FUTURE ENERGY GRIDS FOR WALES (FEW) - INSIGHTS REPORT

Issue 1.1

Quarter 2, 2023

Report Contents

EXECUTIVE SUMMARY

BACKGROUND

The Senedd Cymru has set the highly ambitious target for Wales to reach Net Zero by 2050. Welsh Government intends to establish Wales as a global leader both in technologies that will power the future, and in global responsibility.

But Wales' Net Zero ambitions require a re-examination of the infrastructure needed to deliver rapid and effective change, and to ensure Wales' citizens are not left behind because of infrastructure designed for past needs.

The FEW project aims to contribute to this goal by:

- Consolidating a broad view, across the network companies operating in Wales, of the Net Zero compliant Welsh future energy system pathways to 2050;
- Identifying the key implications for electricity and gas network operators and steps needed to develop energy networks in Wales as part of the wider UK energy system; and
- Developing recommendations for the Welsh Government to take forward, consistent with its ambitions to accelerate decarbonisation and role in the energy governance landscape.

APPROACH

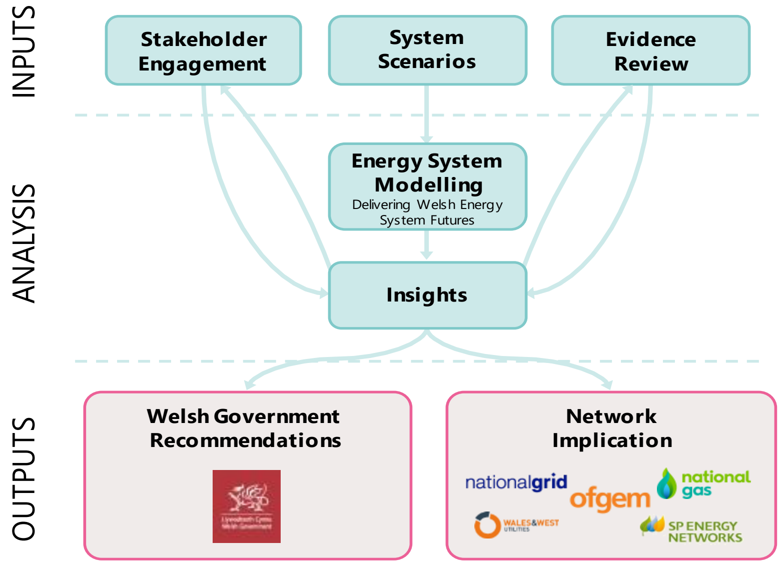
ESC used their Energy Systems Modelling Environment (ESME) to develop future scenarios for a Net Zero Welsh energy system by 2050. These scenarios, including different sensitivities, were supported by a review of existing evidence and engagement with network operators, Ofgem, and the Welsh Government. There were two baseline whole energy system scenarios developed for Wales called 'Technology-Optimistic' (TOC) and 'Societally Optimistic' (SOC), which each focus respectively on a narrative with success in technology innovation and improved consumer awareness and engagement.

Project FEW was delivered using a combination of this whole system modelling; a review of existing evidence; and engagement with the networks operating in Wales, Ofgem and Welsh Government. The project's approach is summarised in the accompanying figure.

KEY FINDINGS

Meeting Net Zero requires a fundamental change in how the Welsh energy system is planned, developed, integrated and operated. Carbon Budgets and infrastructure and market lead times mean many actions are needed soon. Key changes and impacting factors include:

- Significant network reinforcement will be required across electricity distribution and transmission networks, driven by increases in peak demand and renewables.
- Substantial electrification across heat, transport and industry (up to 10TWh by 2035), but there are challenges with meeting peak demands, particularly peak heat – other technology options need to be explored.
- A large increase in renewable deployment in Wales (up to 6.6GW in 2030 and 18.2GW by 2050).
- The scale and production method for hydrogen which has a significant impact on the whole energy system, (e.g., green hydrogen increases electricity demand).



KEY INSIGHTS AND RECOMMENDATIONS

KEY INSIGHT 1. TOTAL ENERGY CONSUMPTION ACROSS WALES

Final energy consumption in Wales could reduce by around one third by 2050 as large parts of energy demand switch from fossil fuels to low carbon electricity, driving greater efficiency.

Summary of Analysis

- The Welsh energy system requires significant change, with fossil fuel consumption being replaced by major electrification alongside district heat, hydrogen and biomass for many end-uses
- Liquid petroleum and natural gas consumption reduce substantially across all Net Zero compliant scenarios although fossil fuel consumption, combined with carbon capture and storage (CCS) is retained in some sectors
- The significantly higher efficiencies of technologies such as electric vehicles (EVs) and heat pumps, relative to incumbent technologies (e.g., internal combustion engines (ICEs) and gas boilers), leads to an overall reduction in final energy consumption

Influencing Factors and Dependencies

- External factors such as global commodity prices and their dynamics will affect both the future demand for energy, and Wales's potential role in supporting the wider UK system.
- How uncertainties such as these are resolved will influence the nature of the real-world Welsh transition pathways, with appealing characteristics of different modelled scenarios emerging, depending on the responses of individuals, business and Government.

Recommendations for Welsh Government

Accelerate enabling conditions for the Net Zero transition. Welsh Government should prioritise skills development, citizen engagement, and access to data. Fostering regional supply chains and collaborating with training providers is essential. As electricity consumption increases, particularly in heat and transport sectors, creating a supportive environment is crucial. Although direct control may be limited, the government can play a vital role in facilitating the necessary changes.

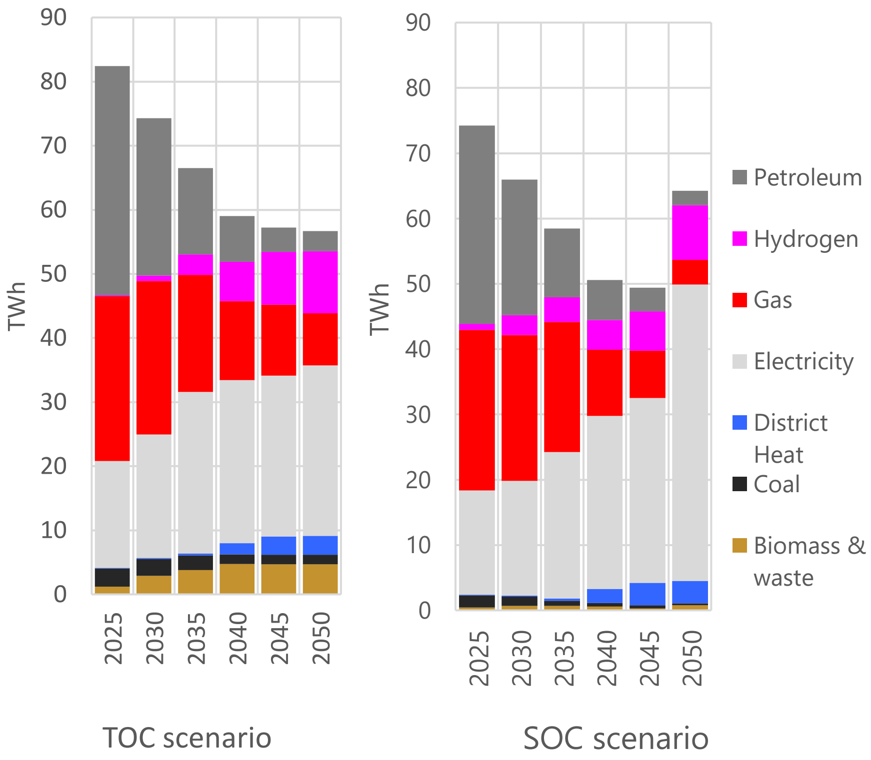


Figure 1: Annual total energy consumption in Wales 2020-2050, left: Technology-Optimistic (TOC), right: Societally-Optimistic (SOC) scenarios

Note: Figure1 and recommendations on fuel-specific changes in energy consumption and implications for networks are available in the full report.

