a format for further sharing information between both networks about the physical connection, average and actual usage for cross-vector technologies. For example, contractual constraints that might impacting gas generation or Active Network Management connections for flexible and controllable loads.**

[8] Capacity factors estimate the percentage of actual electrical energy generated over a year against the theoretical maximum output. For example solar PV systems have a capacity factor of around 14%.
[9] https://www.energynetworks.org/electricity/futures/open-networks-project/

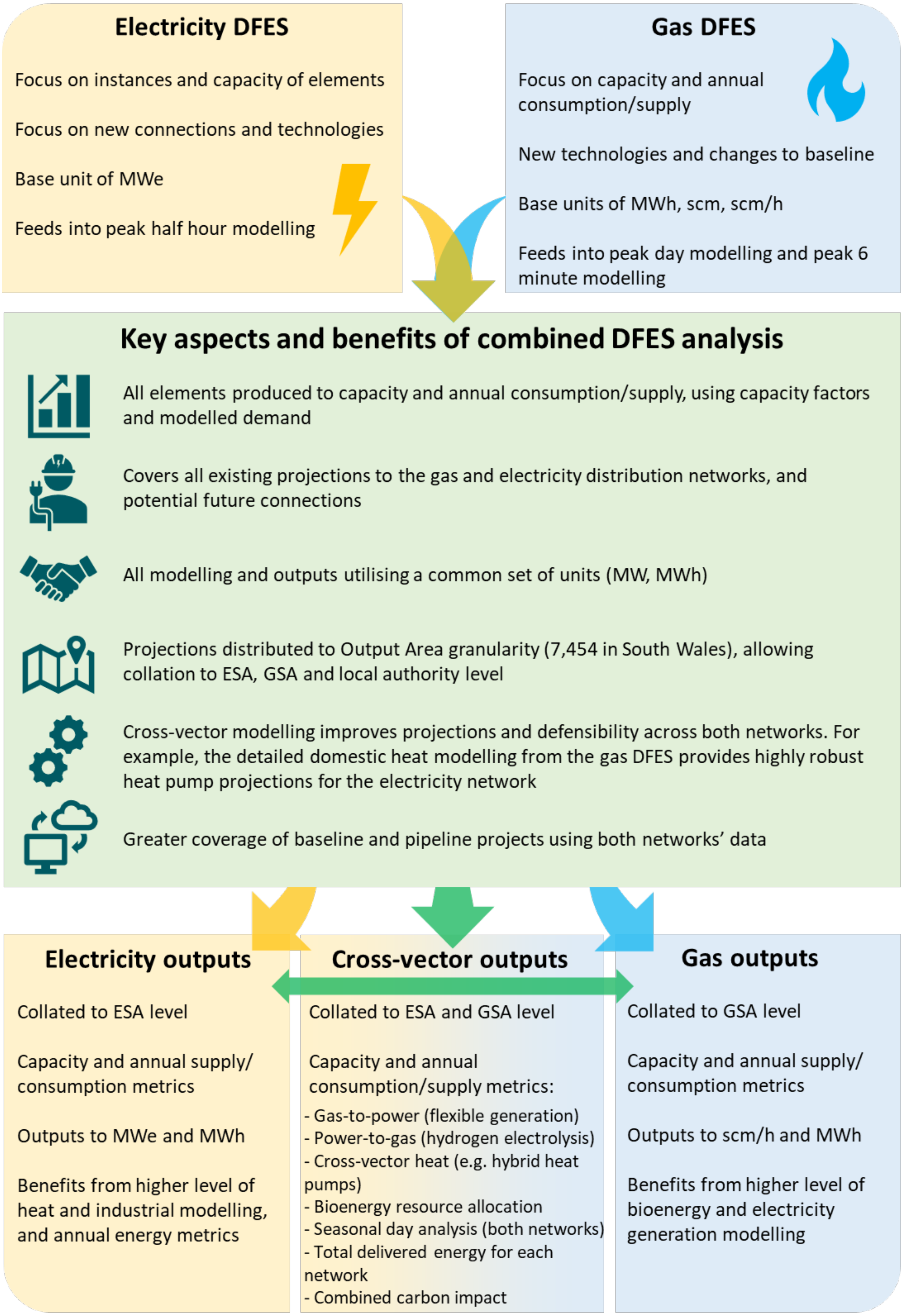


Figure 7: Process for aligning inputs and outputs for the integrated analysis.

