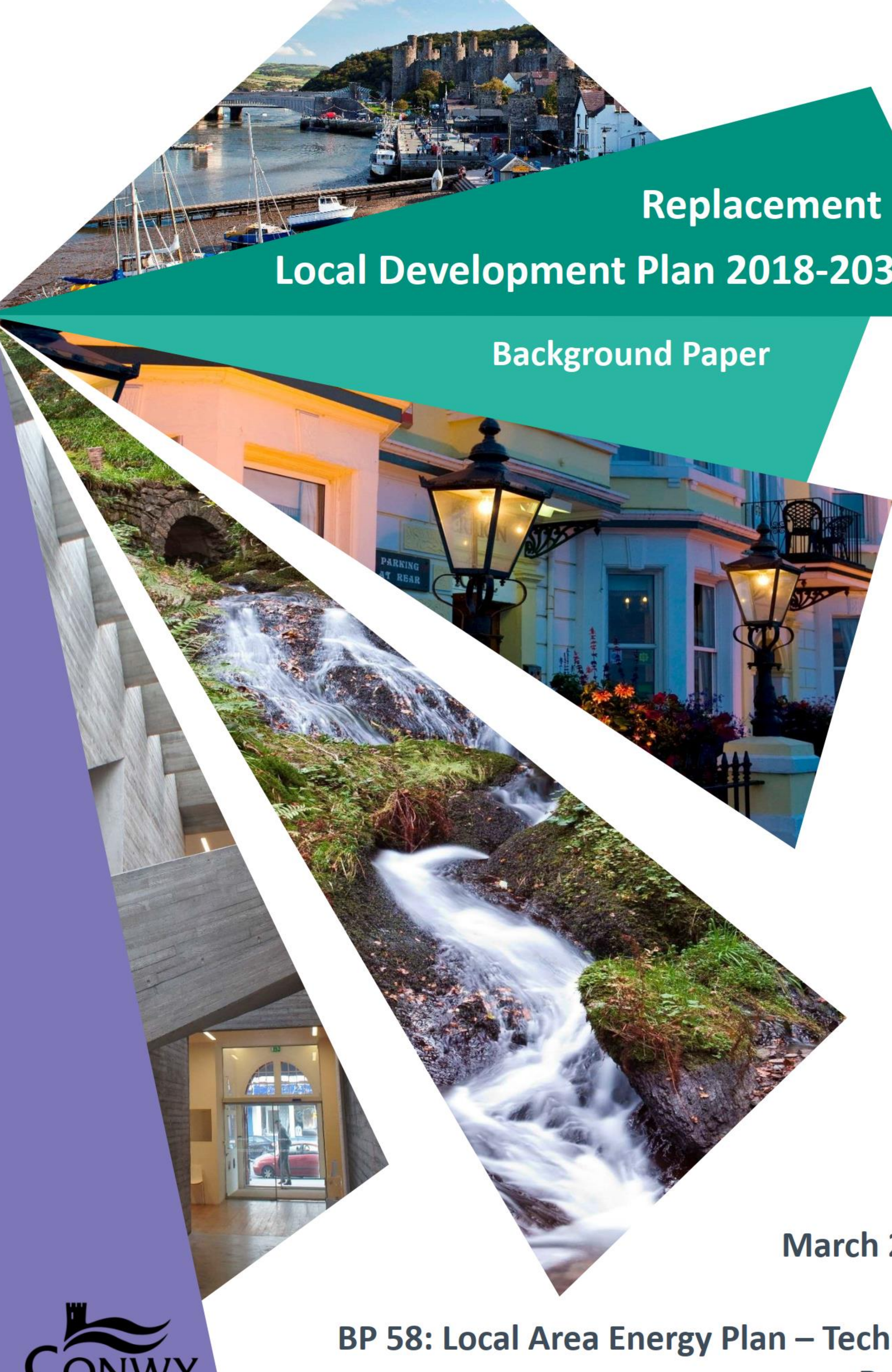


# Replacement Local Development Plan 2018-2033

## Background Paper

March 2022

## BP 58: Local Area Energy Plan – Technical Report

CONWY
CYNGOR BWRDEISTREF SIROL
COUNTY BOROUGH COUNCIL

**Mae'r ddogfen hon ar gael yn Gymraeg hefyd.**

This document is available to view and download on the Council's web-site. Copies are also available to view at main libraries and Council offices and can be obtained from the Strategic Planning Policy Service, Coed Pella, Conway Road, Colwyn Bay LL29 7AZ or by telephoning (01492) 575461. If you would like to talk to a planning officer working on the Local Development Plan about any aspect of this document please contact the Strategic Planning Policy Service on (01492) 575181 / 575445 / 575124 / 574232.

**This document can be provided on CD, electronically or in large-print and can be translated into other languages. Contact the Planning Policy Service on (01492) 575461.**

# Contents



Llywodraeth Cymru
Welsh Government
ARUP

This Plan was prepared by Arup with support from Afallen, on behalf of CCBC and funded by Welsh Government.

# Executive Summary

As we transition to a zero carbon energy system in Conwy, we can see that the scale of change to the system will be truly dramatic and unprecedented.

Conwy's future low carbon energy system will need significant deployment of renewable generation assets in the local area. A relatively high level of off-gas grid properties in 2020 means that installation of heat pumps will be a priority intervention, and there is the opportunity to combine this with a wider retrofit programme.

This report supplements the Conwy Local Area Energy Plan (LAEP) with additional detail about the methodology followed, analysis completed, and the results of this analysis.

**Baseline energy system**

Conwy's energy system today comprises three, mainly separate, systems for heating, electricity and transport. Total energy consumption for these three systems in 2020 was:

- Heating: 840GWh
- Electricity: 240GWh
- Transport: 460GWh

**Future energy system**

Building on the baseline and agreed strategic priorities for Conwy, we developed four main scenarios for a future local energy system. These scenarios were:

- Low demand
- High demand
- High hydrogen
- Islanded high demand

Modelling a range of scenarios allowed us to test the resilience of potential changes in the energy system. This allowed us to have confidence in our modelled results despite the uncertainty around factors that are outside the control of local stakeholders.

For each scenario, we ran a whole systems energy optimisation model which identified the least cost and lowest carbon mix of available energy sources and vectors to meet the modelled profile of energy demand for each hour in 2050.

The results of our modelling indicate the need for significant deployment of technically feasible renewable generation assets in the local area, including:

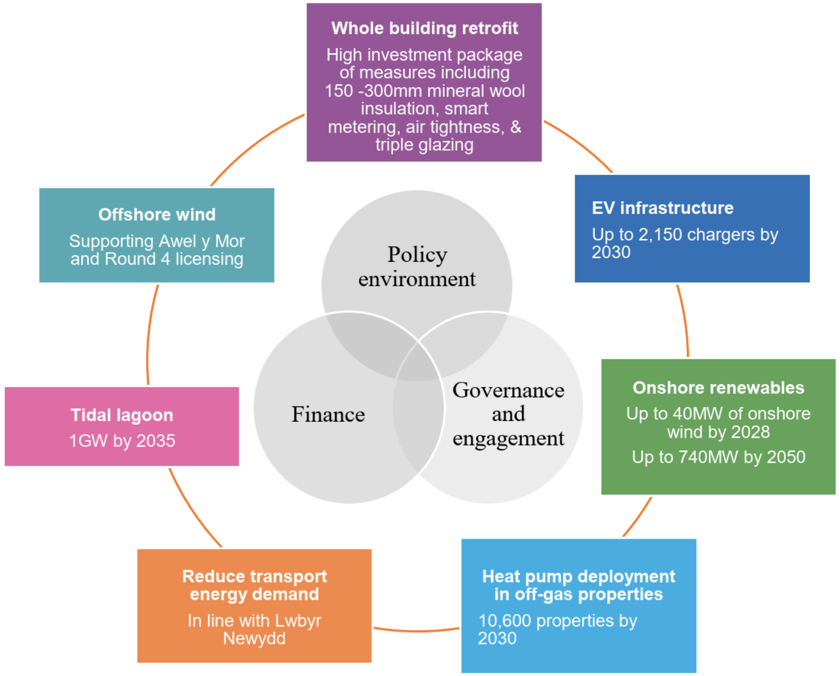
- 760MW of ground PV (maximising technical potential) and between 50 and 95MW of rooftop PV
- Between 40 and 61MW of onshore wind (far below the maximum technical potential)

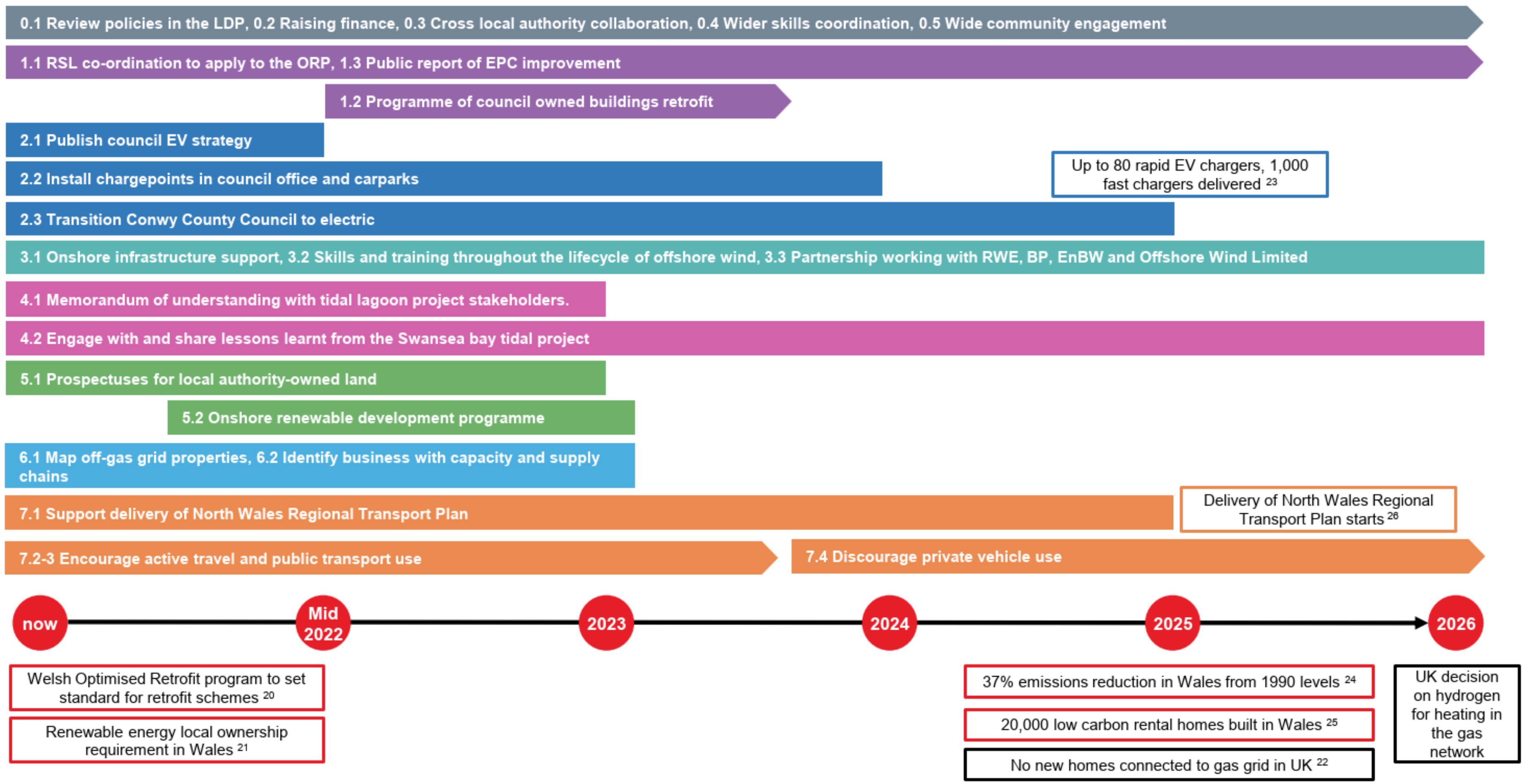
Significant electricity network upgrades and storage are also highly likely to be required in all scenarios.

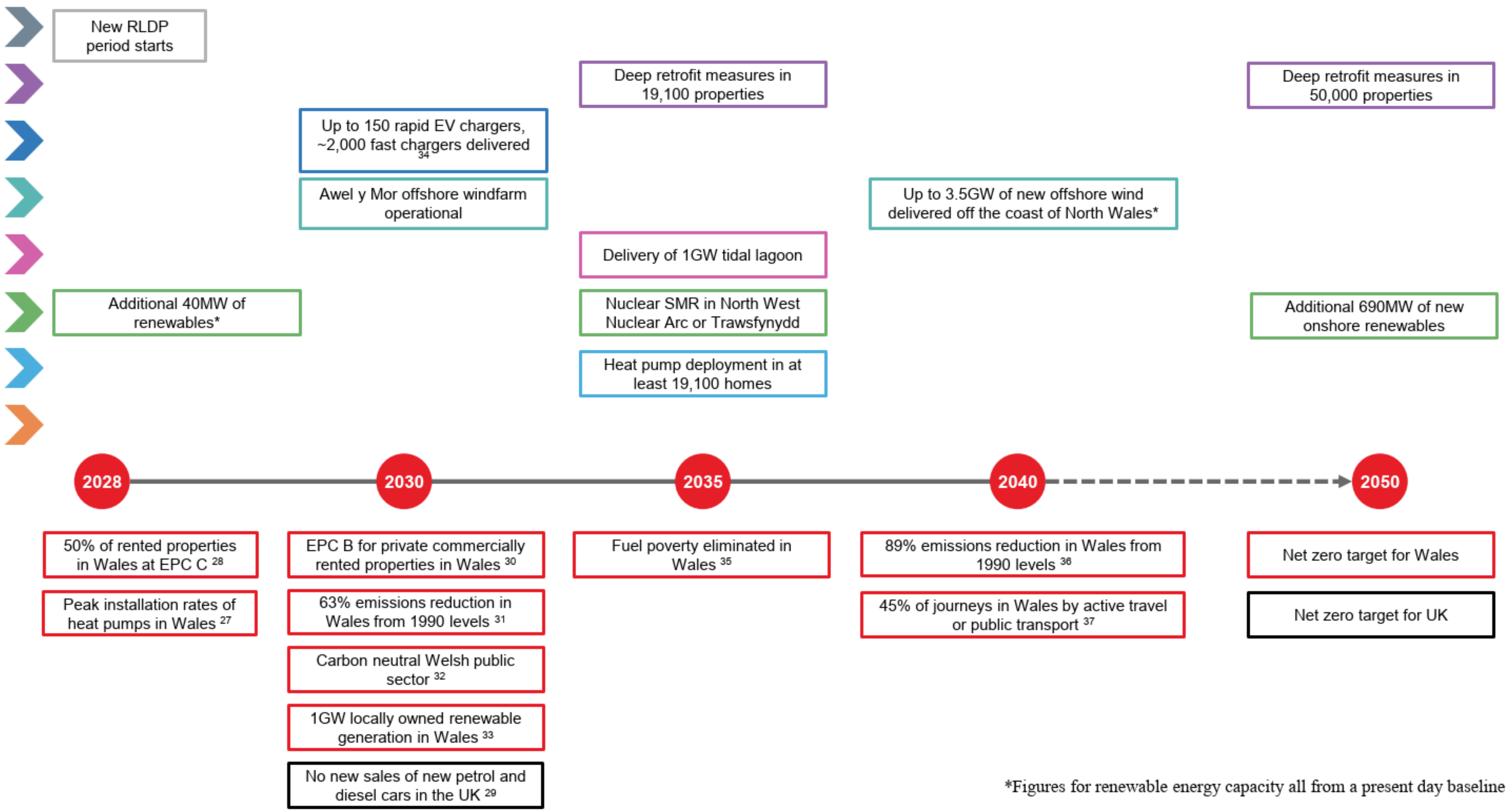
With stakeholder input, we identified priority intervention areas (see right). This plan sets out key actions for the first five years under each of these areas and an indicative roadmap to 2050, shown on the following slides.

We assessed the roles and responsibilities that we have as local authority, and we identified the actions that we can take. Following a review of existing commitments and proposals from other stakeholders, we also identified where we will need input from other partners.

From the evidence presented in this technical report, including our engagement with stakeholders, we developed a Local Area Energy Plan. We will monitor and review progress, and update the Plan over time.




0.1 Review policies in the LDP, 0.2 Raising finance, 0.3 Cross local authority collaboration, 0.4 Wider skills coordination, 0.5 Wide community engagement
1.1 RSL co-ordination to apply to the ORP, 1.3 Public report of EPC improvement
1.2 Programme of council owned buildings retrofit
2.1 Publish council EV strategy
2.2 Install chargepoints in council office and carparks
Up to 80 rapid EV chargers, 1,000 fast chargers delivered [23]
2.3 Transition Conwy County Council to electric
3.1 Onshore infrastructure support, 3.2 Skills and training throughout the lifecycle of offshore wind, 3.3 Partnership working with RWE, BP, EnBW and Offshore Wind Limited
4.1 Memorandum of understanding with tidal lagoon project stakeholders.
4.2 Engage with and share lessons learnt from the Swansea bay tidal project
5.1 Prospectuses for local authority-owned land
5.2 Onshore renewable development programme
6.1 Map off-gas grid properties, 6.2 Identify business with capacity and supply chains
7.1 Support delivery of North Wales Regional Transport Plan
Delivery of North Wales Regional Transport Plan starts [26]
7.2-3 Encourage active travel and public transport use
7.4 Discourage private vehicle use
now
Mid 2022
2023
2024
2025
2026
Welsh Optimised Retrofit program to set standard for retrofit schemes [20]
Renewable energy local ownership requirement in Wales [21]
37% emissions reduction in Wales from 1990 levels [24]
20,000 low carbon rental homes built in Wales [25]
No new homes connected to gas grid in UK [22]
UK decision on hydrogen for heating in the gas network




*Figures for renewable energy capacity all from a present day baseline

# Glossary of Terms

Anaerobic digestion - Processes biomass (plant material) into biogas (methane) that can be used for heating and generating electricity

Batteries - Store electrical energy to be used at a later time

Biomass boiler - A boiler which burns wood-based fuel (e.g. logs, pellets, chippings) to generate heat and electricity

Carbon, Capture & Storage (CCS) - The process of capturing and then storing carbon emissions before they enter the atmosphere

Electrolyser - Use electricity to split water into hydrogen and oxygen

Heat pump - Use a heat exchange system to take heat from air or ground and increases the temperature to heat buildings

Hydro-electricity - Use water falling between two reservoirs to turn turbines to generate electricity

Hydrogen - A flammable gas that can be burned, like natural gas, to generate heat or power vehicles.  The by-product is water

Landfill gas - Micro-organisms in a landfill site produce gases such as methane that can be used as a source of energy

Methane reformation - Process of producing hydrogen by heating methane from natural gas and steam, usually with a catalyst

Microgeneration - Small-scale generation of heat and electricity by individuals, households, communities or small businesses for their own use

Nuclear Small Modular Reactors (SMR) - Small nuclear reactors that can provide up to 300MW of power per unit

Purchase Power Agreement (PPA) - A contract between two parties where one produces and sells electricity and the other purchases electricity.