KEY INSIGHT 2. ELECTRICITY DEMAND TRANSITION

Electricity demand will increase substantially due to the electrification of heat and transport. If favourable conditions for green hydrogen production (i.e., electrolysis) emerge in Wales, this increase will be significantly higher.

Summary of Analysis

- Wales's electricity demand may almost triple by 2050 (from around 16TWh to between 27TWh and 46TWh).
- Electrification of heat and transport are responsible for some of this increased demand, but the upper demand is primarily due to green hydrogen production via electrolysis
- Other end-use cases may also contribute to higher electricity consumption, but electrolysis shows the greatest potential for increasing future demand growth.

Influencing Factors and Dependencies

- Increasing electricity demand requires network reinforcement and interventions at distribution and potentially transmission levels (increased renewable exports will mainly drive transmission reinforcement), necessitating anticipatory investment ahead of need.
- The scale of anticipatory investment will be determined by price control frameworks and certainty about when demand will increase.
- The impact of hydrogen production on electricity demand is influenced by factors such as hydrogen demand, production methods, safety considerations, public acceptance, production technologies, fuel prices, and potential global export markets.
- Further discussion on these issues, particularly the future role of hydrogen in Wales, can be found in section 14 of the Technical Report. In this short form report all notes to refer to other sections and recommendations refer to the numbering in the main report.

Recommendations for Welsh Government

Support energy networks to plan and invest for technology uptake and increases in peak electricity demand, particularly through the coordination of Local Area Energy Plans (LAEPs).

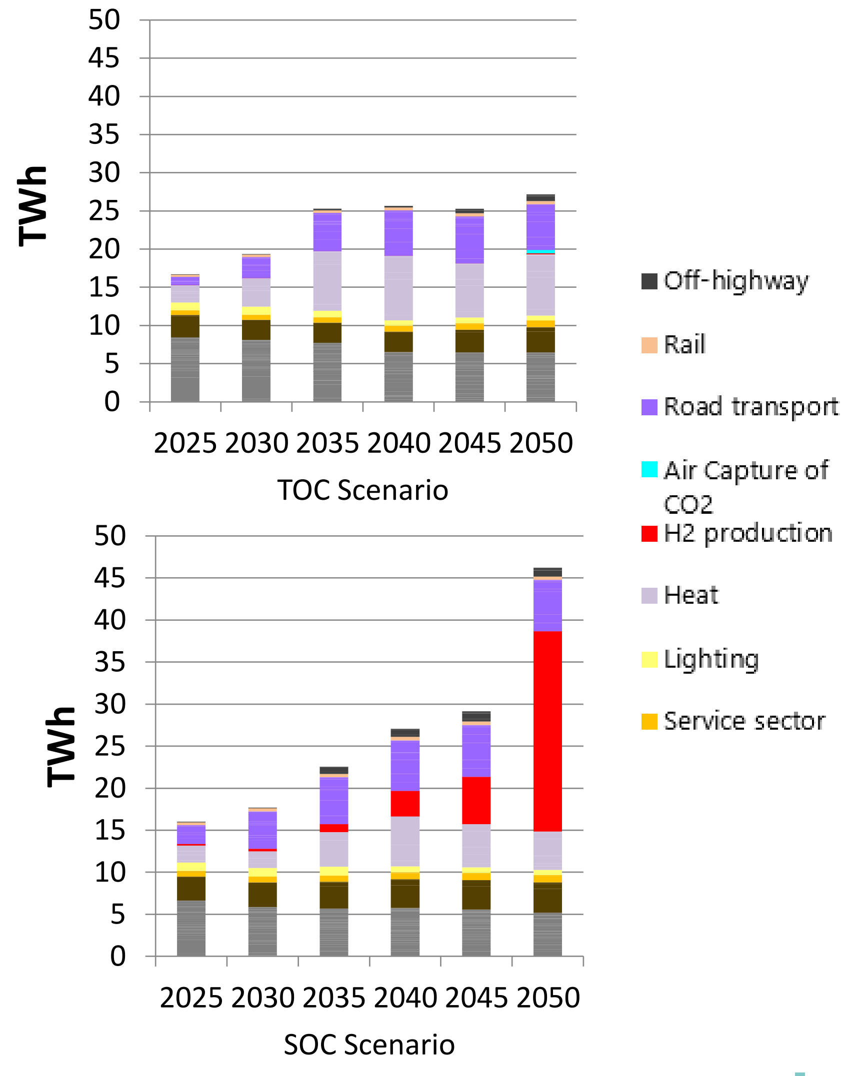


Figure 2: Annual electricity consumption to 2050 in Wales

KEY INSIGHT 3. TRANSITION OF HEAT TO NET ZERO IN WALES

Electrification will meet most annual heat demand in buildings in a Net Zero future, supported by district heat networks.

Approaches will be needed to meet peak demand and minimise network reinforcement, such as behind-the-meter thermal storage, building energy efficiency improvements, different patterns of household heat use and the potential use of hydrogen boilers in some locations.

Summary of Analysis

- Decarbonisation of heating in Wales will primarily rely on demand reduction and electrification; Air Source Heat Pumps (ASHP), and Electric Resistive Heating (ERH). Meeting peak heat demand presents a key challenge with heating systems, requiring investment in both networks and secure electricity supply.
- Alternative technologies like in-home thermal storage, building energy efficiency improvements, and hydrogen boilers (standalone or in hybrid systems) can help manage peak demands, reduce upfront costs, and mitigate network reinforcement.
- District heating plays a role in urban areas with high population density or near large heat sources (e.g., nuclear power stations). It utilises insulated underground pipes and energy centers with diverse heat sources such as nuclear cogeneration or large-scale heat pumps.

Influencing Factors and Dependencies

- Meeting peak heat electricity demand is challenging due to uncertainties influenced by factors such as energy efficiency retrofits, occupant behavior, and emerging heating technologies.
- Hybrid hydrogen boiler systems show potential in reducing heat pump size and upfront costs, but their adoption faces barriers like the need for a hydrogen distribution network, consumer acceptance, demonstration of the safety case, supply chain considerations, and hydrogen availability.

Recommendations for Welsh Government

Welsh Government can help support accelerate electrification and low carbon heating and encourage electrified heating solutions through support of the Local Area Energy Plan process.

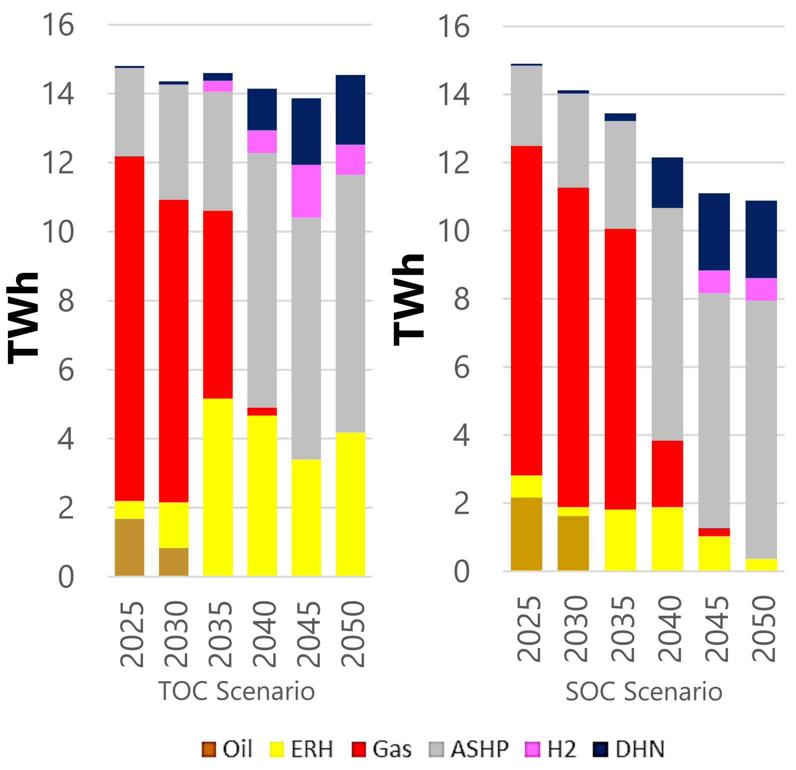


Figure 3: Annual total heat energy consumption in Wales 2020-2050, left: Technology-Optimistic (TOC), right: Societally-Optimistic (SOC) scenarios. By 2050, hydrogen is the main contributor to meeting peak heat demand across all regions in both scenarios, except for Mid-Wales in the Societally-Optimistic scenario, due to challenges in meeting high heat demands with electricity alone.