Theme 3. Modelling network impacts

DFES analysis develops annual projections that vary by scenario for all of the key elements that directly connect to the two networks, e.g. generation technologies and new sources of energy demand.

However, in a net zero future **what** is connected to either network (the focus of earlier DFES) starts to become of less importance than **how and when** it is operated. This is particularly true for cross-vector technologies like hybrid heat pump systems and gas-fired generation.

Forecasting future peak network demand and supply on both networks is key to determining future network infrastructure reinforcement, required flexibility procurement and associated investment. However, at present the 'peak' or representative day definitions can be principally different for gas and electricity, depending on the network geography and the objective of the analysis (see info box below).

The difference between gas and electricity 'peak' calculations

Both gas and electricity distribution networks have different approaches and definitions of an operational peak on their networks which are founded in the physical differences and physical limits in their respective energy vectors.

Electricity networks are mainly concerned about what could theoretically happen at any one instantaneous point on a given day, due to the need to manage system frequency, thermal and voltage limits. Gas networks are more concerned about the gas day demand and flows over a given day, due to the need to manage pipe network pressure and storage capacity though in-pipe pressurisation or line pack.

This leads to different considerations of network peaks and how they are calculated. For example, gas networks seek to identify the "1-in-20" gas demand day across a given winter season as part of their licence condition. The peak hour and peak 6 mins for distribution area also key.

Electricity networks now have more than one seasonal period of concern due to the increase in distributed generation. For example, WPD seek to identify the distributed generation peak half hour (usually related to summertime solar output) as well as the traditional winter evening peak half hour demand. Analysis is also done on spring and autumn shoulder periods which may coincide with arranged outages.

A key outcome of this project was to consider the impact of the net zero transition on the electricity and gas distribution networks in South Wales, and to develop further understanding about how the impacts on both networks can be assessed jointly.

To address this, the project undertook analysis to simulate a summer and a winter day on the electricity and gas distribution networks in 2019, 2035 and 2050, under each of the three scenarios. This was a limited exercise that attempted to define a 'typical' day rather than to replicate a 'peak' assessment.

We found that the technology and demand energy profiles needed to model these days were diverse, often related to what type of original analysis the profiles had been developed for. Some were used by WPD and WWU and others based on actual profiles in 2019 whilst others were sourced from relevant innovation projects.

A key issue for the process was that 'non-dispatchable' renewable generation might be expected to have similar energy profiles in both 2019 and 2050, however the profiles currently used for the dispatchable or cross-vector technologies were unlikely to be a good guide to future net zero operation.

3.1. Building a shared understanding of network days or events

In order to model simulated days, the project needed to first define the conditions that would be modelled, and then identify relevant electricity and gas profiles for each demand and generation technology, in 2019, 2035 and 2050.

The definition we used for these days was separate from the approach and definitions used by networks for their respective network forecasting analysis and was instead intended to be an illustrative exercise to examine the potential operation of cross-vector and flexible technologies. It did not attempt to replicate critical peak analysis but aimed instead to provide a shared understanding and comparison point from the two networks' perspectives.