Renewable Energy Guarantees of Origin (REGO) Agreement - A scheme that tells consumers what proportion of their electricity comes from renewable sources

Resistance heating - Generate heat by passing electrical currents through wires

Sewage gas - Use a reciprocating gas engine to convert sewage gas into heat and electricity

Solar PV - Converts solar radiation into electricity using photo-voltaic (PV) cells

Wind power - Harness wind to turn a turbine to generate electricity

# Introduction

### Introduction to evidence report

### Introduction and report contents

This report supplements the Conwy Local Area Energy Plan (LAEP) with additional detail about the methodology followed, analysis completed, and the results of this analysis.

In this report, we document the approach taken and the results for each of the eight key methodology steps:

1. Define stakeholders and boundaries
2. Review and set objectives
3. Characterise baseline
4. Establish strategic options and priorities
5. Perform optimisation modelling
6. Develop roles and rules
7. Assess risks and benefits
8. Present routemap and recommendations.

This eight-step process integrates Ofgem's LAEP methodology, through which we explored possible energy futures with emphasis on the importance of robust technical analysis and comprehensive stakeholder engagement.

### Overview of approach

Arup, with Afallen, led the development of the plan through this methodology. Engaging with a range of stakeholders such as Welsh Government, the network operators (Scottish Power Electricity Networks and Wales and West Utilities (WWU)) and other local stakeholders enabled us to establish objectives and priorities clearly and effectively.

The modelling provided insights into physical infrastructure requirements, investment decision making, and near-term actions required.

Following the modelling, we reviewed the technology deployment for different scenarios, identified those consistently deployed, and scored them against a matrix of agreed wider objectives. To this, we added the agreed strategic priorities to develop a list of interventions.

These interventions formed the basis of a route map, with recommendations for CCBC to act on in the near term, as well as highlighting input and support needed from others.

Ysgol Bro Gwydir School, Llanrwst, Conwy

## Methodology overview

The eight key methodology steps built on the guidance outlined in Ofgem's methodology, as shown in Figure 1. This section gives an overview of each of these stages.

**1. Defined stakeholders and boundaries**
Laid foundations for the stakeholder engagement of the entire LAEP process by mapping the key stakeholders. Explored the scope of the LAEP, defined our energy system boundary and planned our modelling methodology.

**2. Reviewed and set objectives**
Engaged stakeholders to understand LAEP objectives and prioritised these. Considered the levers which could deliver these objectives.

**3. Characterised baseline**
Developed a detailed understanding of the context of the plan, both in terms of existing policy and the current energy system & associated emissions.

**4. Established strategic options and priorities**
Engaged with stakeholders to understand the priorities that will shape the future energy system. Used this to define scenarios to be modelled.

**5. Performed optimisation modelling**
Created a model for the optimal 2050 energy system under each scenario. This identified how components of the energy system could be located to work together as a unified low carbon system.

**6. Developed LAEP roles and "rules"**
Considered which stakeholders have roles to play in the delivery of the future energy system through a policy lens.

**7. Assessed risks and benefits**
Looked at commonalities across scenarios and factor in qualitative priorities, considered the relative risks and benefits associated with energy system components. Used this to identify high priority recommendations.

**8. Presented routemap and recommendations.**
Matched energy system changes and policy recommendations with relevant stakeholders at key decision points between now and 2050.

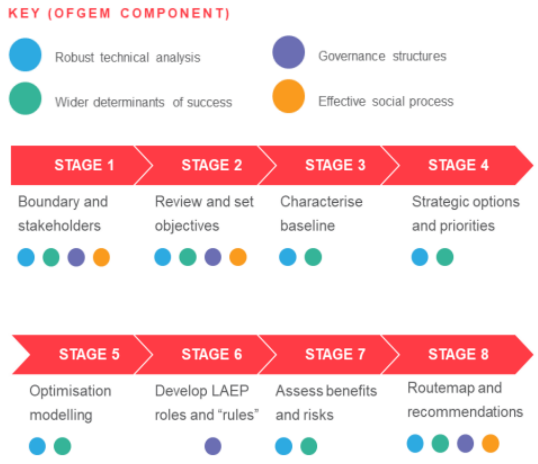



Figure 1: Project approach

# Stage 1: Boundaries and stakeholders

**Boundaries**

Project boundaries were discussed at an early stage in the project and the agreed geographical boundary is shown in Figure 2. Whole energy system modelling was applied at Middle Layer Super Output Area (MSOA) level. There are 15 MSOAs within the Conwy local authority and modelling at this level gave an appropriate balance between having a detailed and meaningful study while also allowing clear findings to be drawn.

In line with Ofgem guidance, boundary considerations included:

- Costs and revenues
- Geography
- Time
- Energy system complexity and scope
- Uncertainty and no regrets
- Other local objectives

Decisions relating to these dimensions are shown overleaf in Table 1. It was agreed that the study should omit any national level generation assets and focus on assets connected to the distribution level grid.

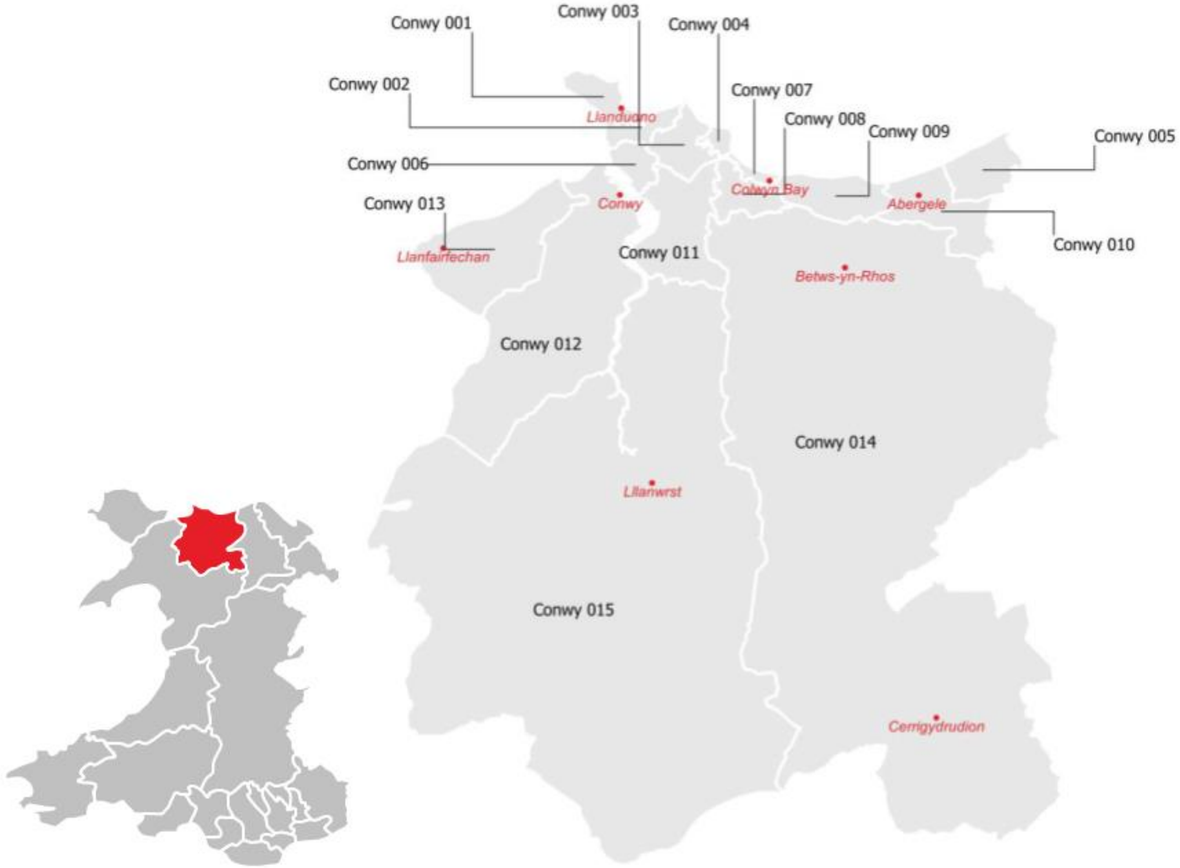



Figure 2: Conwy's location within Wales (left) and project geographical boundary split by MSOA (right)

| Costs and revenues | Geography | Time |
|---|---|---|
| • Include the following costs:<br>  ◦ Monetary – capital and operating<br>  ◦ Carbon – operating costs<br>• Model **cost to society** (rather than a particular stakeholder) to determine optimised overall system. Who pays for what is considered in Stage 7.<br>• Use **wholesale price** for electricity and gas imports.<br>• Compare costs of different scenarios. | • Model local authority energy system as a series of interconnected 'nodes' :<br>  ◦ Granularity at **middle super output area** (MSOA) level.<br>  ◦ Each MSOA node can be connected to geographical neighbours.<br>  ◦ Include option to **import and export** energy carriers from local authority area.<br>  ◦ Import allowed at MSOA nodes that have grid supply points.<br>  ◦ Cross-check with **network capacity maps** to determine where upgrades are needed.<br>• **Exclude national assets** (i.e. above 100MW) because these are on the transmission network and serve GB<br>• **Include national electricity demands** because the data is not split dependent on where the energy comes from | • Two timesteps for quantification:<br>  ◦ 2020 – baseline characterisation<br>  ◦ 2050 – optimisation modelling.<br>• Input **annual** profiles for demand and generation potential on an **hourly basis**.<br>• Modelling outputs to provide annual totals and granular data for peak periods:<br>  ◦ Annual energy generation and consumption<br>  ◦ Detailed hourly modelling for a full year |
| **Energy system complexity and scope** | **Uncertainty and no regrets** | **Other local objectives** |
| • Model existing energy assets, such as renewable generation and energy networks, as minimum capacities:<br>  ◦ Renewable energy capacities based on Energy Generation in Wales and Renewable Energy Planning database<br>  ◦ Network data from SPEN and WWU.<br>• Technologies to be included in model are noted on page 30. | • Use scenarios to test areas of uncertainty and highlight no regrets options.<br>• **Scenarios** – these are defined based on inputs of demand profiles.<br>• **Sensitivities** – these are defined to test critical uncertainties. | Contributions to objectives other than cost and carbon to be considered in Stage 7. |

**Table 1: Boundary considerations**

**Stakeholders**

Stakeholders for the plan were identified jointly with the Council and Welsh Government project team, and then ranked both by likely level of interest and influence on the project.

Stakeholders fell into the following categories: commercial and industrial demand; domestic demand; transport demand; transmission and distribution; generation and storage; and cross-cutting stakeholders.

Within each of the categories, stakeholders were split by which roles they were likely to undertake:

- Design and build
- Own and operate
- Finance
- Policy and regulation
- Research
- Communication and engagement

Through this exercise we identified which key parties to invite to workshops throughout the LAEP process, as well as which stakeholders were likely to have roles in the delivery of the LAEP itself.

# Stage 2: Review and set objectives

### Objective setting

A workshop was held with stakeholders to understand the key objectives for Conwy in the delivery of a Local Area Energy Plan.

A variety of organisations were present including Conwy County Borough Council, Welsh Government, and the North Wales Economic Ambitions Board.

Participants were asked to consider LAEP objectives using the seven well-being goals outlined in the Well-being of Future Generations (Wales) Act as framing. This enabled us to capture the widest possible view of the local objectives that the energy system can contribute to delivering.

From this exercise, we developed a vision and a set of objectives for Conwy, as presented in the final plan, and summarised in Figure 3.

In order to inform our approach to modelling and analysis, we then ranked the objectives in a matrix depending on perceived importance in driving decisions and whether the objective could be assessed quantitatively or qualitatively. This fed into our modelling boundaries, as set out in Table 1 on page 11.

### Understanding the purpose of the plan

In addition to developing objectives for the plan to deliver against, we also considered how the final Plan could be used in order to inform, incentivise, or enforce others to take action in order to support the vision for the future energy system. This supported our analysis in Stage 6 (described on page 41).

- To maximise reductions in carbon emissions while minimising financial costs.
- To provide a resilient energy system capable of meeting future energy demand.
- To empower the local economy, through increasing access to local employment and promoting local ownership and supply chains.
- To support the creation of quality and long-lasting local job opportunities.
- To provide community engagement, leadership, and ownership.
- To deliver affordable solutions for all.
- To account for our varied rural and urban locations

Figure 3: Objectives of the Conwy LAEP

# Stage 3: Characterise baseline

## Characterising baseline policy and emissions

### Overview

In this stage, we characterised Conwy's baseline both quantitatively, through producing demand profiles and examining existing capacities of renewable assets and transmission infrastructure; as well as qualitatively, through review of existing policy. This gave a composite picture of where the energy systems stands today.

### Policy

We conducted a policy review to understand the nature of existing local decarbonisation targets, as well as other key local commitments. From this, we were able to consider if and how the LAEP could be an enabler of these policies. From a local and regional perspective, this included:

- Conwy's Climate Emergency Declaration[1]
- Conwy's Green Programme board
- Conwy's Carbon Management plan for council activities[2]
- Conwy's LDP and RLDP[3]
- Conwy and Denbighshire local well-being plan[4]
- The North Wales Regional Energy Strategy[5]
- Investment plans from Ambition North Wales[6]

The review also set out key UK and Welsh government commitments that the plan could build on and key legislation that the plan should sit within.

The policy review also highlighted positions of important stakeholders including Ofgem, utilities and relevant local community energy groups. The policy review is available in Appendix 1.

### Emissions profiles

We used the Department for Business, Energy and Industrial Strategy's (BEIS) UK local authority and regional carbon dioxide emissions statistics to characterise the baseline emissions profiles, by sector.[7] Note that emissions from land use, land-use change, and forestry (LULUCF) are negligible in comparison to other sectors. These are shown in Figure 4. A further breakdown of emissions is included in Appendix 2.

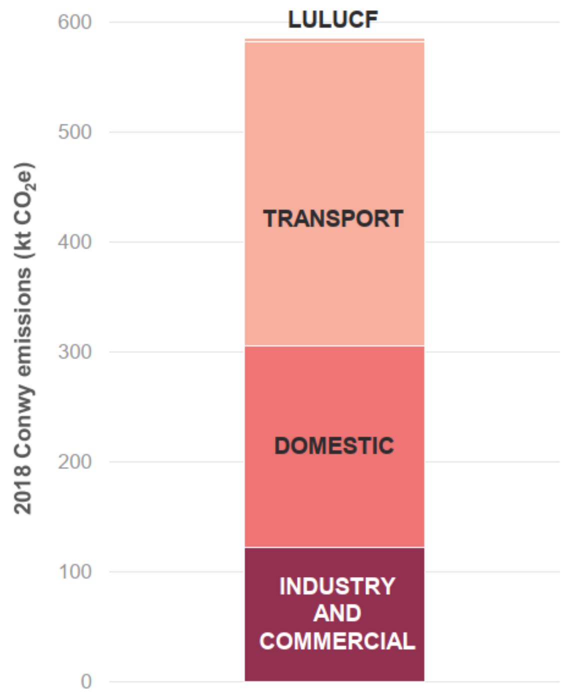



Figure 4: Conwy baseline emissions by sector

**Historic greenhouse gas emissions**

Conwy's greenhouse gas emissions have been decreasing over the past 15 years, following the trend of the wider UK emissions. Figure 5 shows emissions by sector in Conwy since 2005, based on data published by the UK Government.[7]

Decarbonisation of the national electricity grid has driven much of the reductions across the domestic, industrial and commercial sectors.

**Local authority control and influence**

Conwy County Borough Council has a varied degree of control and influence over emissions sources. The UK Government reports emissions that are within the boundary of the local authority (territorial emissions), and also notes those that are within the scope of influence for that local authority.