KEY INSIGHT 4. INDUSTRIAL TRANSITION

The decisions made by a small number of large industrial actors will have a significant impact on the shape of the future energy system. Continued uncertainty within large industry around decarbonisation options, is slowing the transition to Net Zero. Increased collaboration between industry, Welsh government and other key energy stakeholders is therefore important.

Summary of Analysis

- The Welsh energy system has several large demand assets. Just 3 sites account for 91% of South Wales industrial emissions, making their decarbonisation decisions crucial in shaping the future energy system and economic activity in key locations.
- Least-cost decarbonisation options (for a whole energy-system perspective) for industry by 2050 could involve a combination of electrification, gas with CCS (Carbon Capture and Storage), hydrogen, and bioenergy.
- The use of green hydrogen for industry adds to electricity demand, resulting in an increase in electrification across many cases.

Influencing Factors and Dependencies

- Uncertainty remains regarding future industrial demand for different energy vectors despite emerging decarbonisation plans through initiatives like the South Wales Industrial Cluster (SWIC) and stakeholder involvement in North Wales.
- There is a need to address uncertainties related to how key policies driven by the UK Government will support industrial decarbonisation proposals, specifically in Wales.

Recommendations for Welsh Government

The Welsh Government, networks, and heat providers should collaborate with Net Zero Industry Wales and stakeholders to assess industry decarbonisation options, considering shared infrastructure and resources. Clean growth hubs could be established, periodic reviews conducted, and barriers to electrification and other decarbonisation options removed. Collaboration with the UK Government is important in achieving cost-effective industry decarbonisation.

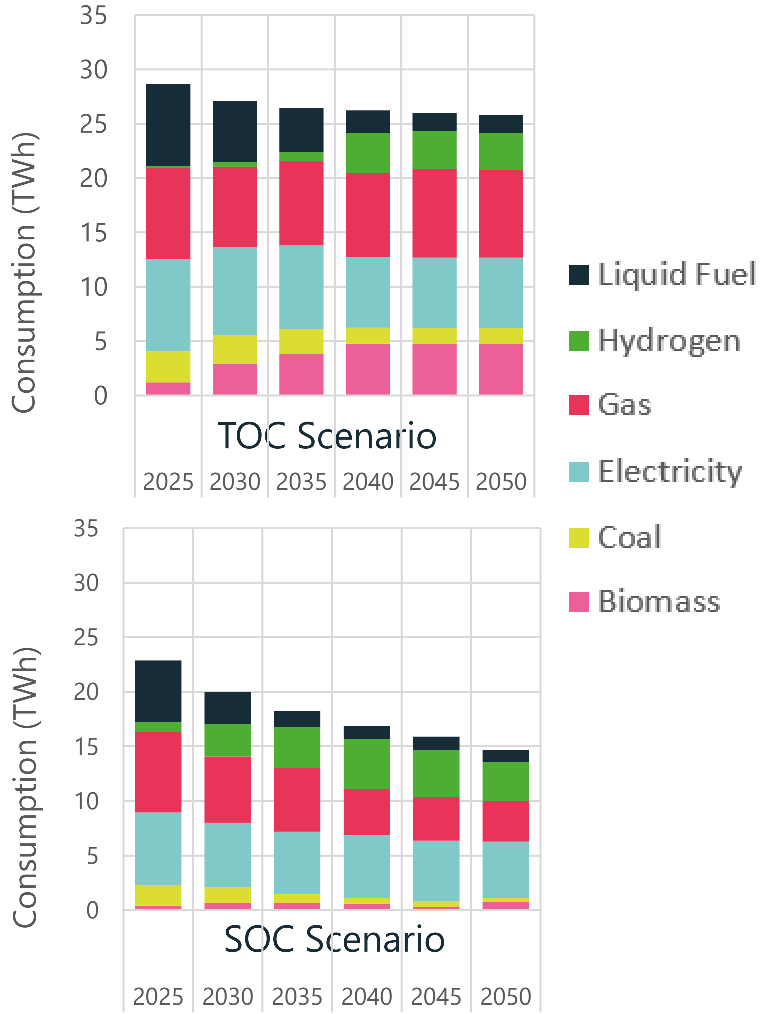


Figure 4: Total industrial energy consumption in Wales 2025-2050 for top: Technology-Optimistic (TOC) and bottom: Societally-Optimistic (SOC) scenarios (other scenarios available in full report)

KEY INSIGHT 5. POWER GENERATION TRANSITION

Offshore wind can efficiently decarbonise electricity generation in Wales, complemented by firm and flexible options like nuclear and hydrogen-fired turbines. Collaborative efforts are necessary to address network challenges posed by increased renewable energy deployment.

Summary of Analysis

- Analysis showed that offshore wind will be the predominant low-carbon electricity source in Wales, potentially reaching 10-13GW by 2050.
- Other renewables like onshore wind, solar, and tidal energy can help diversify supply.
- System stability with high levels of renewables requires careful management, alleviated by technologies such as hydrogen-fired turbines and nuclear power.
- Gas CCS is not deployed for power generation. Gas CCS is used sparingly as not all carbon emissions are captured, and its limited use is prioritised for specific industrial processes where other options are limited.

Influencing Factors and Dependencies

- Renewables, especially offshore wind, are vital for a cost-effective Net Zero Welsh energy system.
- Support for other renewables and consideration of business cases may influence technology choices.
- Nuclear power, whether large-scale or Small Modular Reactors (SMRs), can contribute to achieving Net Zero.
- Flexible nuclear plants can provide cogeneration for heat networks and hydrogen production, adding value to the energy system.

Recommendations for Welsh Government

Offshore wind is projected to be the most cost-effective and prominent electricity source in a Net Zero Welsh energy system, providing up to 80% by 2050. Alongside offshore wind, a diverse range of technologies such as solar, onshore wind, tidal generation, hydrogen-fired turbines, and nuclear generation will be necessary. The Welsh Government can lead by supporting diverse renewable technologies, facilitating renewable energy schemes, and addressing barriers through collaboration with Local Authorities and developers.