The project developed profiles for a winter and summer day as a baseline, 2035 and 2050. The conditions on these days were defined as below. The simulated days used a baseline of 2019 and it was noted that this did not reflect the potential climate change impacts by 2035 and 2050

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	

Recommendation 5: Develop a suite of shared 'peak' and 'representative' day definitions
National Grid and distribution networks should work together develop a suite of shared representative or peak day definitions for use in processing projections across gas and electricity DFES and net zero analyses. **This should also include baseline and weather assumptions and particularly where climate change may be expected to change heat and cooling demand by 2035 and 2050.** **Within this suite of definitions, there is value in understanding both 'worst case' (which will remain important for gas and electricity network planning purposes) and 'typical' illustrative operating days, for local authorities and policy makers particularly when assessing future net zero impacts and trajectories.**

3.2. Energy profiles now and in the future

The simulated day analysis required the collating and processing of different electricity and gas demand profiles which were primarily provided by WWU and WPD.

For some technologies, this process was straight-forward. However, developing a 'static' or average profile for cross-vector technologies in 2019 such as hybrid heat or gas powered generation, was difficult and became increasingly so in the 2035 and 2050 snapshot years. In the future flexible and dispatchable technologies are expected to be system reactive both to the wider market and to local flexibility needs.

The hybrid switcher profile used in our analysis shown in Figure 8, estimates that the heat pump will be operating in the middle of the day, switching away from gas operation. In reality, if this is a low wind and high electricity demand (and therefore price) day, the boiler may continue to operate on gas across the day.

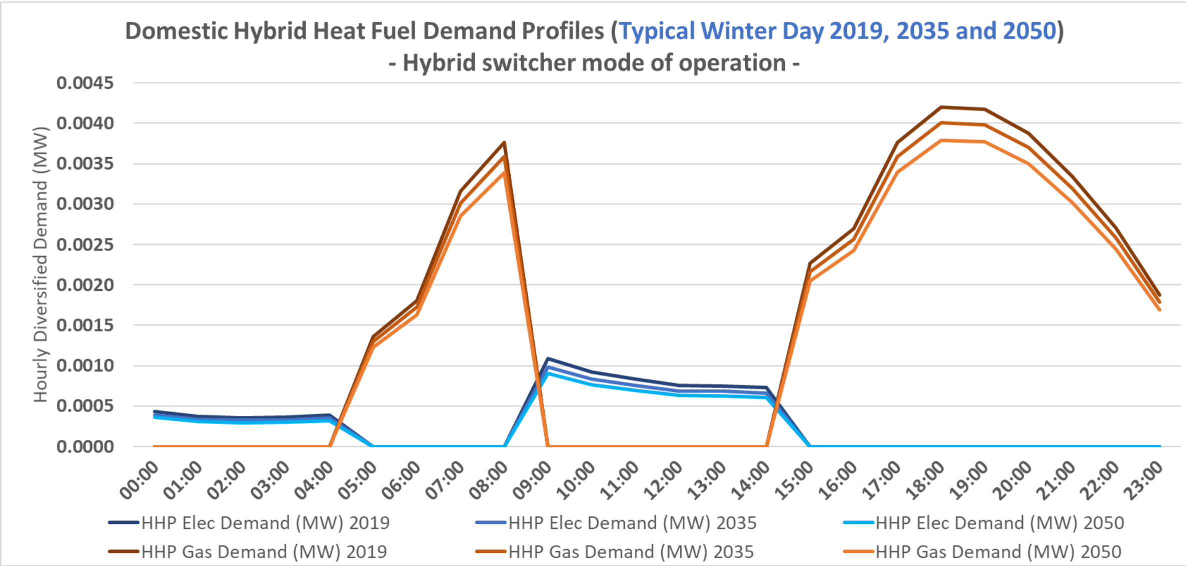


Figure 8: Hybrid heat fuel demand profiles used in seasonal day modelling

There was also significant variety in the profiles often related to what type of original analysis the profiles had originally been developed for. Some were developed to analyse instantaneous 'worse case' electricity demand in a particular season, others were developed based upon 'actual' usage and innovation trials. Some profiles also included assumptions about diversification or fuel efficiency improvements and others did not. Many used different metrics (by MW, scm or %) which needed to be translated from one format into another to create aggregated seasonal network days.