In Conwy, 70% of transport emissions in 2019 were from A roads, as shown in Figure 6. This includes the contribution from the major A55 dual carriageway.[7]

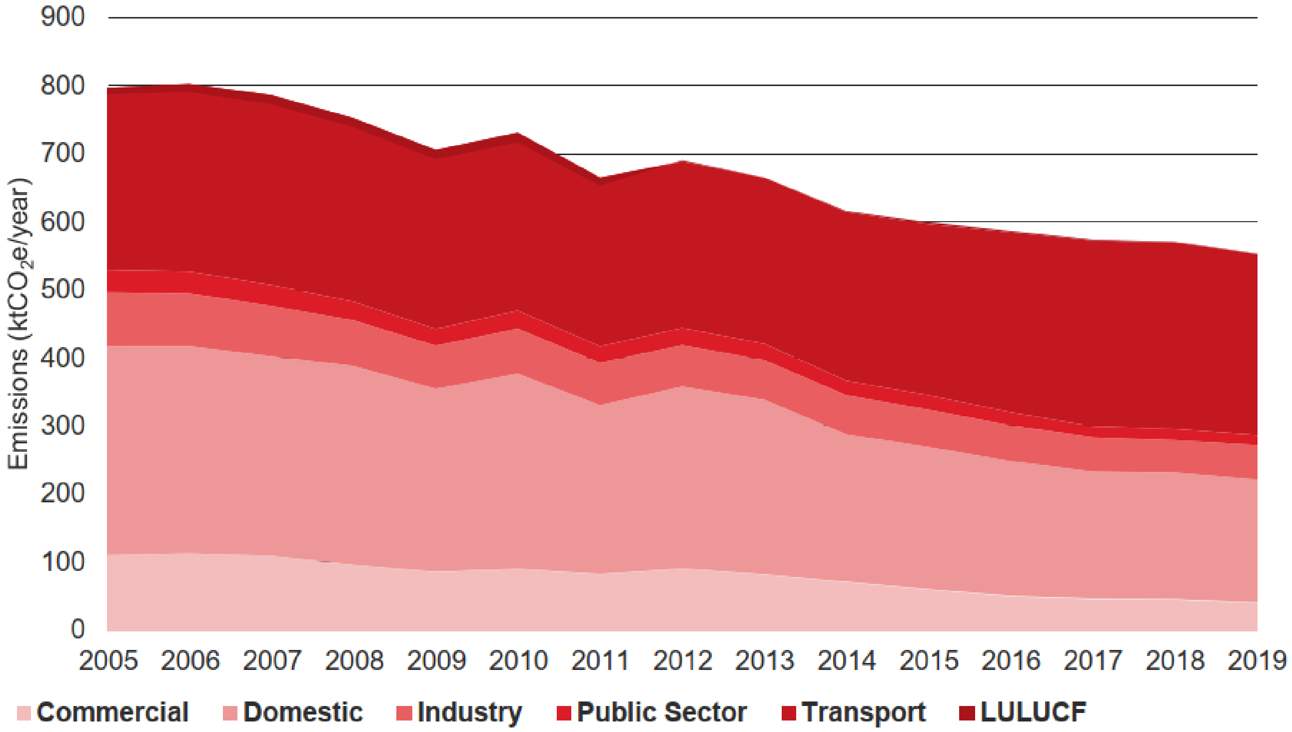



Figure 5: Conwy greenhouse gas emissions 2005-2019

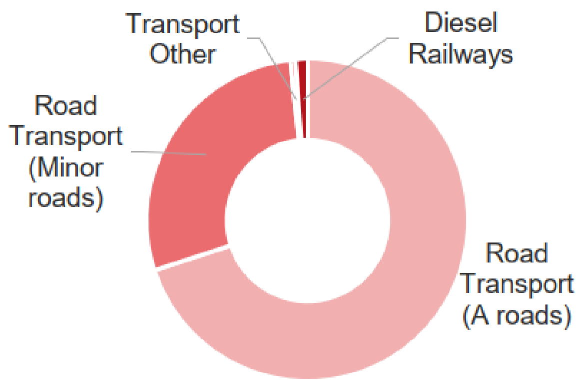



Figure 6: Conwy transport emissions split in 2019

## Characterising baseline energy demands, supply and transmission

In this stage, we established the baseline energy demand in 2020. We modelled this on an hourly basis, broken down into heat, electricity and transport demands.

### Commercial, industrial and domestic electricity and heat demands

We constructed a profile of the energy consumption of each property type for a large sample of properties across the local authority, by connecting the building's Energy Performance Certificate (EPC), building floor area and age to the right archetype and fine-tuning the model to reach accurate levels of energy use. Where buildings had EPCs, these were used to create the energy consumption. An advanced statistical approach was used for the remaining buildings. The sample was scaled to the MSOA level, using Lower and Middle Super Output Areas electricity and gas consumption data from BEIS to produce the annual heat and power consumption.[8, 9] Annual profiles were applied based on building types to create an overall profile for each MSOA. The annual demands for electricity and heating are mapped in Figures 7 and 8 overleaf.

### Heating systems

Information about off-gas properties was obtained from BEIS Lower Super Output Areas (LSOA) estimates of properties not connected to the gas network.[10] The proportion of off-gas properties is summarised by LSOA in Figure 9. The percentage of non-gas properties with heating supplied by electricity is summarised in Figure 10.

### Transport demands

Transport data was received from Transport for Wales (TfW) for journeys beginning in each MSOA which allowed the number of miles per year to be calculated for each area, for each vehicle type (car, buses, vans and HGVs).[11] The total miles per year figures were transformed into hourly time series through scaling by standard hourly transport profiles, and are summarised annually in Figures 11 to 15.

### Transmission and distribution

We used QGIS to analyse network data received from gas and electricity utility providers to quantify the existing connections between each MSOA. This data was given to us under non-disclosure agreements so we are unable to share the outputs.

### Generation and storage

We used data provided through the BEIS Renewable Energy Planning Database and Energy Generation Wales to understand the existing capacity of renewable energy assets.[12, 13] We used Conwy's Renewable Energy Assessment[14] to assign the maximum installed capacity of relevant technologies that could be installed for each MSOA.

**Electricity and heat demand**

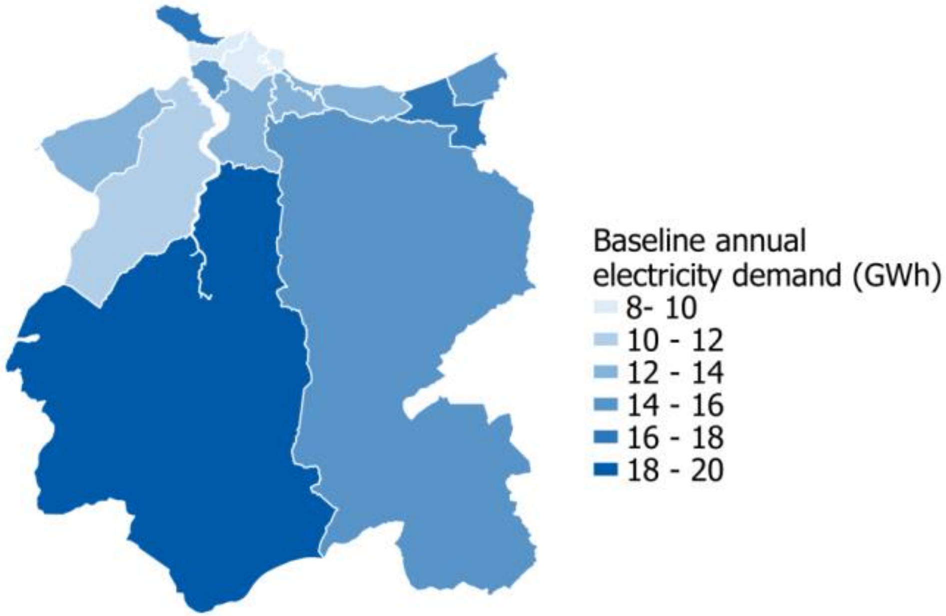



Figure 7: Baseline electricity demand by MSOA

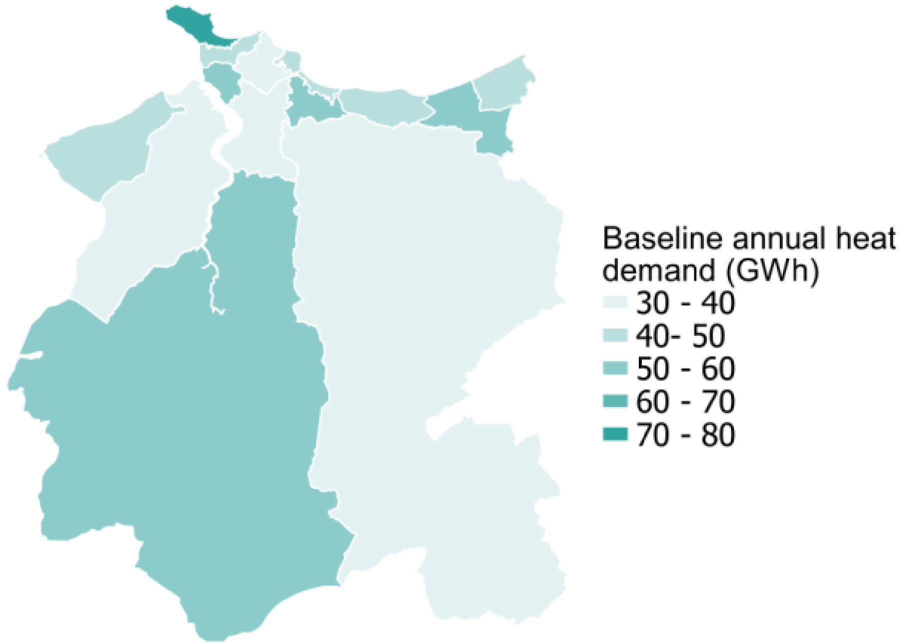



Figure 8: Baseline heat demand by MSOA

**Current heating systems**

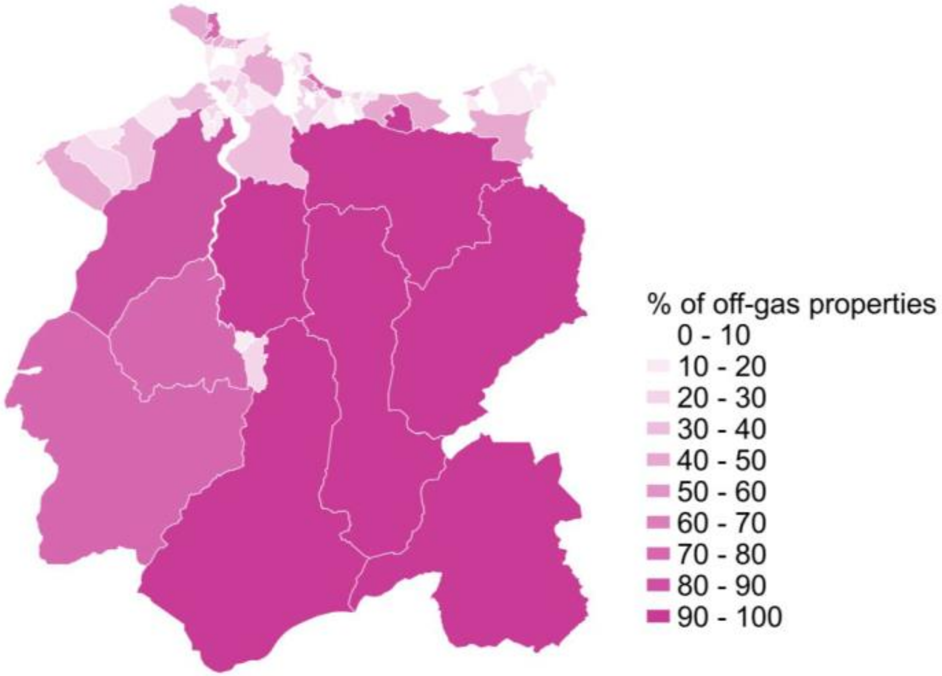



Figure 9: Off-gas properties by LSOA

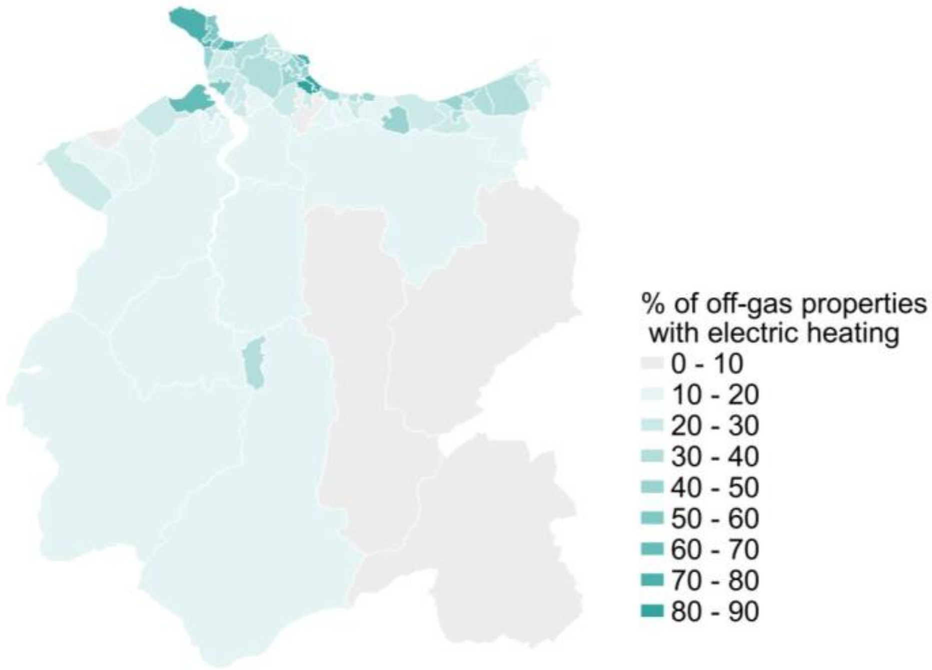



Figure 10: Proportion of non-gas properties with electric heating

## Transport demand

Figure 15: Conwy baseline public transport mileage by MSOA

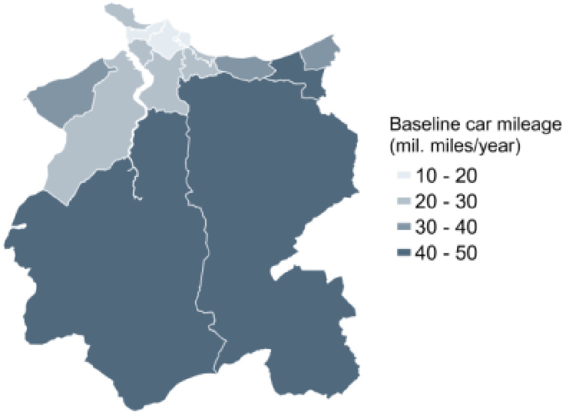



Figure 11: Conwy baseline car mileage by MSOA

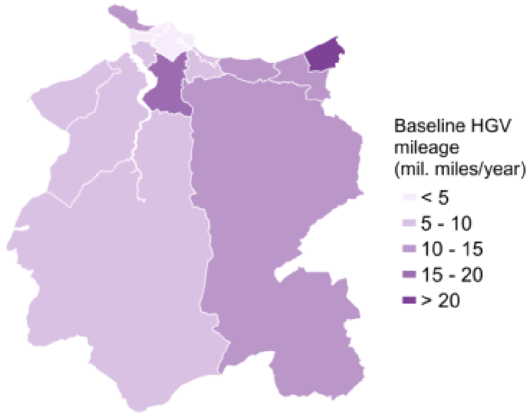



Figure 12: Conwy baseline HGV mileage by MSOA

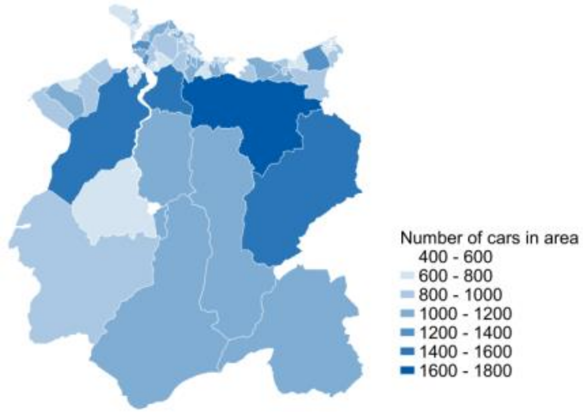



Figure 13: Car ownership by LSOA

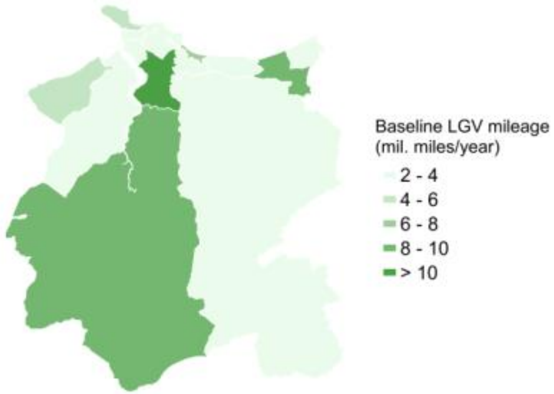
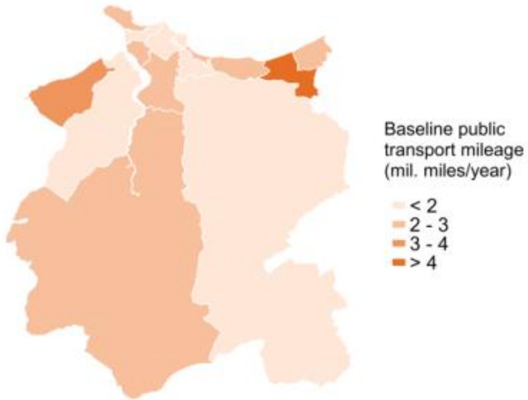



Figure 14: Conwy baseline LGV mileage by MSOA



**Existing renewable supply assets**

As mentioned previously, two datasets were considered when assessing the significant (>5MW) existing renewable energy assets within Conwy:

- BEIS Renewable Energy Planning Database[12]
- Energy Generation in Wales data compiled by Regen.[13]

We used the BEIS Renewable Energy Planning Database to calculate the percentage of wind and solar assets in each MSOA.

We then used figures from Energy Generation Wales 2019 (considered to be a more complete total) multiplied by percentage per MSOA (from the BEIS data set) to get a minimum installed energy capacity for wind and solar per MSOA. For solar, we assumed that >50kW was ground PV.

Despite being included in the BEIS dataset, offshore wind is not included in our evidence base as it is a national asset.