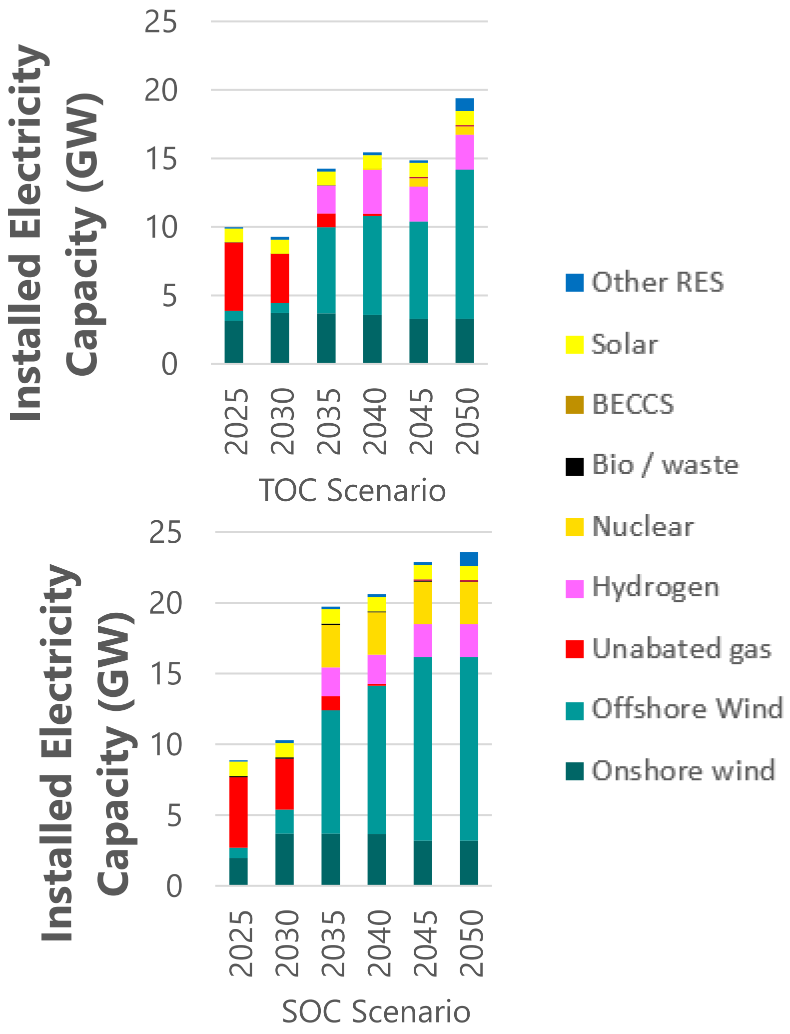


Figure 5: Installed electricity generation capacity in Wales 2020-2050, top: Technology-Optimistic (TOC), bottom: Societally-Optimistic (SOC) scenarios

KEY INSIGHT 6. THE REQUIREMENTS ON NEW AND EXISTING NETWORKS

To achieve Net Zero, energy networks in Wales require substantial investment. Electricity networks must be reinforced to accommodate growing generation and demand. Heat networks are key for decarbonising the energy system. Gas networks require a combination of redesign, recommissioning, and decommissioning to manage reduced demand or transition to hydrogen.

<u>Summary of Analysis</u>

- Reinforcement is required for the electricity networks in North and South Wales by 2030, along with approaches like Dynamic Line Ratings (DLR), Demand Side Response (DSR), increased system flexibility, and innovative technologies.
- Network preparedness is crucial for accommodating multiple heating and industry solutions, including but not limited to heat pumps and resistive heating.
- Natural gas consumption will significantly decrease by 2050, but some industrial processes and hydrogen production may still require a gas transmission network.

<u>Influencing Factors and Dependencies</u>

- Transition to Net Zero requires extensive network changes, including reinforcement of electricity networks and development of heat and potentially hydrogen networks.
- Factors influencing network development include electricity network reinforcement, management of peak heat demand, and hydrogen production and consumption in Wales.
- Strategic siting of electrolysers can alleviate electricity network constraints, while deploying heat networks can reduce peak electricity demand but could require localised infrastructure upgrades.

<u>Recommendations for Welsh Government</u>

Welsh Government should provide leadership, minimise uncertainty, and set out priority outcomes for the energy system, considering economic benefits, environmental sustainability, and home insulation ambitions. This includes working with network operators to inform citizens about potential benefits and impacts of network connections, ensuring top-down and bottom-up priorities align, and collaborating with stakeholders to deliver on these priorities, fostering confidence for investment decisions.

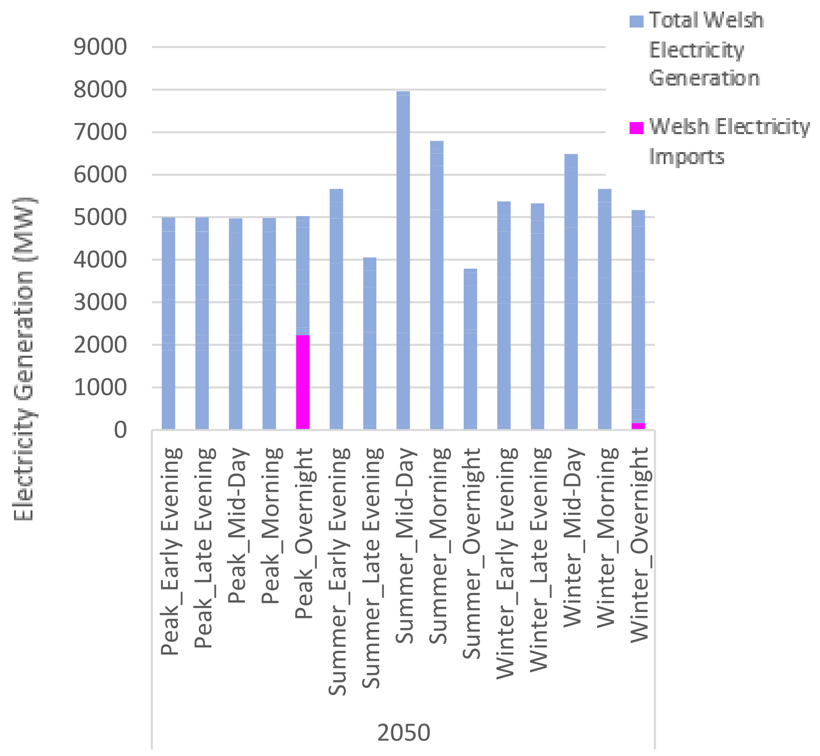


Figure 7: Electricity production in Wales for different time periods across a year, showing when electricity imports are needed for 2050 – 'Renewable Electricity 1.25 x electricity consumed' sensitivity

KEY INSIGHT 7. WELSH NORTH SOUTH LINK DRIVERS AND OPPORTUNITIES

Building a Welsh North-South transmission system link would present several opportunities for Wales.

Summary of Analysis

- The Welsh North-South link is important for GB to achieve the offshore wind capacity target of 50GW by 2030.
- It is recognised by NGESO in the Holistic Network Design (HND) that the estimated delivery time is beyond 2030 but efforts are being made to accelerate delivery of the project and reduce the time to identify and build onshore electricity transmission assets.
- The link can support the electrification of energy demand and decarbonisation in Mid-Wales, reducing emissions and promoting a low-carbon energy system.
- Construction and operation of the link can create job opportunities in construction, operation, maintenance, and related industries like renewable energy.

Influencing Factors and Dependencies

- The North-South link in Wales has the potential to provide various benefits, especially for Mid-Wales, depending on the chosen route. An onshore route can support low-carbon generation assets, distribution network reinforcement, and minimise environmental impact, while an offshore route may have fewer visual amenity concerns.
- In Mid-Wales, the electricity demand is relatively low, but there will be a modest peak demand increase that requires distribution network reinforcement. Building the North-South transmission link can support distribution network reinforcement by providing more Grid Supply Points, enhancing stability, and enabling interconnection of radial sites.

Recommendations for Welsh Government

Welsh Government should engage with NGET to convene and feed-in the views of Welsh stakeholders around potential routes during the initial stages of design.