The simulated seasonal day modelling process established that applying generic profiles developed in 2019 are likely not reflective of the way dispatchable or flexible sources of distributed demand and supply will operate and interact with the network in 2035 or 2050.

The seasonal day modelling process highlighted the increasing differences between dispatchable and non-dispatchable technologies where both energy demand and dispatchable technologies are expected (at least in part) to be a function of the non-dispatchable technologies like solar and wind.

Some of the key variable elements that are likely to have very different profiles in the future, compared to now, are listed below.

Variable element	Profile effect on network
Flexible/dispatchable electricity generation (e.g. AD and hydrogen peaking plants)	Peaky/variable export to electricity network Peaky/variable demand on gas network
Electricity storage charge and discharge profiles	Very variable and market-reflective import and export from/to the electricity network
Electric vehicles with more abundant and dynamic smart charging regimes in-place	Potential to heavily diversify and flatten the demand from electric vehicle charging, potentially moving out of current evening peak demand periods
Domestic and non-domestic heating technologies (including hybrid heating systems) with more sophisticated control philosophies	Potential to be variable and diversified switching between electricity and/or gas network fuelled heating systems

To try and reflect these possible shifts, limited assumptions were made as to how some profiles could change between 2019, 2035 and 2050, some of which were augmented by operational data and future technology conversion efficiency improvements.

It is also possible that profiles could vary also by the scenarios themselves, reflecting some of the societal and policy distinctions between the three scenarios that could affect energy behaviour in the home, businesses or from energy generators and green gas producers.

This suggested that for the variable sources of demand and generation, up to 54 individual profile permutations could be adopted for each of them in this seasonal analysis, see below.

Seasonal days (x2)	Snapshot years (x3)	Scenarios (x3)	Profile permutations (x54)
Simulated Summer Day Simulated Winter Day	2019 2035 2050	High Electrification Core Hydrogen High Hydrogen	Summer 2019 HE Summer 2019 CH Summer 2019 HH ↓ …… ↓ ↓ …… ↓ Winter 2050 HE Winter 2050 CH Winter 2050 HH

Recommendation 6: Develop dynamic technology profiles
In order to aid local energy planning and net zero analysis it would be useful to develop an agreed set of system dynamic technology profiles for all 'dispatchable' technologies today, and for core years to 2050. These profiles would need to reflect national electricity price and time of use operation as well as both local and nationally procured flexibility. There would also be value in an analysis to determine the different factors and trajectories in the National FES scenarios that will affect not only the growth or uptake of certain technologies, but also their behaviour on the network at different times of the year.

3.3. Network forecasting in a net zero energy system

The baseline figures and future projections were then applied to these profiles and a snapshot of summer and winter's day in 2035 and 2050 on both networks were produced. These provided an illustration of the potential daily flows of energy (distributed supply and demand) and estimate some of the potential seasonal peaks on both networks now and in the future.