The baseline assessment for onshore wind, ground PV, rooftop PV, and hydroelectricity is shown in Table 2.

| Renewable technology baseline assessment | Existing capacity (MW) | Notes |
|---|---|---|
| Ground PV | 10.3 | Of which all in Kinmel Bay and Towyn (Conwy 005) |
| Onshore wind | 39.9 | Of which 31MW in the Llanwrst & Betws-y-coed area (Conwy 015), rest in Betws-yn-Rhos, Llangernyw & Llansannan (Conwy 014) |
| Rooftop PV | 5.2 | Present in all MSOAs. |
| Hydroelectricity | 34.0 | Of which vast majority in in Betws-yn-Rhos, Llangernyw & Llansannan (Conwy 014) |

Table 2: Baseline renewable energy assessment of significant generation assets

## Baseline Sankey diagram

Conwy's energy system today comprises three, mainly separate, systems for heating, electricity and transport. Figure 16 provides a "Sankey" diagram which, when read from left to right, shows how different energy sources (i.e. fuels and renewable energy resources) meet various types of demand via energy vectors or conversion technologies. The majority of heating comes from gas and almost all transport demand is met by petrol and diesel. Electricity comes from a broader range of sources, the largest contributors being local hydroelectric facilities and National Grid imports.

It is instructive to reflect on the relative consumption between the three main types energy in Conwy: For each unit of electricity consumed, there are more than five units of the other two forms of energy consumed. As we contemplate moving our demands from one vector to another to access low or zero carbon energy sources, we can see that the scale of change to the system will be truly dramatic and unprecedented.

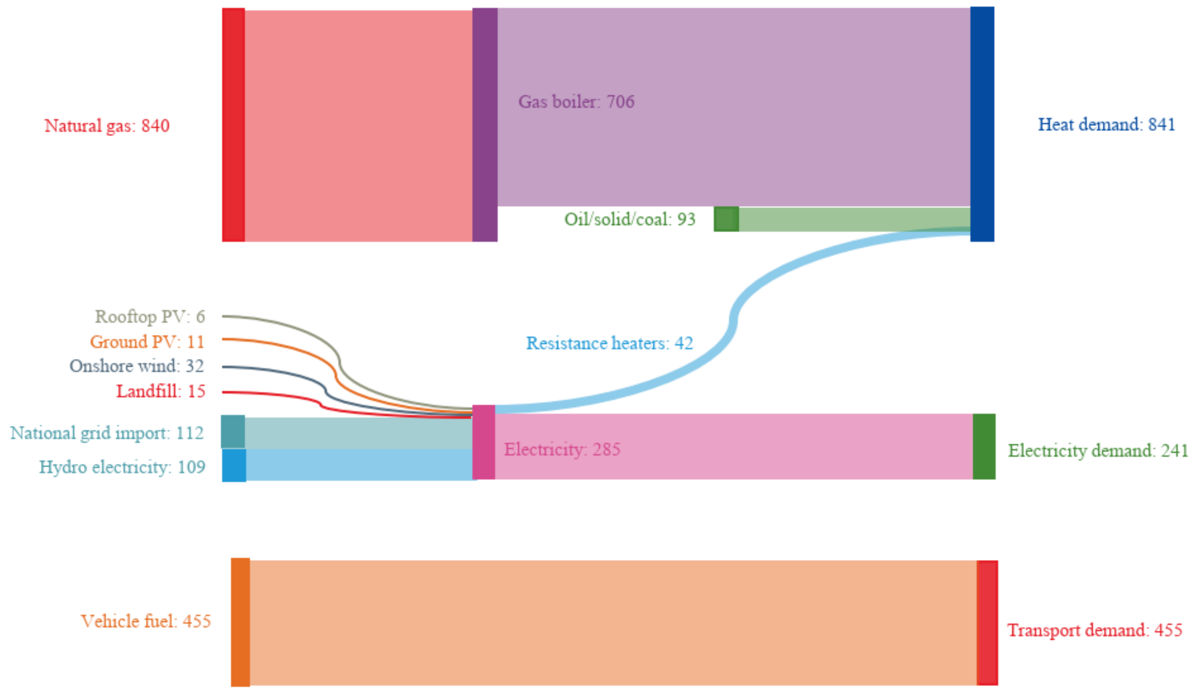



Figure 16: Sankey diagram of energy flows (GWh/year)

## Stage 4: Determine strategic options and priorities

Strategic options and priorities workshop

A strategic options workshop was held in July 2021. Within this workshop, we set out the energy system context for the area and asked participants to feed back their understanding of the local energy system with the key priorities for decarbonisation.

In Conwy, the top three strategic priorities identified for particular focus in the LAEP were:

1. EVs / other transport options
2. Domestic energy efficiency
3. Multi-vector energy systems

Discussion on Conwy's strategic priorities covered a range of topics and options which fell under four main categories – demand reduction, supply, infrastructure and other – and are as follows.

Demand reduction:

- Retrofitting and improving domestic, commercial and public building energy efficiency
- Behaviour change – reduce car use through increased use of public transport and active travel

Supply:

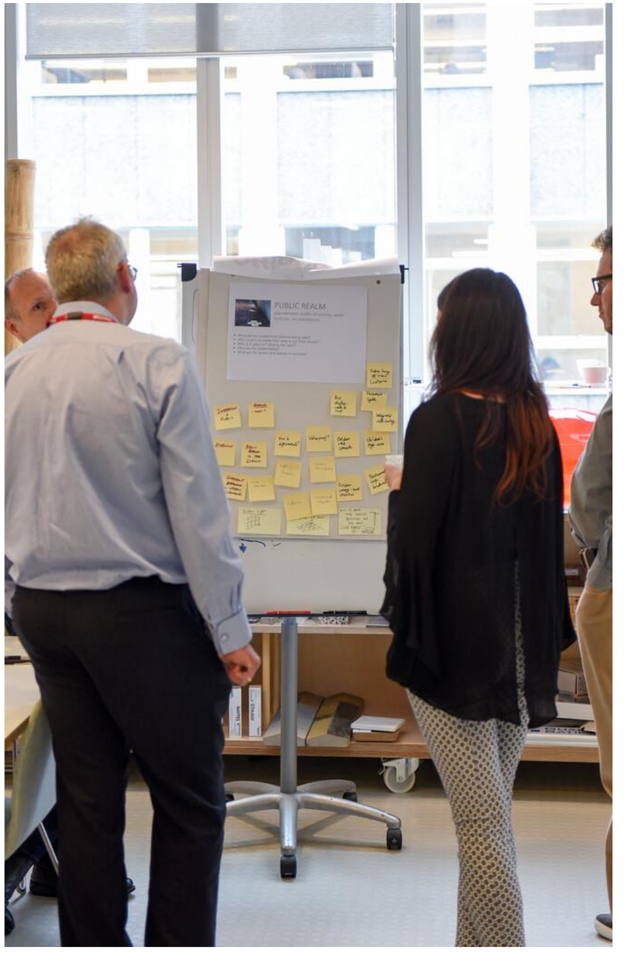
- Need to balance supply and demand, e.g. seasonal variation due to tourism
- Installation of PV in schools
- Need for alternative heating technologies, e.g. hybrid, hydrogen, heat pumps

Infrastructure:

- EV infrastructure, particularly charging
- Grid reinforcement

Other points:

- LAEP results should reflect the role of LAEP within a national context, leadership and responsibility of Conwy, and should recognise the difference in need between rural and urban areas
- Rural properties' reliance on fossil fuels will make switching to decarbonised heating solutions challenging
- Engagement and conversations with local stakeholders will be key
- Using local goods will help reduce carbon footprint of importing



# Stage 5: Optimisation modelling

### Introduction to optimisation modelling

### Modelling purpose

To understand the limitations and opportunities of the future energy system, we constructed a model to represent the complex dynamic relationships between energy vectors and system components.

Using the outcomes of the strategic options and priorities workshop, we identified future demand scenarios to be modelled, to explore the breadth of possible solutions to our future energy system.

Modelling a range of scenarios allows us to test the resilience of potential changes in the energy system. This allows us to have confidence in our modelled results despite the uncertainty around factors that are outside the control of the local authority.

We also modelled a 2020 baseline scenario for comparison of our 2050 system scenarios against an optimised model of today's energy system.

Comparing the outputs of this model in different scenarios and combining this with our understanding of plan objectives and local strategic priorities allowed us to identify recommended actions for the routemap in later stages.

Figure 17 gives an overview of this approach, including how the modelled scenario results were used in the following stages.

Figure 18 overleaf gives a more detailed overview of the optimisation modelling process contained within the dotted line.

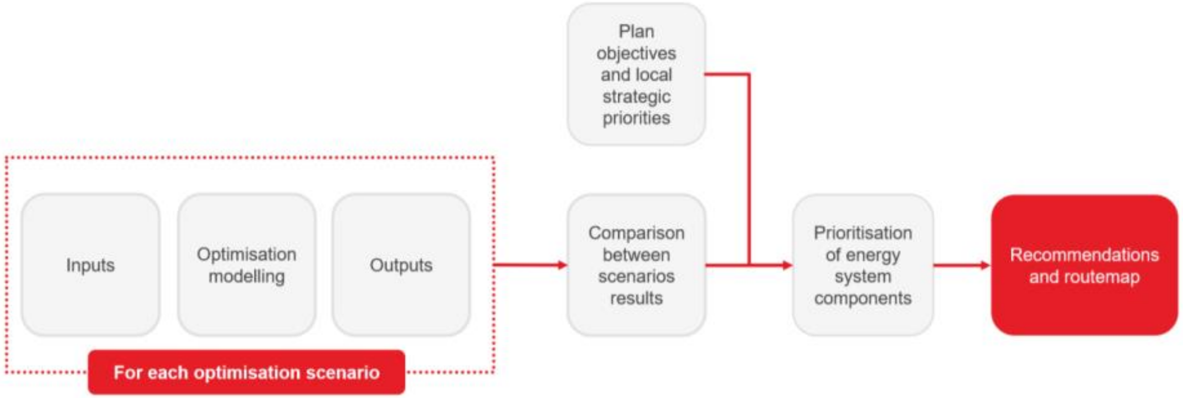



Figure 17: A high level overview of the role of scenario modelling in creating LAEP recommendations

## Modelling approach

Modelling was conducted using an open-source linear optimisation package, with a database and python wrappers to ensure efficiency and minimise errors.

Figure 18 gives an overview of the approach taken in a single scenario. This approach was repeated for each of the four 2050 scenarios, as well as the baseline 2020 scenario.

For each modelled scenario, the inputs shown on the left were collected and fed into the model, which optimised technology mix and dispatch.

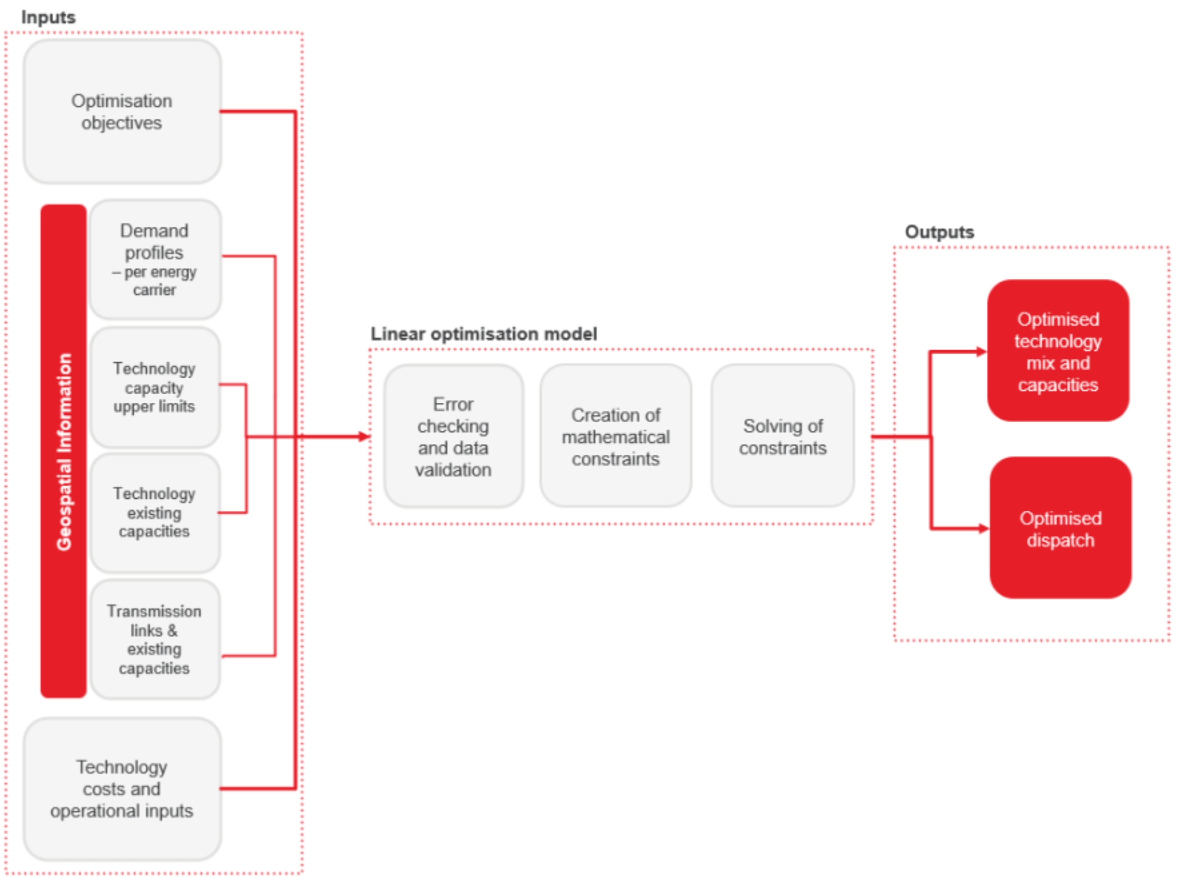



Figure 18: Optimisation model overview including inputs and outputs, for one scenario

**Scenarios based on strategic options and priorities**

Using the outcomes of the strategic options and priorities workshop, we identified scenarios to model to explore the breadth of possible solutions to our future energy system.

Modelling a range of scenarios allowed us to explore and test different combinations of potential changes in the energy system and to understand how complex trends such as population growth, migration and climate change can be planned for. This allowed us to have confidence in our modelled results despite the uncertainty around factors that are outside the control of the local authority.

We identified four key scenarios for 2050 in addition to a 2020 baseline model for our analysis. These are shown in Figure 19, with a detailed breakdown of what is included and excluded from each scenario given over the subsequent pages.

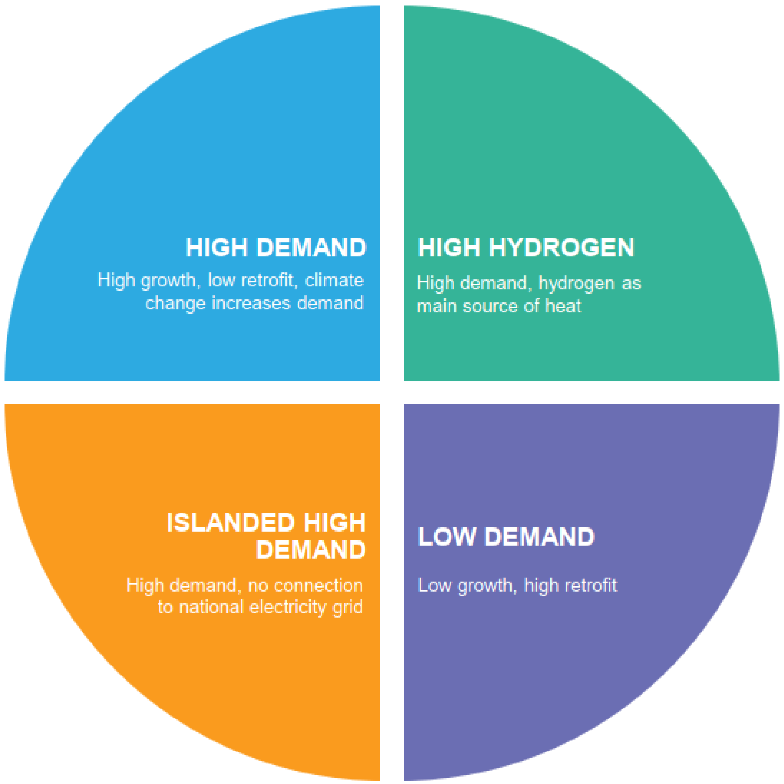



Figure 19: Modelled 2050 scenarios for Conwy's LAEP

**Baseline, low and high demand scenarios**

Heat and electricity demand form two of the most fundamental and impactful inputs to the modelling approach, each with several contributing factors to uncertain futures. With these components overlapping and influencing all three of the strategic priorities for Conwy, we chose to model two separate demand scenarios: High Demand and Low Demand.

Our demand assumptions for the these scenarios are summarised in Table 3.

Population growth and economic predictions were used to project 2050 demands along with the anticipated changes in demand for high and low demand (depending on retrofit).

TfW provided baseline and projected (2036) transport demands.[11] Transport projections closer to 2050 or in a higher level of detail were not available, so the 2036 projection was used across all 2050 scenarios. In practice, transport demand would be expected to vary in line with factors such as population and commercial growth. If more accurate projections become available in the future a further study could be valuable to understand the magnitude of the impact a higher or lower transport demand could have on the energy system.

| Scenario | 2020 baseline | 2050 low demand | 2050 high demand |
|---|---|---|---|
| **Growth rates** | None – based on current data | • 0.2% - Conwy's current population annual growth<br>• 1% commercial annual growth<br>• 1% industrial annual growth<br>• 2036 transport growth provided by TfW | • 0.4% - Conwy doubled (assuming more single households by 2050) population annual growth<br>• 2% commercial annual growth<br>• 2% industrial annual growth<br>• 2036 transport growth provided by TfW |
| **Retrofit uptake** | Based on current data | High retrofit investment:<br>• Low retrofit +<br>• Add 150mm mineral wool insulation below floor<br>• Utility and specific metering<br>• Add 150mm external mineral wool insulation and rendering<br>• Improve air tightness<br>• Increase loft insulation by/to 300mm<br>• Replace ventilation units<br>• Window sealing<br>• External solar devices<br>• Replace with triple-glazed coating windows | Low retrofit investment<br>• BMS check<br>• Temperature set point calibration<br>• Upgrade to LED lighting and improve controls<br>• Incorporate VSDs to HVAC motors<br>• Power factor correction<br>• Ventilation ducts swept, airflow measured and adjusted<br>• Recommission ventilation<br>• Check/repair ductwork leakage<br>• Optimise free cooling<br>• Internal solar control |
| **Climate change** | None – based on current data | • Based on historical climate data | • Weather extremes that increase energy demand |

Table 3: A summary of defining characteristics of the baseline, low and high demand scenarios

**Energy demands in high and low demand scenarios**

Figure 20 shows energy demands for the high and low demand scenarios.