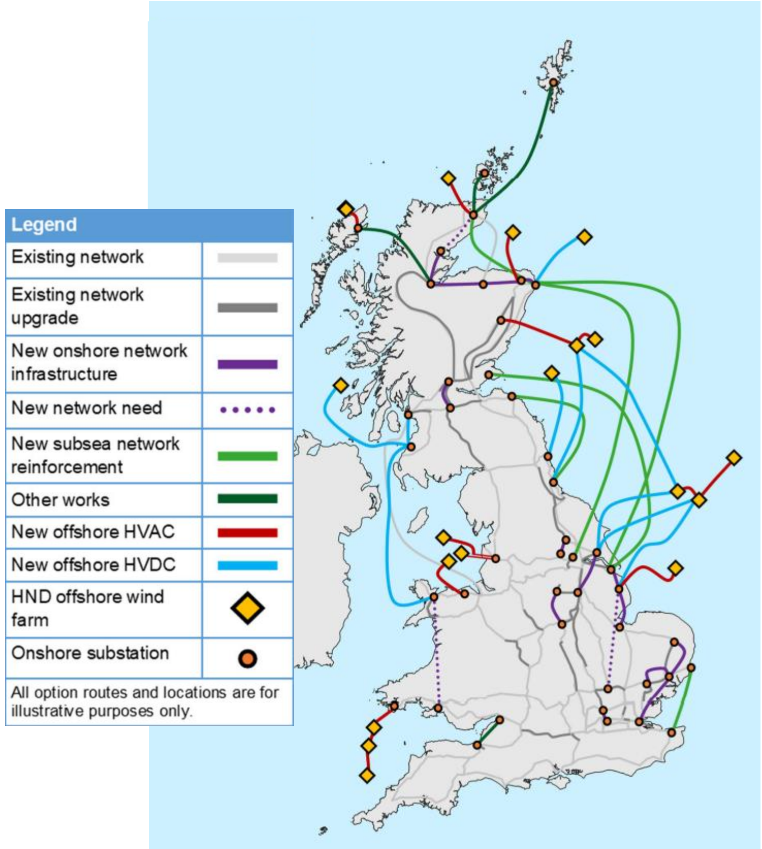


Figure 8: Final HND proposal, courtesy of NGESO. The diagram shows the 'new network need' flagged in Mid-Wales to facilitate the 50GW GB offshore wind target

KEY INSIGHT 8. THE ROLE OF KEY DEMAND-SIDE INTERVENTIONS TO REACH A NET ZERO WALES

Welsh heating and road transport demand will be underpinned by electrification. A smart, innovative approach across energy vectors will reduce the level of network reinforcement required to meet peak electricity demand

Summary of Analysis

- Demand side flexibility, enabled by options like smart EV charging and smart heating with thermal storage, is crucial for an efficient and economically viable energy system.
- Industrial sectors can participate in demand side response (DSR) by adjusting electricity demand based on supply availability, through electrification or green hydrogen adoption.
- Insulation retrofits and behavioural changes in heat demand can also contribute to reducing peak demands, resulting in lower system and network costs.

Influencing Factors and Dependencies

- Demand side response (DSR) and interventions should consider user needs, especially regarding thermal comfort levels, while reducing peak demand.
- Intelligent control systems and digital infrastructure are essential for effective implementation of demand side flexibility options like smart EV charging and smart heating.
- Emerging markets and business models can incentivise individuals and businesses to participate in demand side response, presenting economic opportunities in Wales through smarter energy systems.

Recommendations for Welsh Government

Welsh Government should collaborate with Local Authorities to accelerate the adoption of Demand Side Response (DSR) and other demand side options, such as thermal storage, smart heating, EV charging, and building retrofits. Smarter energy systems with increased potential for DSR could open up market opportunities for people in Wales and help to support networks to reduce the impact of peak energy. And so facilitate the transition to a low-cost energy system.

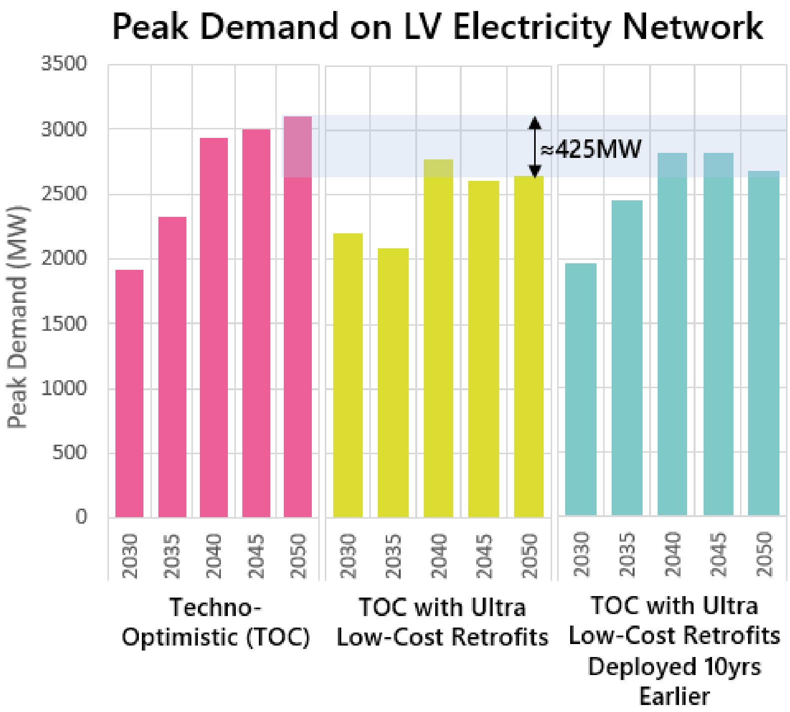


Figure 9 : Peak demand in 2050 for left: Technology-Optimistic (TOC) scenario vs, central: 'TOC Retro Ultra Low' scenario (low cost insulation retrofits) vs, right: 'TOC Early Retro' scenario. Figure shows how more numerous or earlier retrofits could reduce demand by over 400MW by 2050.

KEY INSIGHT 9. ROLE OF HYDROGEN IN THE WELSH ENERGY SYSTEM

Hydrogen has a role in the decarbonisation of the Welsh Energy System, particularly in decarbonising industry and shipping and providing flexible electricity generation. The overall energy system cost is higher in scenarios without hydrogen.

Summary of Analysis

- Hydrogen use for meeting some industry, heavy transport, and electricity generation demands in Wales results in the most cost-effective energy system.
- Further investigation is needed to determine the extent of hydrogen's role in residential heating and other sectors.
- Hydrogen production in Wales can come from various sources, including electrolysis, natural gas with CCS, bioenergy, or nuclear cogeneration.

Influencing Factors and Dependencies

- Welsh Government can shape hydrogen production and consumption in line with decarbonisation goals.
- Factors like safety, public acceptance, technology costs, and fuel prices (e.g., natural gas price for blue hydrogen) can influence deployment levels.
- Consideration of the global hydrogen market is also important in decision-making.

Recommendations for Welsh Government
Welsh Government should explore technology options, assess drivers, and assess the benefits and risks of different hydrogen production technologies for informed investment decisions. Timeframes should recognise the UK's 10GW hydrogen production target by 2030.