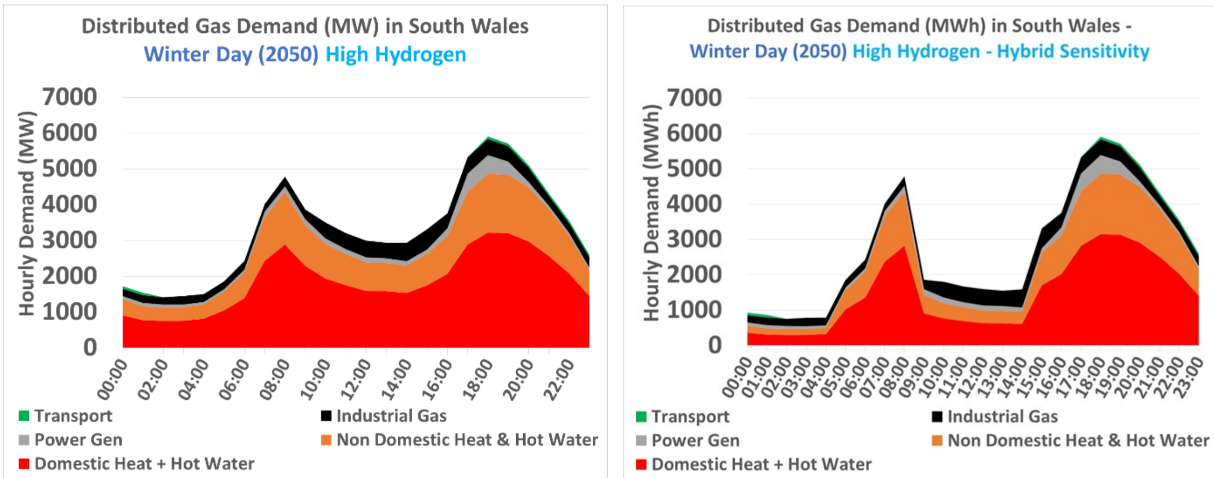


Figure 9: A High Hydrogen and hybrid sensitivity gas demand on a winter day 2050 (not inc. CCGT)

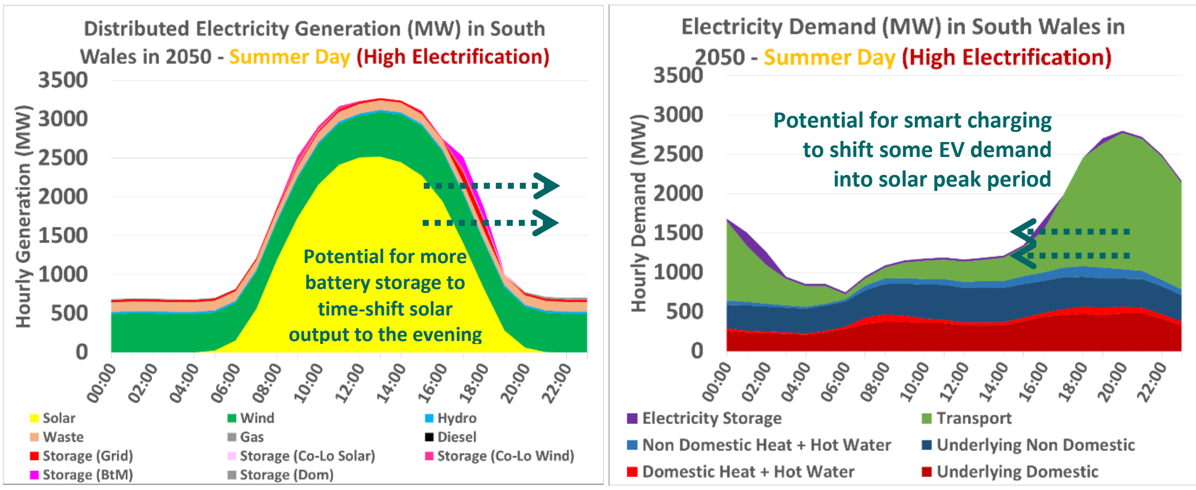


Figure 10: Simulated 2050 summer day electricity demand and generation

Applying the profiles to the net zero projections suggests that the peaks, particularly on the electricity network could become larger out to 2050. However, given the system responsive nature of some of the cross-vector technologies and technologies such as smart charging or hybrid heating, there is a question as to whether these anticipated peaks will actually materialise or whether they will be effectively managed through the national electricity pricing, time-of-use tariffs and smart technologies.

This raises the question about whether there is a better methodology that could be developed that reflects (and better identifies the need for) the system dynamism and flexibility that may be needed to operate a net zero energy system.