As shown by the graph, there is significantly higher demand for heat in the high demand scenario and a slightly higher demand for electricity. This is due to the inclusion of deep retrofit measures in the low demand scenario as described in previous sections, resulting in significant demand reduction

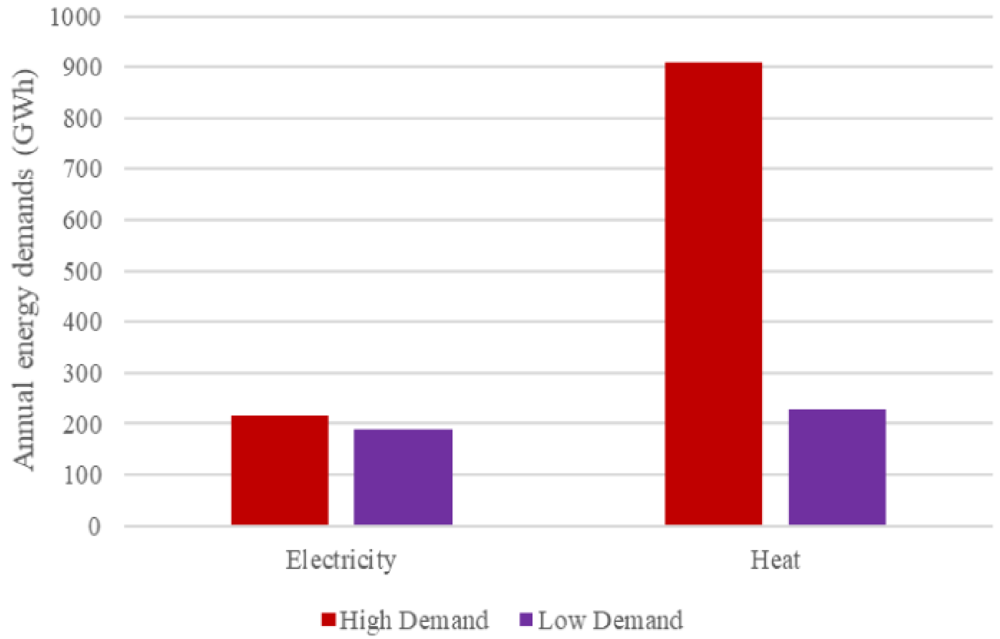



Figure 20: Annual heat and electricity demand in the high and low demand scenarios

**High hydrogen and islanded high demand scenarios**

The potential future role of hydrogen in the energy system is a source of some uncertainty, not only in Conwy but nationally. With multi-vector energy systems identified as a key priority for Conwy, to test this potential future energy system we included a High Hydrogen scenario, in which hydrogen is assumed to play a significant role in meeting heating and industrial demands.

To do this, specific hydrogen demand profiles were generated. In the high hydrogen scenario, we assumed all on-grid gas homes would transition to hydrogen by 2050. Estimates for the number of on gas grid homes by MSOA was taken from BEIS' MSOA estimates of properties not connected to the gas network.[10] Hourly heat and hydrogen heat demand profiles were generated by utilising standard demand profiles from Arup.

Finally, to test our potential energy system to its furthest limit, we included an Islanded High Demand scenario, in which energy demand are assumed to be high and Conwy is completely autonomous from the national grid, operating an energy system with no imported electricity. This allows us to understand the most extreme case for the future energy system.

Table 4 gives an overview of these scenarios.

| Scenario | 2050 high hydrogen | 2050 islanded high demand |
|---|---|---|
| **Growth rates, retrofit uptake and climate change** | • As 2050 high demand. | • As 2050 high demand. |
| **Demand profile** | • Assumed all on-gas grid homes in each MSOA transition to hydrogen by 2050.<br>• Hydrogen demand profiles generated for 2050 high demand heat profiles and assuming boiler efficiencies of 84%. | • As 2050 high demand. |
| **Technologies allowed** | • Hydrogen boilers to meet domestic hydrogen demand. All other technologies allowed. | • National grid electricity imports not allowed. |

Table 4: A summary of defining characteristics of the high hydrogen and islanded high demand scenarios

## Characterising technologies – constraints, costs and emissions

The scope of technologies included in the energy system model are broadly categorised as supply, demand, conversion, transmission and storage.

Figure 21 overleaf shows the technologies and carriers (energy vectors) that were modelled for Conwy's LAEP.

For each technology we collected key information defining costs, deployment and relationships with other technologies. The key parameters collected are summarised in Table 5. These parameters are then used in the linear optimisation approach build up a representation of the entire energy system and optimise for a solution that minimises cost and operational carbon emissions. The results created by the model include choices on how to meet each demand, such as whether hydrogen or electricity should be used for transportation or heating.

Alongside the baseline information collated on demands, existing energy assets and potential renewable locations and capacities, this information was loaded into a database. Automated python scripting was used to handle this data and transform it into formatted model inputs in preparation for running the model. This approach ensured efficiency and consistency, and minimised opportunities for manual errors.

There are challenges to projecting out many of the technological data parameters, and some will carry greater confidence than others. Novel technologies, for example, might have a wider spread of potential costs in 2050 depending on the source consulted. For quality assurance purposes, sources of costs and details of any data transformations taken to normalise all units were stored alongside their values in the database.

| Technology data parameters |
| --- |
| Technology costs<br>• Capex (£/kW capacity)<br>• Opex (£/kWh output) |
| Technology emissions<br>• Operational carbon emissions ($tCO_2e$/kWh) |
| Technology essentials<br>• Efficiencies where applicable (%)<br>• Technology lifetime (years) |
| Technology constraints<br>• Maximum technology capacity per MSOA where applicable (kW)<br>• Minimum renewable energy technology capacity per MSOA, from baseline assessment (kW)<br>• Minimum connection capacities between modes. |

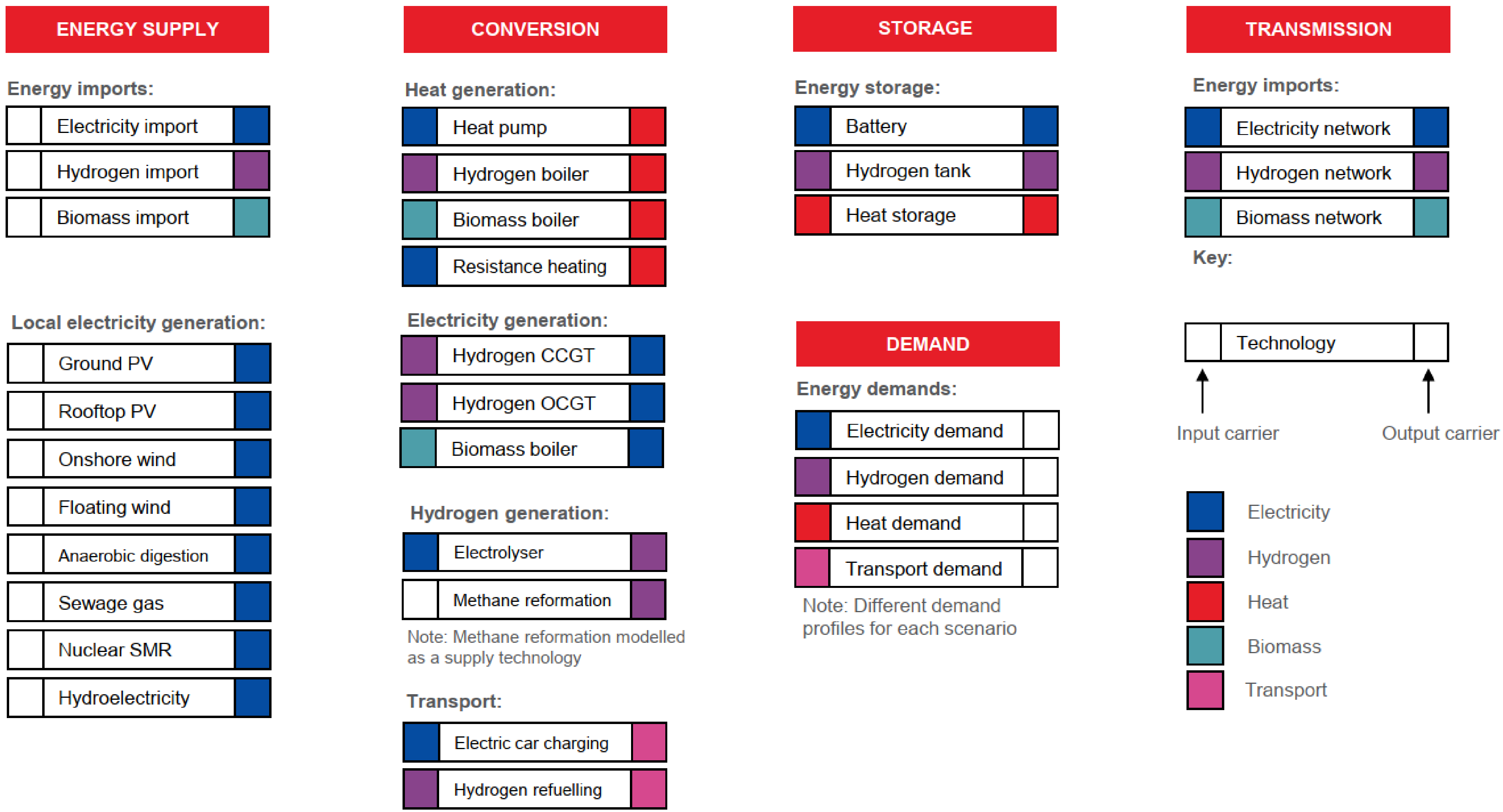



Figure 21: Technologies included in optimisation modelling

# Stage 5: Optimisation modelling – results

**Modelling results – overview**

Figures 22 to 25 show the energy flow Sankey outputs for each scenario.

Comparison of all of these with the baseline scenario shown in Figure 16 highlights a key fundamental change in the energy system: moving from three semi-isolated systems for heat, electricity and transport to a single coherent energy system which capitalises on the complex interconnections between energy vectors.

For readability, some results in this section focus on the low demand scenario only.

**Building energy efficiency**

Reducing energy demand from buildings is a key step in our transition to net zero. This comprises:

- Improving controls and introducing LED lighting
- Insulation of walls, roofs and floors
- Installing triple glazed windows.

**Electrification of heat and transport**

Electrification of heat and transport are included in all scenarios. Battery electric vehicles are currently more competitive than their hydrogen counterparts, and heat pumps deliver greater efficiencies than hydrogen boilers. Hydrogen boilers are only deployed at scale in the high hydrogen scenario, where domestic and non-domestic heat demand is forced to be met with this technology.

**Onshore renewables, low carbon generation and storage**

Electrification of heat and transport requires significant amounts of new generation assets: around 760MW of ground PV and between 50 and 95MW of rooftop PV. This quantity of ground PV would cover approximately 760 hectares – equivalent to 1,000 football pitches – which is less than 0.1% of the total area of the county borough. Deploying this much rooftop PV would see solar panels on between 12,500 and 23,750 rooftops, representing between 22% and 41% of total dwellings in Conwy.

In addition to this, our modelling suggests deployment of between 150 and 250GWh of battery storage with a connection to the national grid of up to 160MW. This capacity would constitute a mixture of long-term storage including stationary batteries at grid level for maximising use of highly variable wind generation and the abundant solar resource during summer months; and shorter-term batteries for utilising rooftop PV and variable energy tariffs in meeting daily energy demands.

There is an estimated technical potential for up to 2.8GW of onshore wind capacity in Conwy. However, the optimised system never builds more than 61MW, equivalent to around 24 turbines.

This analysis of renewable technology has focused around cost and carbon factors. Other land use requirements and the RLDP policy should be taken into consideration.

In the high demand scenario, a small amount (44MW) of nuclear SMR is built. We suggest that nuclear SMR is unlikely to be located in Conwy, but rather within the North West Nuclear Arc. Significant (up to 10%) amounts of electricity may come from existing hydroelectricity assets, but these are aging and must be maintained or replaced.

### Hydrogen

In the high hydrogen scenario, where we model hydrogen for heating, hydrogen boilers are forced to provide a approx. two thirds of heating demand. Under this constraint, the modelling results show electrolysers providing up to 23% of the hydrogen for heating, the remainder is supplied from methane reformation with CCS and general imports. We consider that Conwy would not invest in methane reformation plants but would import hydrogen from HyNet North West. Electrolysers are not deployed in our core scenarios, but are deployed in the islanded scenario, suggesting that they could potentially be piloted in the future to provide resilience.

### Heat networks

Heat networks were assessed as a potential source of heat in Conwy but with a limited number of high demand density areas and no major heat sources, were not found to be viable.

The following section of the results presents Sankey energy flow diagrams for each of the four 2050 scenarios. As previously, when read from left to right, these diagrams show how different energy sources meet various types of demand via energy vectors or conversion technologies.

### Modelling results – Sankey diagrams

Comparing the high demand (Figure 22) and high hydrogen demand (Figure 23) scenarios highlights key differences between the two. Using hydrogen to meet heat demand results in a system with the same quantity of renewable electricity generation, but a smaller amount of electricity imported from the national grid. Electricity that would otherwise have been used for low carbon heating is instead used in electrolysis to generate around 30% of Conwy’s hydrogen, with the other 70% coming mainly from methane reformation.

Removing connection to the national grid in the islanded scenario (Figure 24) results in a hybrid heating future. In this scenario, both electricity and hydrogen are using for heating, but with a majority still dependent on electricity.

The low demand scenario (Figure 25) is similar to the high demand scenario, but with a smaller quantity of national grid import and a lower capacity of renewable generation. All heat and transport demands are met using electricity in this scenario.

## Modelling results – Sankey diagrams

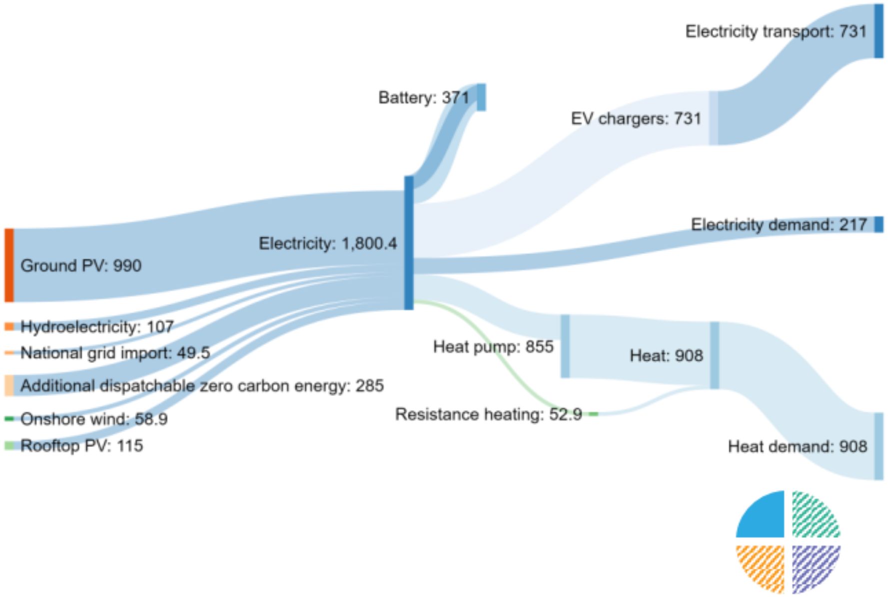



Figure 22: Energy flows in the 2050 high demand scenario (GWh/year)

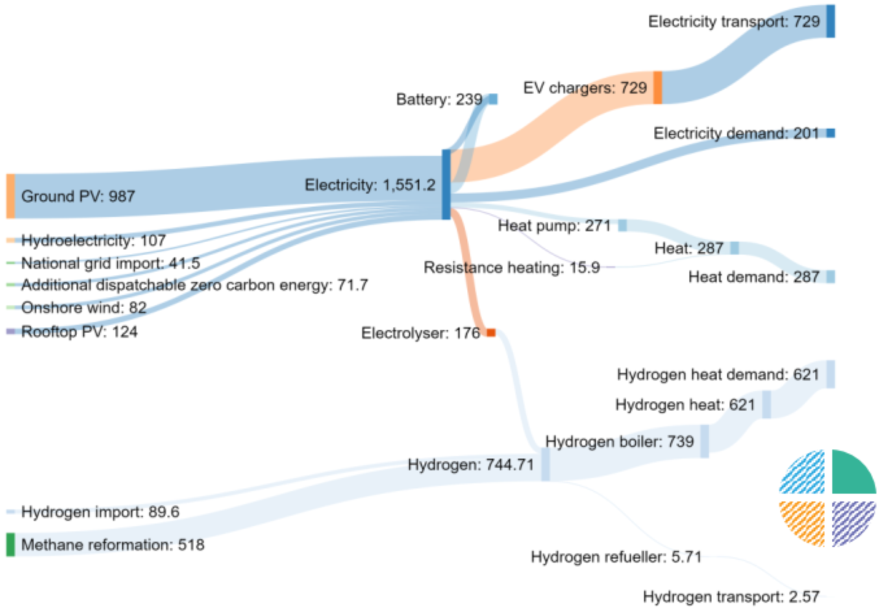



Figure 23: Energy flows in the 2050 high hydrogen scenario (GWh/year)