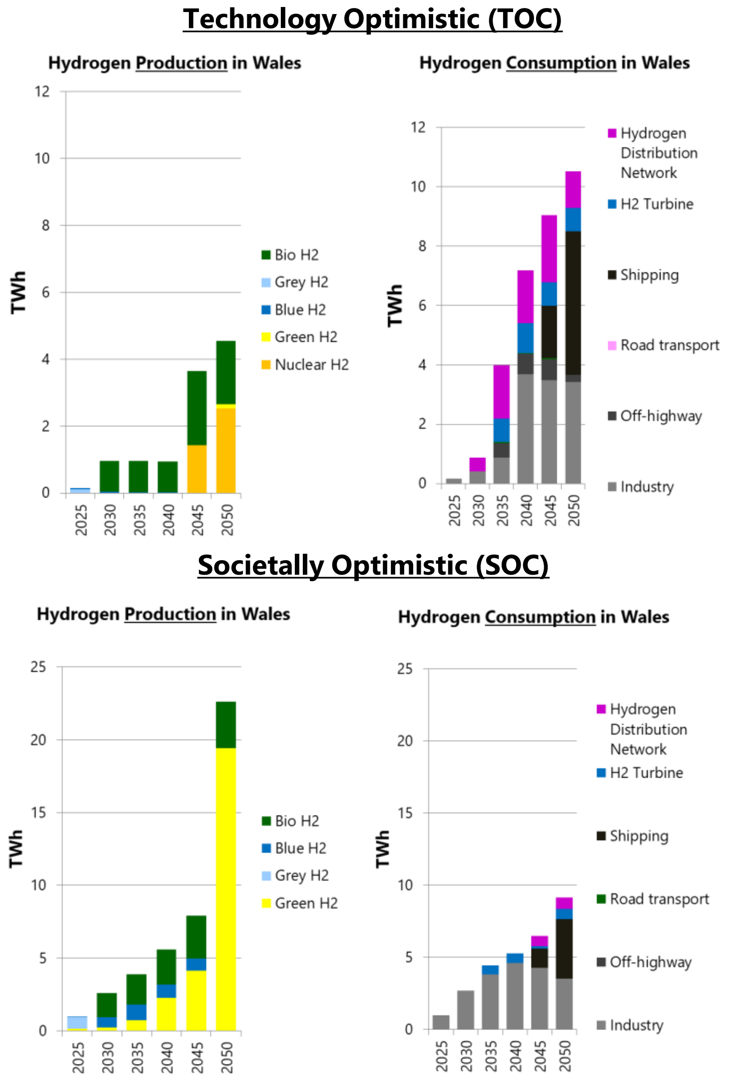


Figure 10: SOC H2 production, consumption compared to TOC H2 consumption, production.

KEY INSIGHT 10. STORAGE AND FLEXIBILITY

The Welsh energy system needs increased flexibility to balance supply and demand with the growth of renewable generation. This includes demand-side response, thermal and electricity storage, and hydrogen storage.

<u>Summary of Analysis</u>

- Increased renewable energy deployment requires new types of flexibility, including demand side response, storage technologies (including batteries and pumped hydro storage), and hydrogen.
- GB electricity and gas networks provide flexibility, allowing energy transfer across regions. Using network flexibility can reduce costs and create economic opportunities, such as increased connection of renewable generation and selling flexibility services to the rest of GB.

<u>Influencing Factors and Dependencies</u>

- Modelling analysis emphasises the significance of effective DSR and a flexible hydrogen system in minimising electricity storage requirements. However, ESME can underestimate the operational need for storage, so it is very likely that more will be needed to address local, regional, and national energy issues. Stakeholder engagement supported this view.

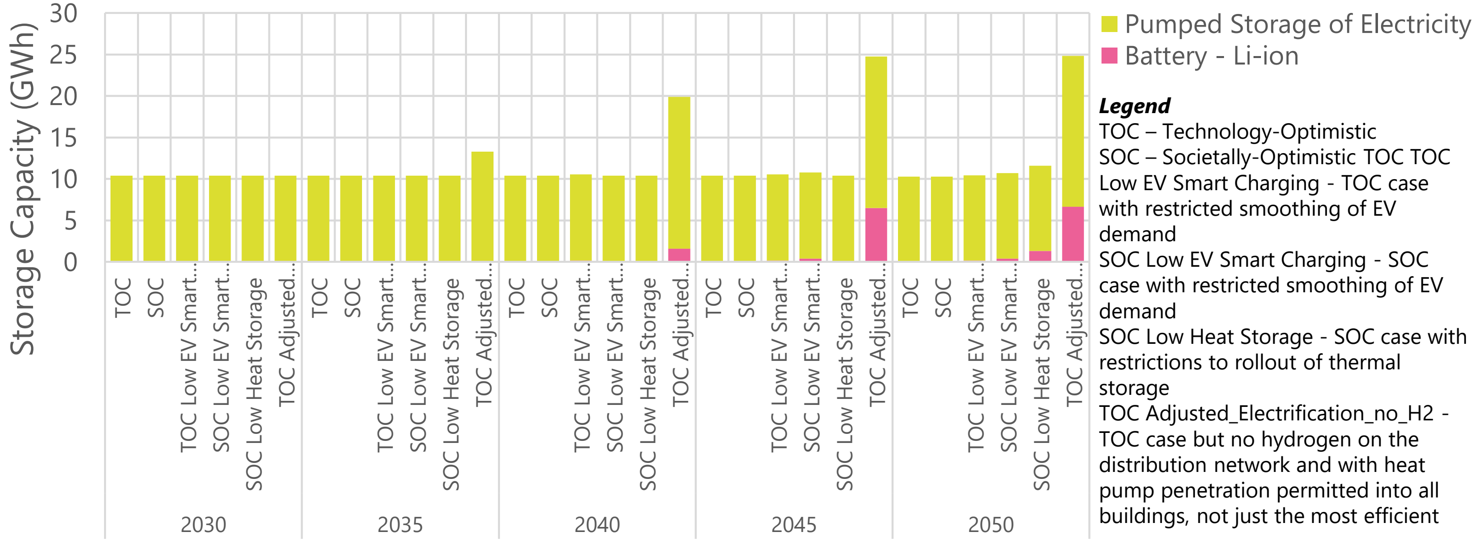


Figure 11: Electric storage capacity for TOC, SOC and selected sensitivities, the chart shows electrical storage volume from 2030-2050 for various pathways. Modelling suggests that additional cost-effective electricity storage beyond existing pumped hydro is not necessary for the period from 2030 to 2050.

<u>Recommendations for Welsh Government</u>

Welsh Government should work with developers and providers to support flexibility and storage projects, which should include continuing to ensure a positive planning environment for projects on the distribution network, where planning is a devolved matter, and working with Local Authorities to support storage and flexibility in domestic properties.

KEY INSIGHT 11. HYDROGEN TRANSMISSION

Hydrogen transmission infrastructure could be needed in South-West Wales from the early 2030s, with timely decision-making necessary for design and construction. In North Wales, potential hydrogen turbines, nuclear power, and a hydrogen transmission network in North-West England, could result in hydrogen production in the area, prompting the need for hydrogen transmission.

Summary of Analysis

- Hydrogen is crucial for various sectors in localised areas in Wales to achieve a cost-effective Net Zero energy system.
- Sectors benefiting from hydrogen include industry, power and heavy transport. Hydrogen network infrastructure will likely be necessary in several regions, particularly South-West Wales and North Wales due to siting of industry and heavy users.
- Gaseous transmission infrastructure in South-West Wales is driven by the need to supply power generation and industry, as well as to access storage facilities in England for system support during low wind conditions. Hydrogen production in North Wales can be linked to the hydrogen infrastructure in North-West England through a transmission network.

Influencing Factors and Dependencies

- The adoption and role of hydrogen in the energy system is still in early stages, leading to high levels of uncertainty.
- Location decisions for hydrogen production and facilities are influenced by global hydrogen trade and electricity generation developments.
- Increased certainty in the availability of hydrogen infrastructure in Wales could reduce uncertainty for Welsh industry, power generation, and heat sectors.

Recommendations for Welsh Government

Welsh Government should evaluate the benefits of a hydrogen transmission network in Wales, considering uncertainties and economic advantages. Collaboration with networks and industry is crucial to quantify potential benefits, costs, and impacts on the Welsh economy. Prompt analysis is recommended due to the lengthy infrastructure development process.

Technology Optimistic (TOC) – Gaseous consumption with Hydrogen in Distribution Network

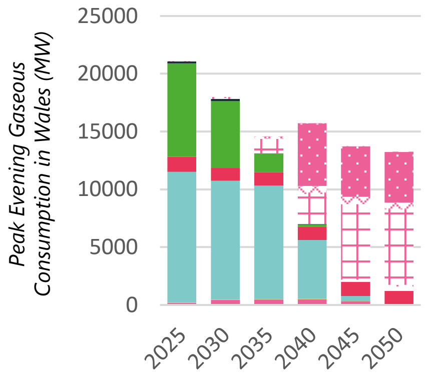


Figure 12 : Technology-Optimistic (TOC) scenario illustrating gaseous peak consumption in MW, showing both natural gas and H2 consumption. H2 consumption is relatively large as it is used for the decarbonisation of heat.