Recommendation 7: Assess the future of risk and energy profiles for net zero networks
The simulated seasonal day analysis identified the difficulties with projecting the impact of system responsive and cross vector technologies on the network when modelling a future net zero system. Distribution electricity networks currently use conservative profile assumptions (e.g. battery storage exporting at time of high solar load) to model an edge-based credible worst case to minimise the risk of network non-compliance under all conditions. Ensuring the network is secure to the minimum standard for all faults and contingencies will always be required, however the increase in flexible, variable and system reactive technologies may allow for some of these connected loads to change behaviour and potentially provide a more economical solution than traditional reinforcement. Consideration should be given to widen the application of a risk based approach to network security and operability One option for risk based assessment of network security could be to use dynamic profiles for dispatchable users (Recommendation 6) that are based on observed trends, or forecast behaviour, in addition to existing worst case scenarios. This combined approach would develop a more detailed view of risk and probability of network non-compliance which, along with comparisons of operability cost, could be directly related to the value of whole system flexibility. Altering the existing system will require a different approach from both Ofgem and the distribution networks to non-compliance risk along and require the development of a range of technical and commercial actions to provide the required operability mechanisms. Distribution networks would also likely need greater monitoring, visibility and control of user actions across the network, particularly high energy users and those with dispatchable, flexible and cross vector technologies.

Conclusion

Key points and recommendations outlined in this Learning Report are summarised below:

<table>
<tr><th>Summary of learnings</th><th>Recommendations</th></tr>
<tr><th colspan="2">Theme 1: Framing the scenarios</th></tr>
<tr><td>A scenario based approach itself is critical to delivering a cross-vector DFES as it allows the two networks to agree on a set of possible futures.</td><td rowspan="4">Recommendation 1: National Grid FES and DFES synergy and coordination

Recommendation 2: Integrated DFES supporting local energy planning</td></tr>
<tr><td>Producing a combined DFES emphasised the key role of the National Grid FES in setting credible envelopes for future energy scenarios, providing frameworks and assumption consistency for regional analysis.</td></tr>
<tr><td>Making local decisions on heat pathways will require a thorough, transparent, and consultative process, starting from a clear national heat strategy and then involving gas and electricity networks, local councils, local authorities, and many other stakeholders.</td></tr>
<tr><td>The sooner these decisions about heat pathways are made the better, for carbon and cost, for networks, people, and the whole energy system.</td></tr>
<tr><th colspan="2">Theme 2: Producing an integrated DFES</th></tr>
<tr><td>Understanding different cross-vector categories and how they interact with both networks, is an important element in undertaking an integrated DFES assessment. The key assumptions related to the operation of these technologies has significant implications for both electricity and gas network planning.</td><td rowspan="3">Recommendation 3: Increased granularity of DFES analysis

Recommendation 4: Continue development of shared definitions in DFES</td></tr>
<tr><td>LSOA areas are of insufficient resolution for an integrated DFES analysis particularly in rural areas. Output area level modelling provides additional benefits allowing analysis to package outputs to other geographic areas such as local authorities or city regions</td></tr>
<tr><td>For most distributed generation technologies, the project produced annual consumption and generation figures using BEIS or FES capacity factors. These capacity factors ended up being an important uncertainty.</td></tr>
<tr><th colspan="2">Theme 3: Modelling network impacts</th></tr>
<tr><td>Forecasting future peak network demand and supply on both networks is key to determining future network infrastructure reinforcement, required flexibility procurement and associated investment. However, at present the ‘peak’ or representative day definitions can be principally different for gas and electricity, depending on the network geography and the objective of the analysis.</td><td rowspan="3">Recommendation 5: Develop a suite of shared ‘peak’ and ‘representative’ day definitions

Recommendation 6: Develop dynamic technology profiles

Recommendation 7: Assess the future of risk and energy profiles for net zero networks</td></tr>
<tr><td>The simulated seasonal day modelling process established that applying generic profiles developed in 2019 are likely not reflective of the way dispatchable or flexible sources of distributed demand and supply will operate and interact with the network in 2035 or 2050.</td></tr>
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