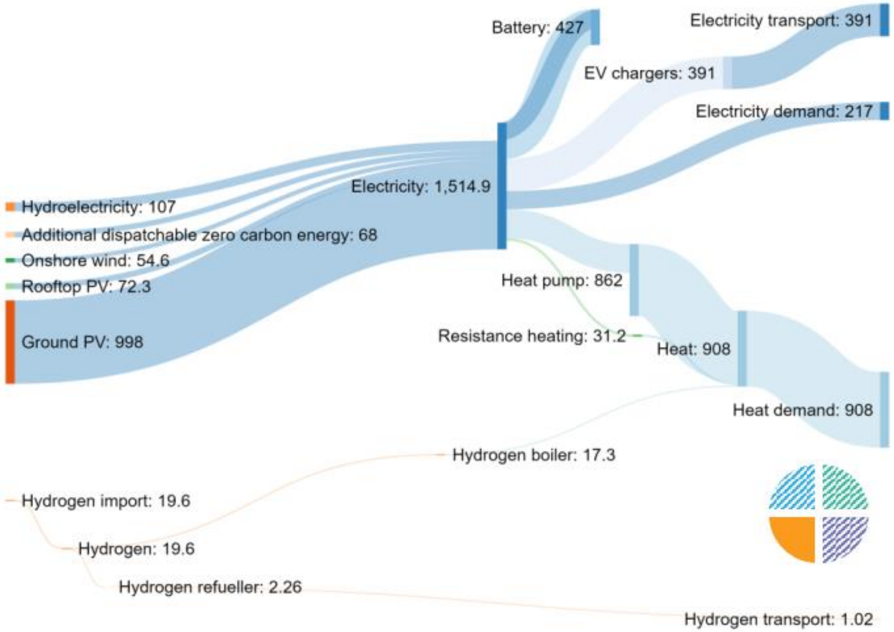



Figure 24: Energy flows in the Islanded 2050 high demand scenario (GWh/year)

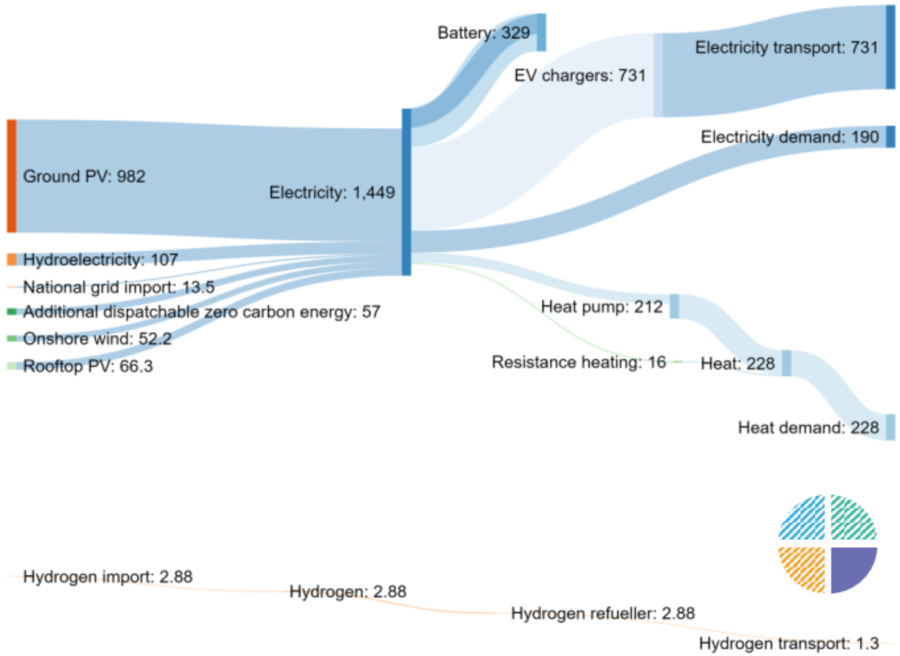



Figure 25: Energy flows in the 2050 low demand scenario (GWh/year)

**Optimised dispatch – low demand scenario**

The optimised generation and dispatch of electricity to meet demand over the modelled year in the low demand scenario is shown in Figure 26, with production of electricity shown above the x-axis with positive numbers, and consumption of electricity below the axis with negative numbers.

The electrification of transport makes up a significant amount of the final electricity demands. This is due to their higher well-to-wheel efficiencies compared to hydrogen vehicles. Demand from heat pumps represent the next largest consumption of electricity, followed by building electricity demand.

Ground PV represents a lower cost and less carbon intensive form of electricity, and is deployed almost to maximum capacity (see Figure 30) to meet the significant demand from electric vehicles.

Long term battery storage is used to maximise benefits from solar and wind resources in Conwy, with batteries charging during summer months and discharging to meet demand during winter.

Figures 27 and 28 overleaf show the annual heat production and consumption, as well as a more detailed breakdown of the transport demand.

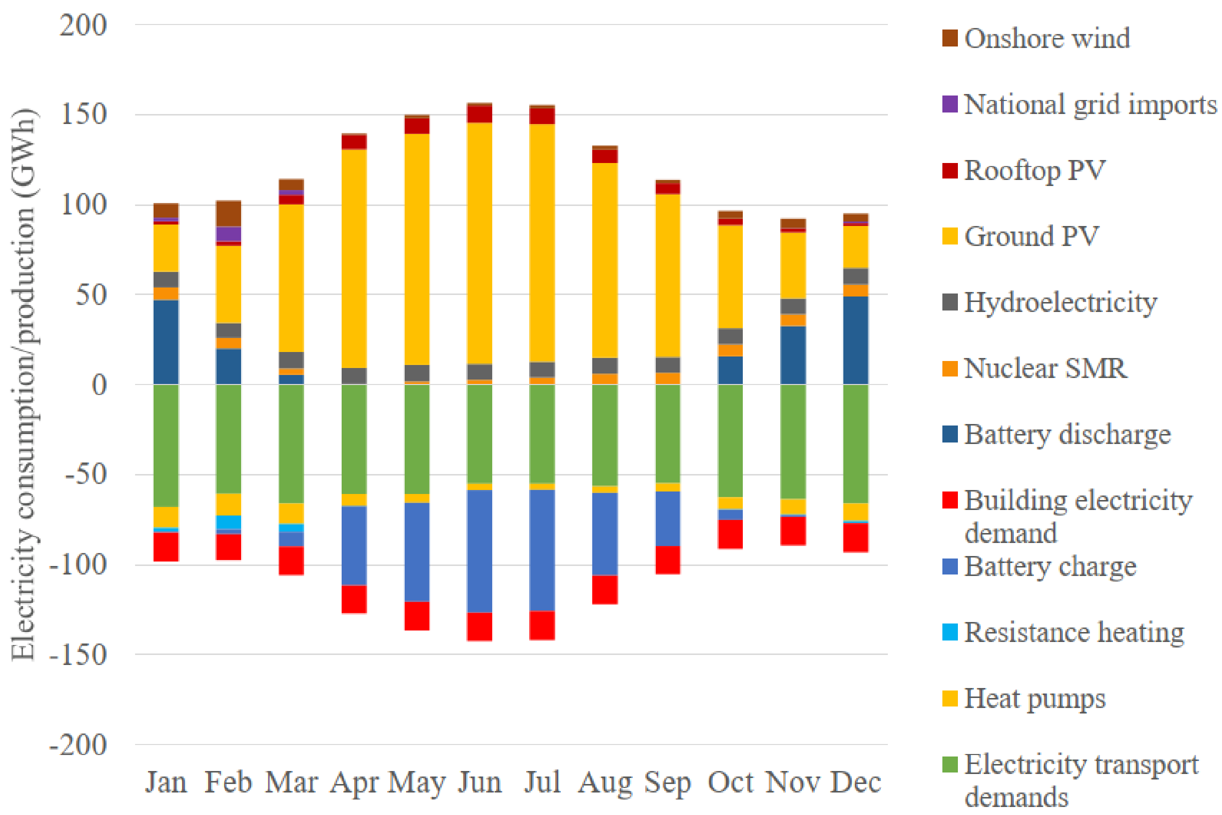



Figure 26: Monthly electricity generation and consumption

**Optimised dispatch – low demand scenario**

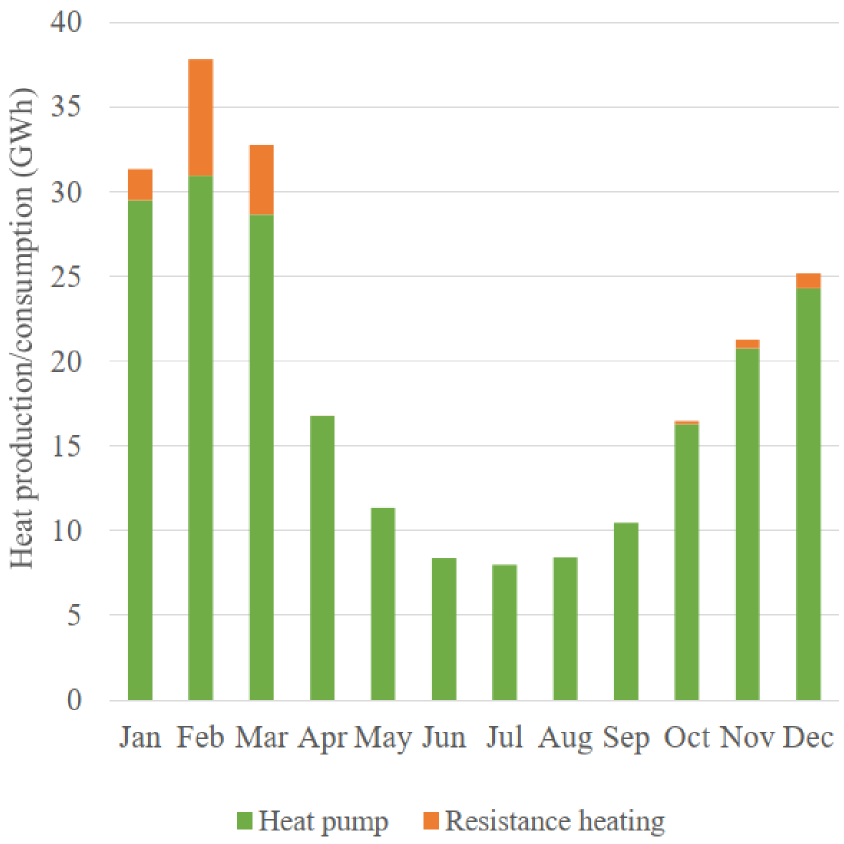



Figure 27: Annual heat production and consumption

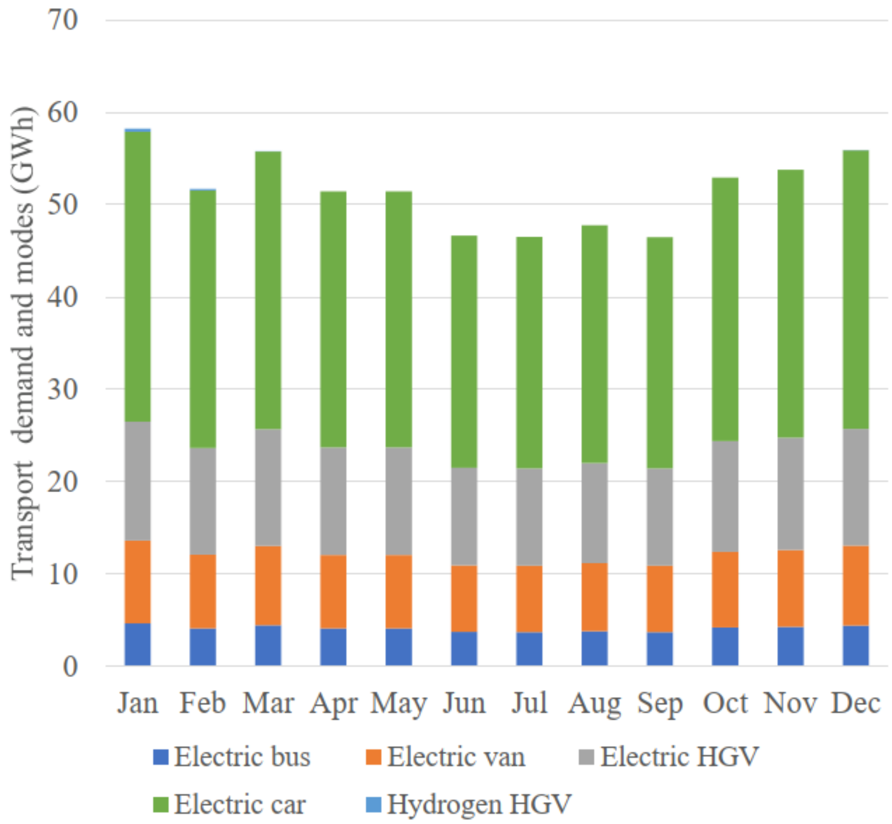



Figure 28: Annual transport demand by vehicle breakdown

### Optimised dispatch – low demand scenario

The modelling approach included detailed hourly modelling of technology dispatch for each MSOA in Conwy. This accounts for the mismatch between renewable generation and demand time periods when sizing technologies such as solar PV, wind turbines and batteries. Figure 29 shows the hourly dispatch for the 4th January, with production of electricity (and release of stored battery energy) shown above the x axis with positive numbers and consumption (and charging of batteries) below the axis with negative numbers.

As shown by the graph, solar generation is limited to a 7-hour time window centred around midday, however heat pump, electricity and transport demands occur throughout the day and peak in the mornings and evenings. By discharging long-term battery storage to meet the bulk of this demand, and utilising shorter term battery storage to avoid curtailment during peak generation hours, the system creates balance between supply and demand.

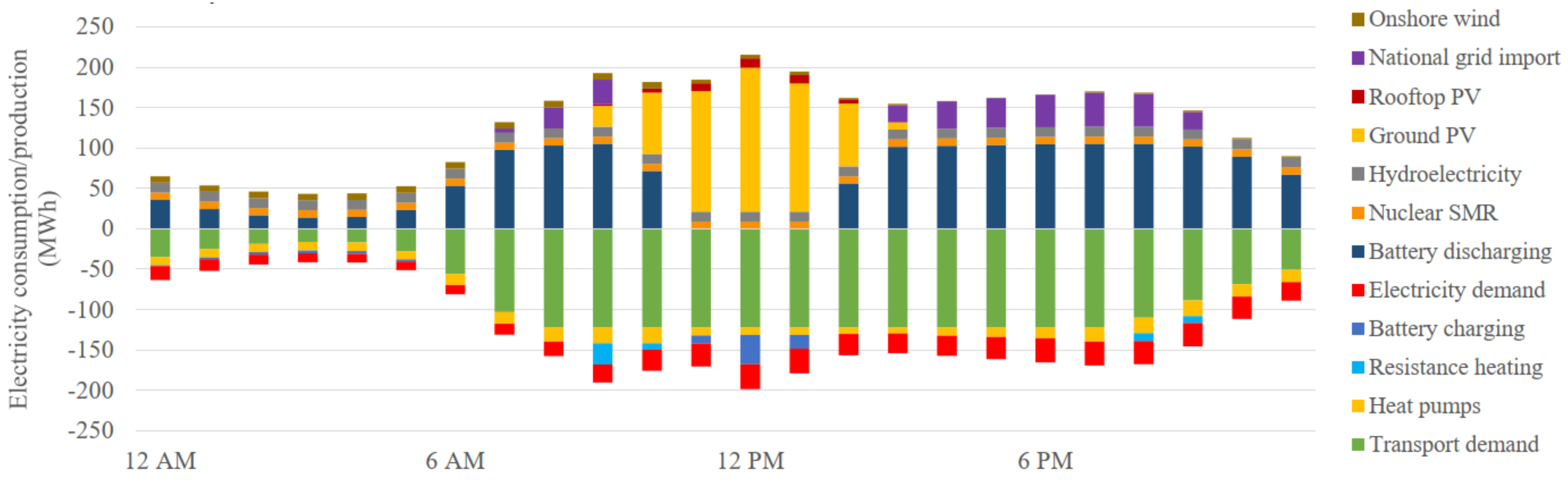



Figure 29: Hourly electricity consumption and production on the 4th of January

**Onshore renewables – deployment in low demand scenario**

The model chooses to meet energy demands through mainly electricity in all scenarios (except the high hydrogen scenario when this is not a choice), reflecting the projected price decreases of renewable and low carbon electricity sources in the future.

The model opts to utilise all of the area available for ground PV to meet the electrification of energy demands, including the large potential area in the MSOA encompassing  Betws-yn-Rhos, Llangernyw & Llansannan (Conwy 014). In areas such as Llanwrst & Betws-y-coed (Conwy 015) solar PV capacity is also maximised, however the potential in this area is much smaller, as shown by Figure 30.

The model does not opt to build more wind, largely because demands can theoretically be met with a large scale up of cheaper PV, (and associated battery storage). However, other land use considerations and the RLDP policy may modulate the amount of solar PV built. This is discussed in further sections.

Note that the theoretical maximum potential of onshore wind is approximately 2.8GW in Conwy 014, and is therefore not plotted on this graph.