Technology Optimistic (TOC) – Gaseous consumption with No Hydrogen in Distribution Network

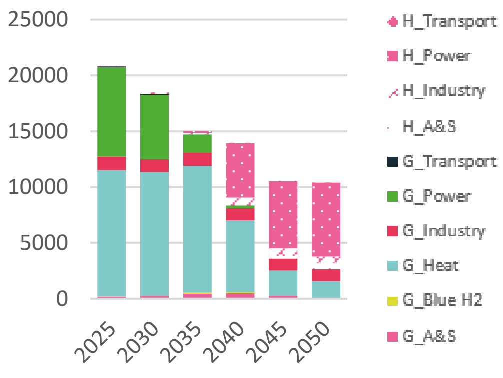


Figure 13 : No H2 Repurpose scenario – a sensitivity conducted where H2 was removed in local distribution networks, which resulted in minimal H2 usage for heat but increasing H2 use for power production. This scenario does not reach Net Zero.

KEY INSIGHT 12. WELSH ENERGY SYSTEM COORDINATION AND INVESTMENT DECISIONS

Llywodraeth Cymru
Welsh Government

CATAPULT
Energy Systems

A new function is needed to represent Welsh aspirations, coordinating with network operators, the Future System Operator (FSO) and other relevant stakeholders, on investment decisions and future planning including the Centralised Strategic Network Plan

Summary of Analysis

- Networks currently plan based on separate scenarios for gas and electricity, making it challenging to incorporate various ambitions and inform decision-making.
- Welsh Government is funding Local Area Energy Plans (LAEPs) by all Welsh Local Authorities to drive energy planning at the local level. A new coordination function can facilitate LAEPs, engage with relevant network operators, and support local decision-making in the absence of an operational Regional System Planner (RSP).
- Planning should consider the interplay between different networks and identify least-cost plans aligned with stakeholders' needs and Net Zero targets.

Influencing Factors and Dependencies

- The proposed function would facilitate collaboration between Welsh Government, Local Authorities, DNOs, and GDNs to enable a whole system approach to alignment and aggregation of LAEPs.
- It would support faster and informed energy infrastructure decisions based on Welsh regional and local plans.
- The function could also serve as an advisor to the Welsh Government on the energy system transition landscape.

Recommendations for Welsh Government

Explore the creation of an independent function focusing on facilitating Welsh whole system network coordination and investment decisions.

This function could facilitate the coordination of LAEPs and engage with the FSO, DSOs, and GDNs. The proposed RSP may eventually fulfil this role, but it's role under consultation so remains uncertain.

Evidence Summary for System Coordination Role

1. ESC's project and stakeholder engagement provides evidence for the need for coordinated planning and anticipatory investment in the energy system, which the suggested function could support.

2. Institutional gaps and lack of coordination between sub-national energy actors act as barriers to anticipatory investment in a net zero energy system.

3. A flexible, strategic, and judgement-based approach to investment decisions for net zero is required to enable networks to facilitate net zero.

4. Greater planning and coordination is needed at the sub-national level, potentially through joined up local energy planning and network planning, to strategically develop infrastructure that delivers local value and benefits networks when making decisions. OFGEM is aiming to address through consultations on Local Network Governance, launched in March 2023.

5. The suggested function can support Welsh Government by providing technical network expertise, bringing the DSO, Local Government, and FSO together to discuss long-term strategic goals, improving coordination between them, and advising local areas on regional investments to drive confidence in network investment.

NETWORK IMPLICATIONS

NETWORK IMPLICATIONS

Network Implication 1: Increases in peak electricity demand will create a need for electricity distribution network reinforcement

The whole system analysis using ESME, carried out in this project, suggests significant increases in peak electricity demand which will require significant electricity network reinforcement, particularly on the distribution network. To provide more clarity on the extent and location of the required reinforcement, increased certainty around the location and composition of generation and end-use demands and future peak network demands is needed. Two areas with significant uncertainty and materiality for electricity networks are how much peak heat demand will be met by electrified options; and how much hydrogen will be produced by electrolysis, which could have a large impact on peak electricity demand. The former is likely to have a more significant impact in the short term as electrified heat options and electric vehicles continue to see increased deployment, whilst the latter could begin to have an impact in the 2030s where there is potential for hydrogen production and demand to ramp up considerably.

Whilst electricity network operators have plans to reinforce in the near-term, through the RIIO-ED2 price control periods, Ofgem’s ASTI process and long-term development statements (LTDS), there is still considerable uncertainty around estimates of future peak demand out to 2030 and beyond, which impacts networks’ ability to deliver reinforcements. The shorter visibility on some demand loads (e.g., EVs, heat pumps) creates challenges for DNOs, but the RIIO-2 uncertainty mechanisms provide an opportunity to respond, as these uncertainties reduce. Improved understanding of likely future peak demands will help to inform the requirement for network reinforcement, which will in turn contribute to enabling networks to invest ahead of need. The uncertainty mechanisms should also be utilised to tackle the current and future challenge of providing additional network connections, both for new distributed generation and additional demand. The future price control structure, currently being consulted on by Ofgem (post RIIO-2, and beyond) should be designed to provide further means to deliver further, timely, anticipatory investment post-2030.

Network Implication 2: The electrification of heat will play an important role in Wales's heat transition, but other strategies should be explored to manage the impact of peak demand on the electricity distribution network.

Electricity networks are designed to meet peak demand, so reducing this can reduce the need for reinforcement requirements. Electrification of domestic heat and transport, will be a major contributor to peak demand which will drive significant reinforcement, particularly in the distribution network. Whilst network operators should prepare for a substantial level of heat electrification, it is important to understand how other technologies and approaches can be leveraged to manage peak demand, and how a combination of these technologies may align within a local area. These options include behind-the-meter thermal storage, DSR, energy efficiency measures, behaviour changes, heat networks and the potential use of hybrid hydrogen boilers in some locations . These are important options to minimise whole system costs by reducing peak demand, and the quantum of reinforcement required. DNOs should maximise the use of innovative approaches to minimise peak demand and accelerate their transition to a DSO, which will also help to optimise supply and demand at the distribution level.

NETWORK IMPLICATIONS

Network Implication 3: Decarbonisation of industry in Wales needs coordinated planning and implementation support

The decarbonisation choices made by large Welsh industrial demand assets will impact the Welsh energy network's transition. There is an opportunity for network companies, across vectors and transmission levels, to work with NZIW, other industry bodies, and Welsh Government to assess decarbonisation options of industry. Industrial clusters should coordinate more with networks and with Local Authorities when implementing LAEPs to make their roadmaps clear to other stakeholders

Network Implication 4: Significant increases in renewable generation will require new electricity transmission network infrastructure.

A significant increase in renewable generation will be needed as Wales decarbonises. The analysis carried out in this project suggests that deployment of offshore wind is the lowest cost option for bulk power supply. However, if other renewable energy technologies such as onshore wind, solar PV and tidal were provided with additional support mechanisms such as improved CfD's or a more positive planning environment across all of GB, then their deployment in the future Welsh (and GB) energy system could increase.

Additional transmission network infrastructure will be needed to bring offshore electricity back onshore (or indeed to transmit electricity generated from increased deployment of onshore renewables) and detailed planning is underway. This includes the North-South transmission link (see Recommendation 7 and section 11). To enable the high deployment of offshore wind needed, or other renewable generation capacity, the delivery of new transmission network infrastructure needs to be accelerated and this will require a regulatory framework which allows strategic and anticipatory investment. This is confirmed by NGESO's HND report.