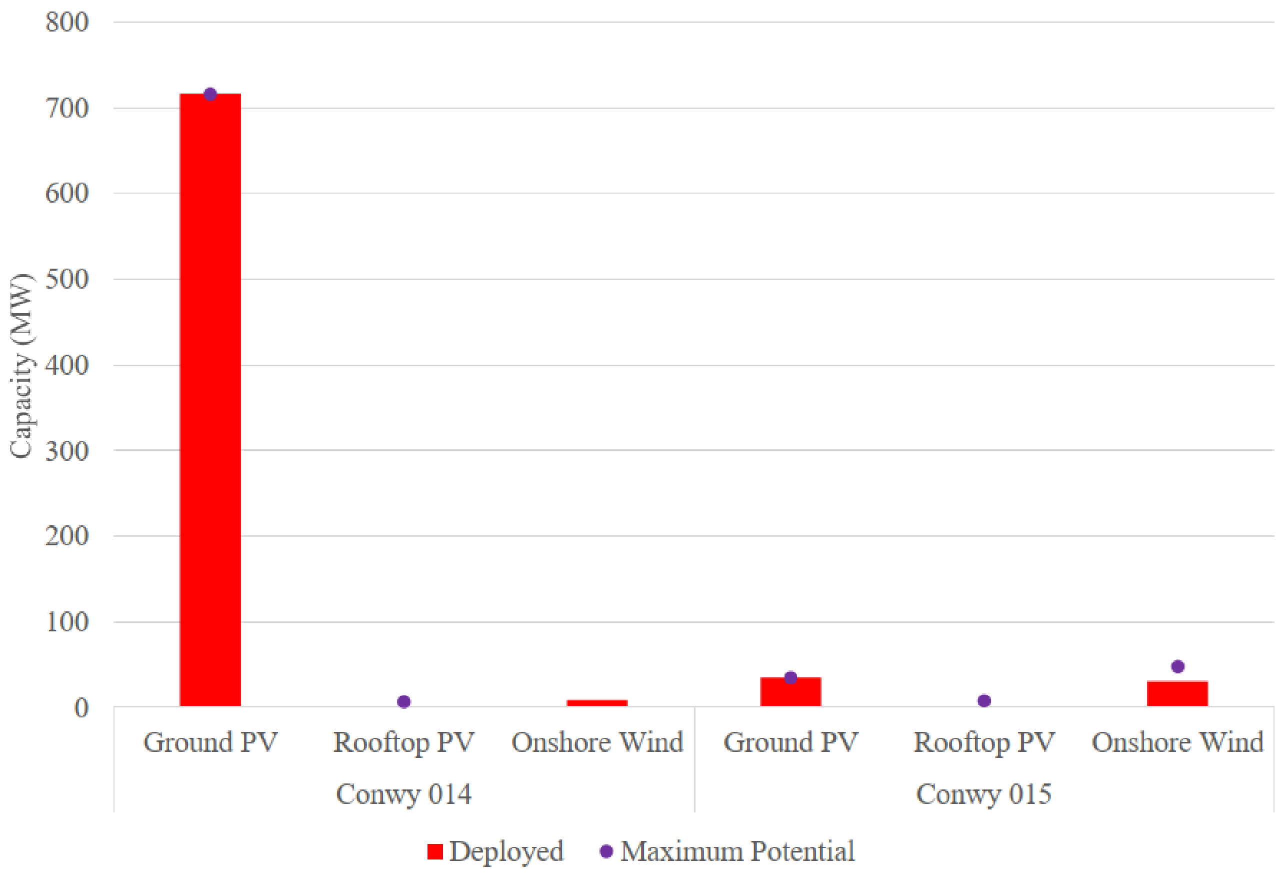



Figure 30: Deployed capacity and maximum potential of key renewable electricity generating MSOAs in Conwy

## Costs

We have included costs for both the high and low demand scenarios. They give an indication of the capital costs (capex) and annualised total costs (totex) for the energy system components.

The annualised totex is calculated by the capex divided by the lifetime of the item added to the annual opex.

We haven't included costs for gas infrastructure because in these two scenarios hydrogen use is minimal so the gas infrastructure would not be converted to hydrogen. There are likely to be some decommissioning costs, but these are currently unclear.

| Energy system component | Capital cost (£/kW) | High demand Capex (£k) | High demand Annualised totex (£k) | High demand Annualised totex (£k/property) | Low demand Capex (£k) | Low demand Annualised totex (£k) | Low demand Annualised totex (£k/property) |
|---|---|---|---|---|---|---|---|
| Domestic retrofit | | 509,000 | 13,000 | 0.25 | 3,188,000 | 80,000 | 1.53 |
| Non-domestic retrofit | | 444,000 | 11,000 | 1.73 | 1,829,000 | 46,000 | 7.23 |
| Electrical infrastructure reinforcement costs | | 50,000 | 1,000 | 0.02 | 26,000 | 1,000 | 0.02 |
| Gas infrastructure | | N/A | N/A | N/A | N/A | N/A | N/A |
| Solar PV | 531 | 452,000 | 22,000 | | 432,000 | 23,000 | |
| Onshore wind | 1,089 | 48,000 | 3,000 | | 43,000 | 2,000 | |
| Hydroelectricity | | Existing | 1,000 | | Existing | 1,000 | |
| Domestic heating systems changes/upgrades | | 1,282,000 | 71,000 | 1.36 | 1,282,000 | 71,000 | 1.36 |
| Non-domestic heating system upgrades | | 737,000 | 41,000 | 6.45 | 737,000 | 41,000 | 6.45 |
| Transportation (EV chargers) | 817 | 141,000 | 12,000 | | 141,000 | 12,000 | |
| Storage (battery) | 197 | 22,000 | 24,000 | | 21,000 | 22,000 | |
| **Totals** | | **3,685,000** | **199,000** | **10** | **7,699,000** | **299,000** | **17** |

Table 6: Annualised total and capital costs for energy system components

## Electricity network upgrades

Based on our analysis we have identified, at a high level, areas of the distribution network most likely to require significant upgrades.

Areas shown in green are those where our modelling indicates that no further significant upgrades are required and the existing system contains enough additional capacity to accommodate increasing demand and the decarbonisation of heat and transport, suggesting significant upgrades are less likely to be required in a future energy system.

Areas shown in orange are those where additional infrastructure upgrades would be required under the high demand scenario, in which minimal amounts of retrofit occur and heat demand continues to increase.

Areas shown in red are those where infrastructure upgrades would be required in both high and low demand scenarios. This suggests that upgrades in these areas are very likely to be important in any future energy system.

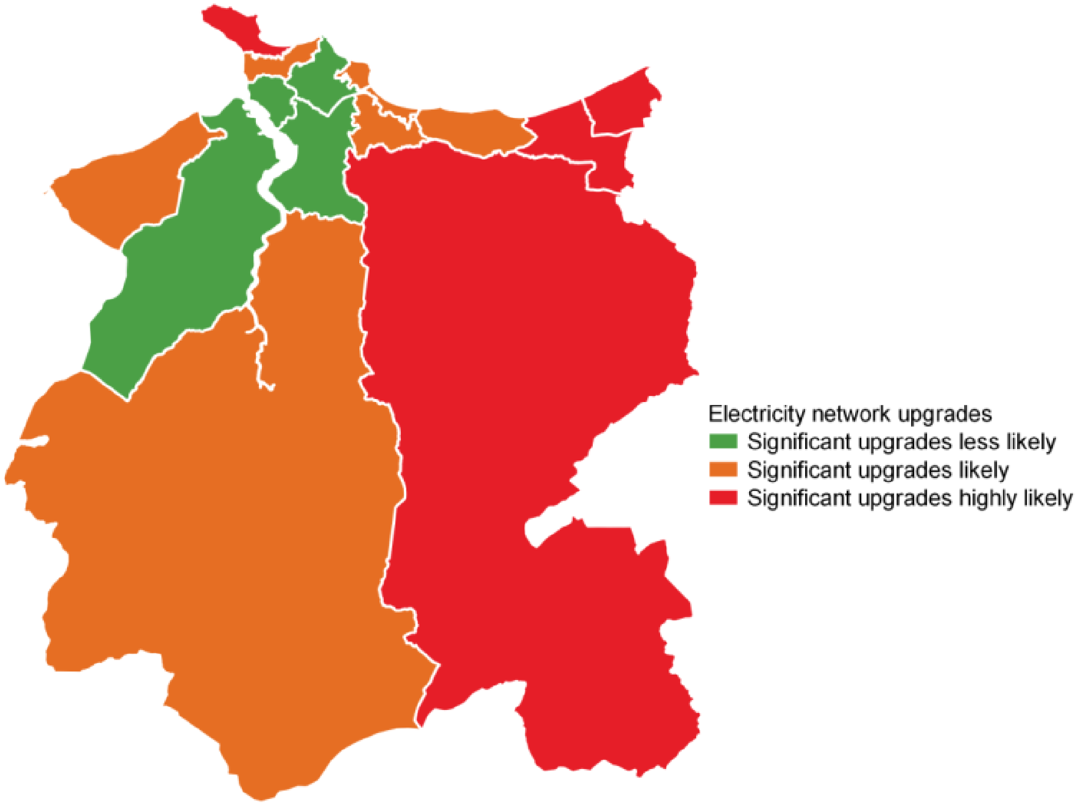



Figure 31: Electricity network upgrades – areas of likely upgrade requirements

## Stages 6, 7 and 8

**Overview**

Figure 32 shows the process followed to develop the key near-term recommendations for CCBC, as well as what CCBC may need in terms of wider support and input from others.

**Energy system modelling**

Our optimisation modelling identified multiple plausible future energy systems, reflecting uncertainties in future demand and technology readiness. This is described over the previous sections of this report.

**Physical energy system components**

We prioritised elements of the energy system for priority intervention in the routemap. This was based on alignment between modelling outputs, plan objectives and local strategic priorities. This is described in more detail on page 42.

**Levers of action**

Using input from stakeholders, highlighted on page 22, and a literature review we identified levers of action each stakeholder could use to facilitate the recommended changes in the energy system.

More detail on each stage is given overleaf.

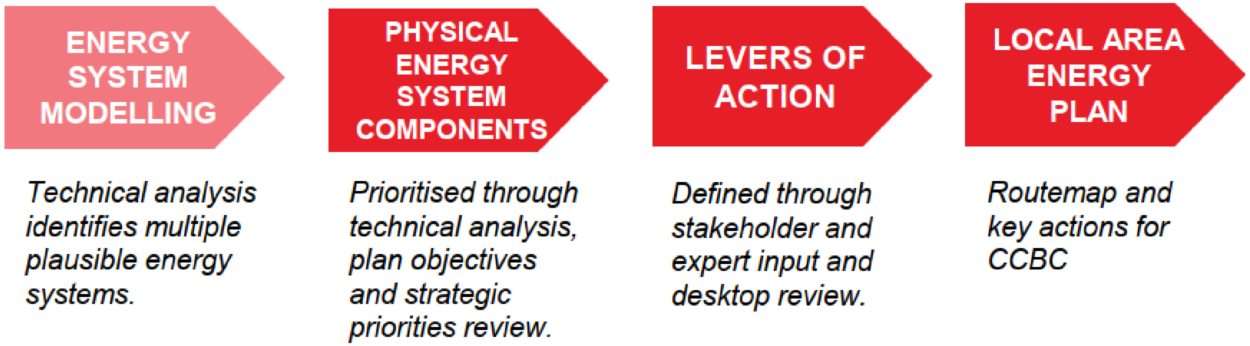



Figure 32: An overview of the approach taken for stage 6 to 8

## Stage 8: Routemap and recommendations

**Energy system components: prioritisation process**

Figure 33 shows the process undertaken to prioritise the components of the energy system that require change in Conwy over time.

Following our optimisation modelling, we reviewed possible intervention areas against three key criteria:

- Was this a strategic priority identified by stakeholders in our engagement with them?
- Does this intervention area align with the wider objectives that we have set for Conwy's Local Area Energy Plan (described in Figure 3)?

Based on the analysis undertaken, we have identified three groups of intervention areas:

- Implement – These will be priority intervention areas for our 2022 LAEP
- Potential future pilot – These are opportunities for pilots, where Conwy should respond to opportunities as they arise

To be reviewed in future LAEP updates – recognising key uncertainties, these are components to consider over time.

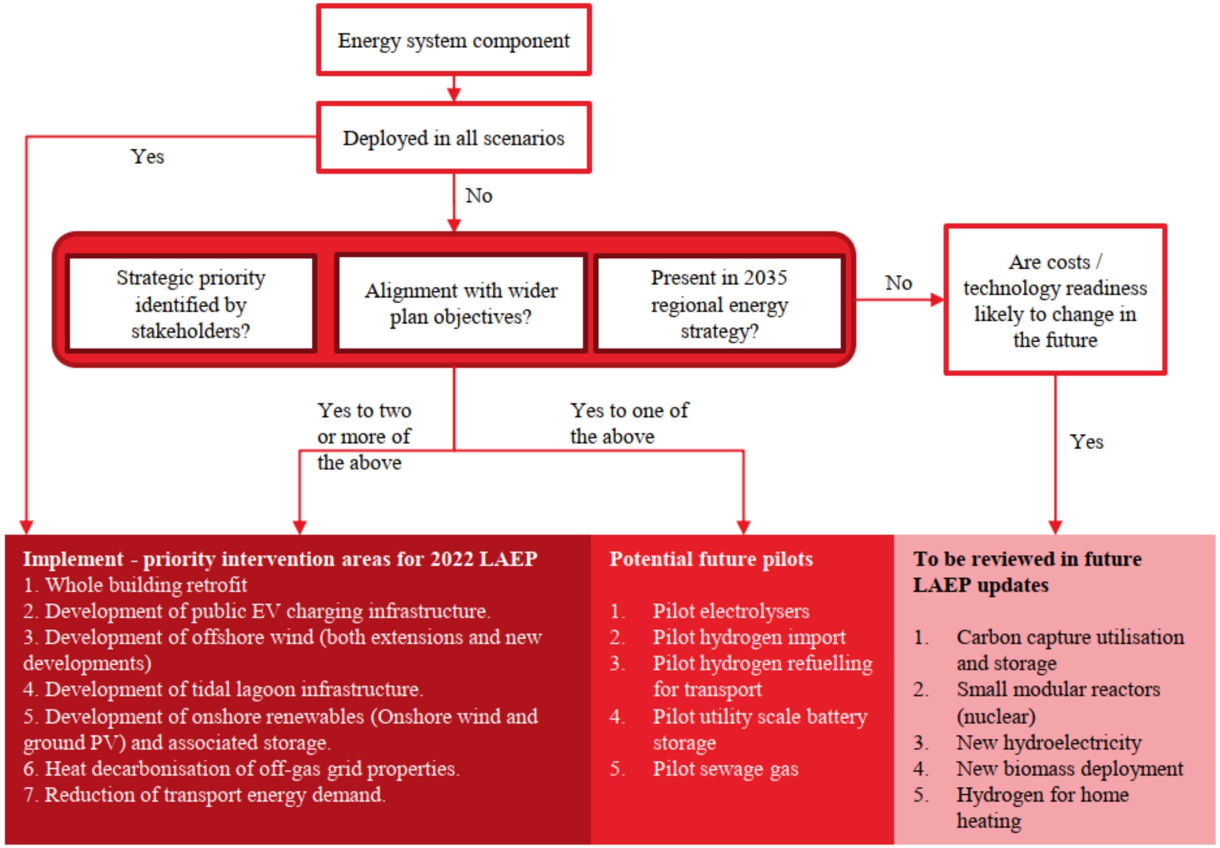



Figure 33: Overview of the prioritisation process

**Developing a routemap with key actions for CCBC**

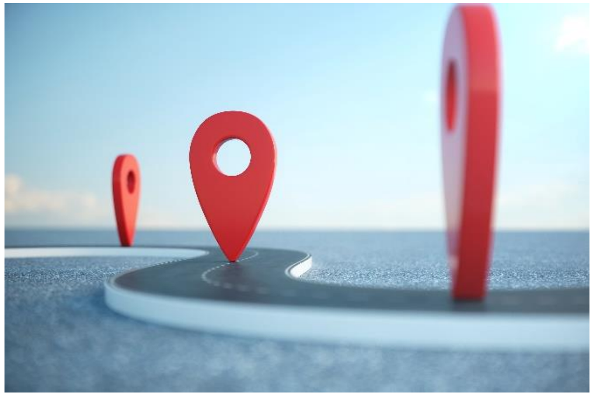
Once the priority interventions were identified, we conducted further policy review to identify key milestones and dates related to these interventions at the UK, Welsh and CCBC scale. This is the high level route map presented in the main report and provided overleaf for reference.

This provided important direction for the scale of change necessary between now and 2050, as well as identifying interim milestones, from the local authority to the national level.

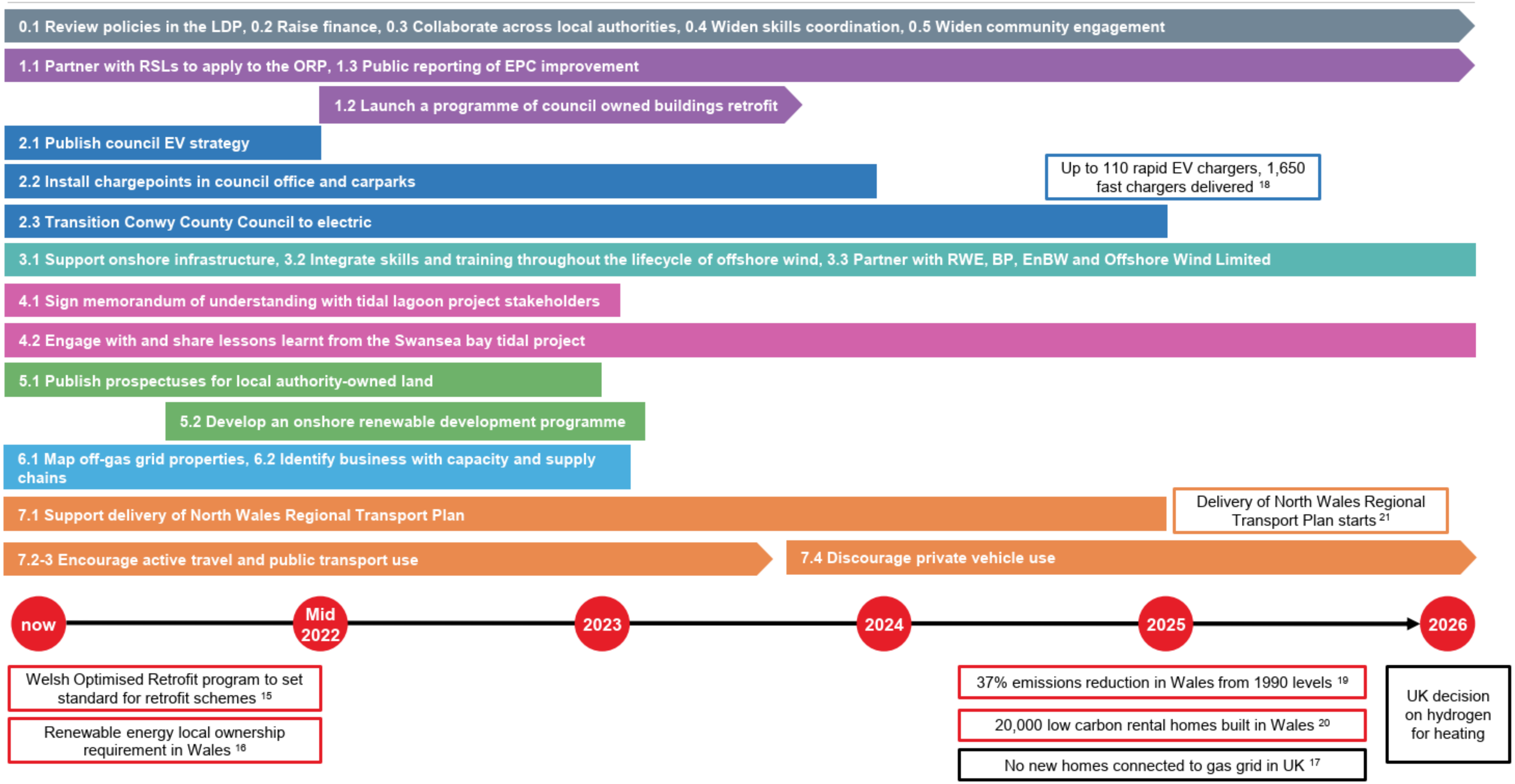
CCBC is the ultimate plan owner, and key actions for priority interventions are focused on what the local authority has capacity to deliver and where and how they can exert their influence. Key actions for the LAEP are therefore written from the lens of the local authority.