Network Implication 5: The continued and accelerated development of renewable energy across Wales will add to the challenges involved in ensuring stability in electricity distribution networks and balancing across the transmission network

A large deployment of renewables, which create a supply with peaks and troughs, will increase the need to manage local operability challenges like voltage and fault level, as well as balancing across the whole electricity network. ESC's analysis using ESME suggests total renewable deployment (especially offshore wind in the Celtic Sea) will continue to rise from 3GW in 2020 to 5.7GW and 6.6GW in 2030 and on to 16.1GW and 18.2GW by 2050, for Technology-Optimistic and Societally Optimistic respectively. Network operators will need to be able to plan for and access a range of market technologies including hydrogen-fired turbines, nuclear generation, DSR and batteries to meet these challenges, by procuring balancing services from storage and generation operators, as well as flexibility providers such as aggregators.

Network Implication 6: The quantity, and production methods, of hydrogen could have a significant impact on electricity, natural gas and hydrogen networks in Wales

There is uncertainty around the future scale of hydrogen production in Wales, as well as the technology that produces it. The analysis carried out in this project suggests that in one future scenario, deployment of large quantities of electrolysers between 2045 and 2050, largely to be exported to the rest of GB, could increase annual Welsh electricity demand by around 18TWh. This could have major implications for electricity network reinforcement, and the need for a hydrogen transmission network for export. However, the technological and business model deployed (e.g., hydrogen production coupled with offshore wind generation) will be a significant determinant of the type of network investment required. If blue hydrogen is produced in Wales, as it is in interim years in some scenarios, then this will create some demand for natural gas which will impact the need to retain parts of the natural gas network. Deployment of hydrogen to meet demand, largely for industry and shipping, is likely to be required in the medium- to longer-term, so network operators should understand the range of future quantities and production types of hydrogen and adapt as the future of hydrogen becomes more certain. Network operators should also work with Welsh and UK Government to reduce future uncertainty around hydrogen.

Network Implication 7: Natural gas network operators should explore the need and value for a hydrogen transmission network in Wales.

Natural gas networks owners should continue to investigate the need for, design and feasibility of a hydrogen transmission network in Wales. As noted in Network Implication 6, uncertainty exists about hydrogen production methods and hydrogen's role within Wales and the rest of the UK's future energy system.

However, this project has found it could start to be cost effective for the energy system for parts of industry and use in dispatchable power generation from the early to mid-2030's.

Hydrogen production is possible from a variety of sources including electrolysers, natural gas with CCUS (blue hydrogen), nuclear heat and biomass. By 2050 the most cost-effective system is likely to include green hydrogen and some combination of the other sources. Detailed local analysis will be required to plan exact routes, but the need to transport hydrogen for these purposes away from potential production centres in North Wales (e.g., Deeside, Connah's Quay or Wylfa regions) and in South Wales at Pembroke, is likely.

Large scale hydrogen storage would be required to support hydrogen turbines in South Wales, which are expected to be needed to provide flexibility, system services and to meet peak domestic electrical heat demand. Whilst large scale hydrogen storage options in Wales should continue to be considered, it is likely that geological siting requirements will mean hydrogen storage in England will be required to support demand in Wales. This would require a hydrogen transmission network linking the potential storage facilities in England to the demand in Wales. However, if cost-effective large scale hydrogen storage options can be developed in Wales, then it may be economic for a transmission network to export hydrogen from Wales to England.

NETWORK IMPLICATIONS

Network Implication 8: Demand Side Flexibility can reduce but not remove the impact of peak demands on electricity distribution networks.

DSR options, especially smart EV charging, and smart thermal storage enabled heating, can smooth electricity demand, helping to limit the impact of peak demands in Wales. This could reduce peak demand by 400MW, ~10% by 2050, based on the modelling carried out in this project (see section 12.2). This can impact how DNOs manage peak demands and so increased understanding of levels of smart charging and heating will be important. This should account for uncertainties such as the rollout of the required technologies, consumer engagement, development of suitable business models (e.g., aggregators) and the deployment of digital infrastructure needed to facilitate efficient DSR.

DNOs should harness demand side flexibility to aid in the efficient operation of the distribution networks as well as reducing the overall reinforcement needed, therefore reducing costs. However, rapid progress on developing DSOs and the associated markets and digital infrastructure required to access flexibility already in the energy system is fundamental to achieving this, so should be prioritised and accelerated. LEMs, which aim to establish a marketplace to coordinate energy use and demand within a local area, can be one way to promote the use of demand side options. DNOs/DSOs can then buy flexibility services which the LEM provides.

Network Implication 9: Energy system planning should be carried out on a whole system basis, aligning local, regional and national network activities. Designed and implemented correctly, the Regional System Planner (RSP) could play a crucial role in the medium-term, aligning local, regional and national network activities.

Network operators already engage substantially with Welsh Government. However, understanding the full implications of complex network activity for the Welsh energy system requires specialist knowledge. A whole system approach to effectively coordinate between Welsh Government aims, local plans and network investment plans would increase the likelihood of a cost efficient and optimised Welsh energy system compared to current institutional arrangements.

The precise role of the RSP is yet to be defined (and a separate function may be required in the near term – see Recommendation 12), however, if the RSP is able to effectively coordinate between Welsh Government aims, local plans and network investment plans, this could increase the likelihood of a cost efficient and optimised Welsh energy system compared to current institutional arrangements

NETWORK IMPLICATIONS

Implication 10: All energy networks should explore how whole system network planning can minimise transition costs

This study highlighted the interactions between different energy vectors, for example the impact of other heat sources on electrical heat demand. It also highlights the need for coordination and engagement between a range of energy stakeholders including, Welsh Government, Local Authorities, network operators, industry and Welsh citizens. This demonstrates the need for whole system network planning, where all vectors and actors are considered when planning for energy network infrastructure, to minimise transition costs. Beyond this work, the Welsh Government's own Renewable Energy Deep Dive and Ofgem's recent consultations all reinforce the need for whole system planning. The challenge now is making this a reality. Welsh Government is uniquely positioned to support whole system network planning through their support of LAEPs across all Local Authorities in Wales. Network operators should engage with each other, Welsh Government and Local Authorities (on LAEPs and more broadly) and wider energy stakeholders to help ensure their network plans and investment process take a whole systems approach.

Network Implication 11: There is an important role for heat networks in a Net Zero Welsh energy system

Heat networks can provide a meaningful contribution to total future heat demand in a cost-effective future Welsh energy system, particularly in urban areas with high population density, or areas near a large heat source (e.g. a cogeneration plant fuelled by nuclear power). Analysis from this project suggests heat network deployment could accelerate through the 2030s and provide around 15% (2TWh) of annual building heat demand in Wales by 2050. This could result in an increased number of heat network operators as well as an increased requirement for the skills required to install and operate them. Such networks are also subject to supply and demand variations due to differing demands across the year. As with the electricity system, a heat network solution must be able to accommodate extreme cold spells. The availability of local resource – for example, whether thermal plant or heat pump – will inform the nature of the heat network solution, with heat storage and backup ("peaking") boilers likely to be required.

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GLOSSARY AND ACKNOWLEDGEMENTS

Glossary of Terms:

- ASHP Air Source Heat Pump
- CCS Carbon Capture and Storage
- DSO Distribution System Operator
- DSR Demand Side Response
- ERH Electric Resistive Heating
- ESME Energy Systems Modelling Environment
- ESC Energy Systems Catapult
- EV Electric Vehicle
- GDNO Gas Distribution Network Operator
- FEW Future Energy Grids Wales
- HND Holistic Network Design
- ICE Internal Combustion Engine
- LAEPs Local Area Energy Plans
- NGET National Grid Electricity Transmission
- RSP Regional System Planner
- SWIC South Wales Industrial Cluster
- SMR Small Modular Reactor (nuclear)