We revisited our action longlist and shortlisted those actions where CCBC was a key action owner. We used the actions whose owners where other stakeholders, such as Welsh Government, SPEN, WWU, etc., to formulate the 'our ask of others' section.  Using the high level routemap enabled us to attach indicative timescales to each action (recognising resourcing constraints).

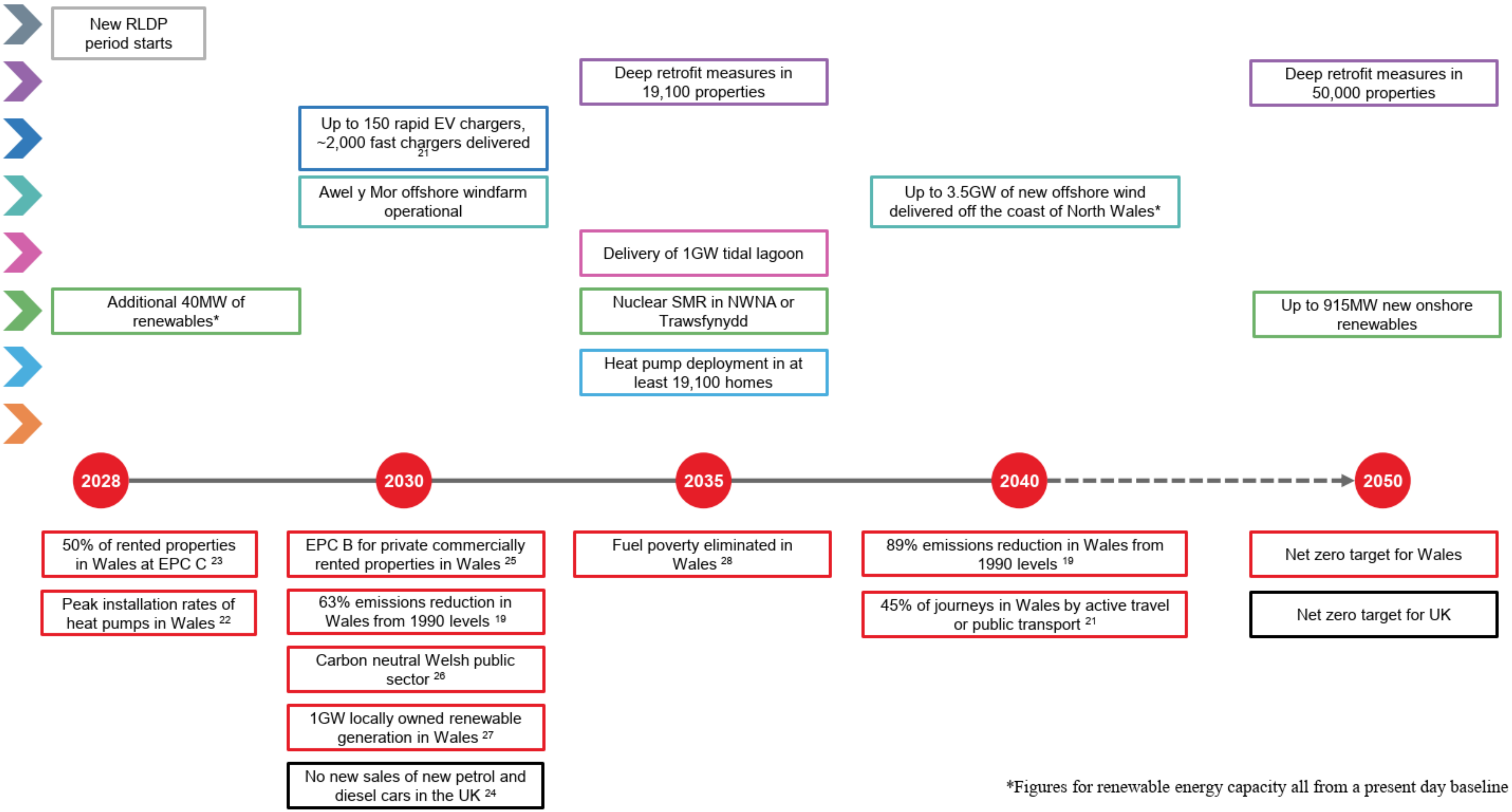
Through this exercise, we consolidated some actions that the local authority could proceed with that had direct relevance to more than one priority intervention area. We termed these enabling actions, which were oriented around updating the RLDP, raising finance, community engagement and skills development.



Short term routemap



Medium-long term routemap




*Figures for renewable energy capacity all from a present day baseline

**Priority intervention areas**

**1. Whole building retrofit**

Retrofit of existing buildings for energy efficiency and decarbonised supply is an essential element of the energy transition. Retrofit reduces the total demand for energy from the system and brings additional social benefits through increased comfort and health of the occupants. For the many buildings which will switch to heat pumps, fabric retrofit is a key to ensuring the heat pumps can operate efficiently at lower supply temperatures.

A whole house approach to retrofit will help to minimise the performance gap and reflects the likelihood that most properties will only have one or two major renovations between now and 2050. A whole house approach includes fabric measures, control systems (smart energy systems), heating technology and solar PV (where suitable).

The LAEP aims for up to 19,100 homes to have deep retrofit measures completed by 2035, representing up to £1 billion of investment. However, retrofitting faces multiple barriers, including long payback periods, lack of access to finance, low homeowner awareness / other priorities, supply chain constraints and an inconsistent policy environment. A range of innovations are urgently needed to overcome these barriers:

- Technical installation measures (to drive down unit costs)
- Commercial and financing solutions (to overcome homeowner lack of finance)
- Supply chain learning rates and recruitment (to deliver retrofit to a consistently high standard)

The Council should work with Welsh Government and local stakeholders to develop a suite of delivery and policy measures to support the scale of ambition for retrofit in the local area.

See Figure 34 on page 49 for details of recommended spatial priority areas.

**2. Development of public EV charging infrastructure**

Replacement of diesel and petrol cars with electric vehicles is well established policy at both UK and Welsh Government levels. EV sales are rising rapidly and the global auto industry is already transforming product lines.

EV charging infrastructure is a key enabler of sales. The Welsh Government EV strategy shows that we require a mix of rapid and fast chargers in Conwy. Our modelling results suggest the future transport system may require up to 110 rapid and 1,630 fast chargers by 2025, and up to 150 rapid and 2000 fast chargers by 2030.

Charging technologies and business models are evolving rapidly as businesses and customers find solutions which meet their needs. In this context, the Council can play an important role in the local area to monitor coverage and target its resources to fill the gaps where private solutions are not delivering, which will support growth without crowding out market-led solutions.

See Figures 35 and 36 (page 50) for more details of our spatial priority zones.

### 3. Development of offshore wind (both extensions and new developments)

Gwyt Y Mor offshore wind farm extension has a potential capacity of 1.1GW. It is currently going through the design and consenting process with plans to be operational by 2030.

As a grid-connected renewable energy solution, the wind farm does not form an explicit part of the modelled future local area energy system. Nevertheless, its delivery will make a major contribution to the UK's energy transition and the Council can play an important role in enabling the related onshore infrastructure and developments, while also working with the developers and consenting body to ensure local environmental and social impacts of the development are mitigated.

Major energy infrastructure developments in the local area also provide an opportunity for local employment and economic development. The Council can support access of local residents to the job opportunities which arise, through skills investment and awareness raising.

### 4. Development of onshore renewables (onshore wind and ground PV) and associated storage

Scale up of onshore renewables, particularly ground PV, is an essential component of meeting Conwy's energy demand. The current LDP supports the development of a 4MW array, and up to 30MW of onshore wind. Whilst these are good steps, this meets less than 10% of the projected optimal level of renewables needed by 2050, not including battery storage. As such, a rapid scale up in the revised LDP is likely needed.

Given the scale of renewables development envisaged, it will be especially critical for the Council to work to maintain local public support for the plan and for implemented schemes. This will involve a sustained communication programme around the need for renewables investment in the area, as well as securing tangible local benefits from this investment.

In addition, the Council can play other roles to support delivery at scale while securing the full local benefit potential from renewables investment and mitigating local environmental and social impacts. These roles include the Council's statutory planning function and use of "soft power" to support project development and enabling investments such as skills and grid reinforcement works.

See Figure 37 for details of spatial priority zones.

### 5. Development of tidal lagoon infrastructure

A 1GW tidal lagoon is proposed in the 2035 North Wales Regional Energy Strategy[5] and was identified as a key strategic objective in the stakeholder workshops, reflecting its support in the Council's preferred RLDP.[3]

As with offshore wind, the Council would not be the consenting body for such a development, but it will have a considerable influence on the design of the scheme and the decision-making process. It will also be critical to the communication of the project's local benefits as well as how local environmental impacts can be mitigated.

**6. Heat decarbonisation of off gas grid properties**.

We have identified the estimated 10,600 properties off gas grid properties as a special area of focus for early decarbonisation investment, in addition to the general need for whole house retrofit across the local area.[10] Off gas grid properties are mainly heated with fossil-based oil and LPG, which have higher carbon emissions than gas-heated homes and are also more costly to heat. Moreover, these properties would be very unlikely to be included in a future hydrogen-based heating system, since such a system would be expected to adopt the existing gas network for hydrogen distribution.

For all these reasons, switching off gas grid properties to air or ground source heat pumps is a high benefit and low regrets measure which should be prioritised in the LAEP.

Action by the Council can include use of resources to secure grant funding and investment finance, targeted communication with off gas grid homeowners and direct investment where the Council has its own off gas grid stock.

A programme of fabric retrofit and heat pump installation of these 10,600 homes would represent an investment of up to £500m (depending on the depth of retrofit). The Council can play a key role in shaping a potential investment programme which would be of interest to investors and industry.

See Figure 34 overleaf for details of the recommended spatial priority areas for retrofit and heat pump installation.

**7. Reduction of transport energy demand through active travel measures**

The Welsh Transport Strategy[21] sets out a transport hierarchy – giving priority to meeting transport demand through active travel and public transport, before private vehicles. Reducing our reliance on energy intensive modes of transport is critical, not only because it supports goals in the Well-being of Future Generations Act,[29] but also because it will free up electrical energy needed for heating and could result in less land area needed for ground PV.

Active travel support comprises a wide variety of measures including new cycling and walking infrastructure, a sustained communication campaign, parking and road pricing policies, investment in public transport and integration of different measures to maximise potential impact.

The Council will have a role to play as local highway authority but will also need to work closely with TfW and local bus companies to achieve a step change in public travel behaviour.

**Retrofit and electrification of heat**

Priorities 1 and 6, relating to retrofit and decarbonisation of heat for off-gas properties, could be implemented in tandem for maximum benefit, since it is most efficient to install a heat pump or other low carbon source of heating when a property undergoes retrofit. Past schemes such as domestic RHI have capitalised on this by requiring the achievement of EPC C to qualify for funding.[30]

Priority LSOAs within Conwy for the dual roll-out of retrofit measures and heat pump installations are shown in Figure 34. Priority LSOAs are ranked with a bivariate score, with one measure the percentage of off-gas properties, and the other measure the percent of non-electric heating. These areas will tend to have higher energy bills and higher carbon emissions, making the net benefits for retrofit and heat technology switching likely to be the highest in the city.

In line with Action 1.2 in the plan, this map may be used as part of the design of building retrofit programmes.

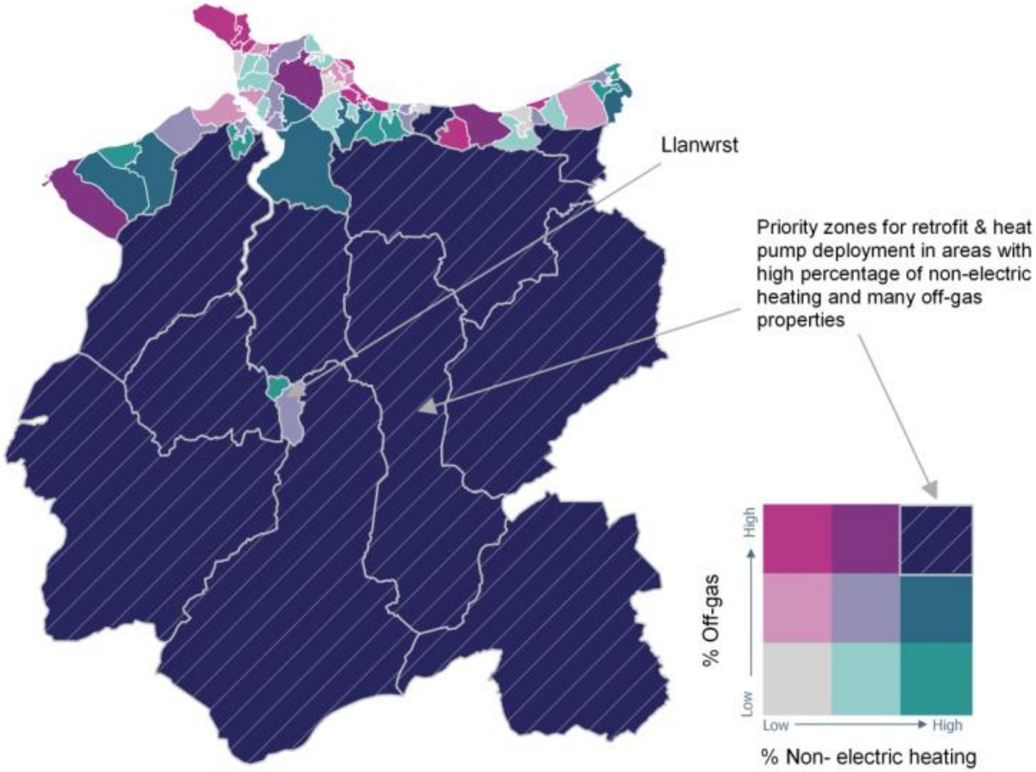



Figure 34: Map of priority LSOAs for building retrofit and decarbonisation of heat

**Decarbonising transport**

Development of EV charging infrastructure is a priority intervention area. Figures 35 and 36 show possible areas within Conwy which could be considered strategic areas for the development of EV charging infrastructure. However, further analysis of off-street parking availability, transport patterns and locations of 'destinations' for destination public charging might be required to refine the strategic placement of EV chargers.

Areas with high car usage could also indicate priority areas for the improvement of active travel infrastructure and public transport services.

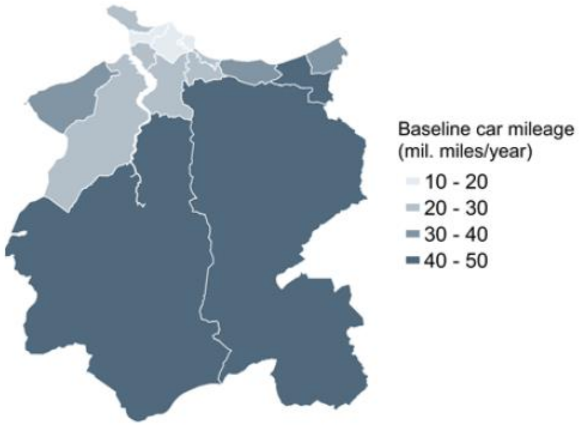



Figure 35: Baseline car mileage by MSOA

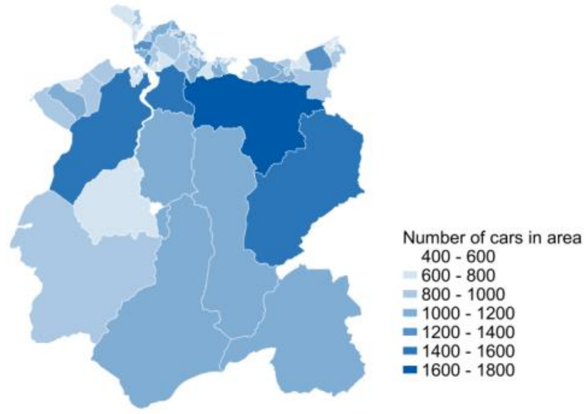



Figure 36: Car ownership by LSOA

**Development of onshore renewables (wind & solar)**

Figure 37 shows the areas identified as suitable for development of wind and solar energy generations assets, taken from Conwy's Renewable Energy Assessment[14] and the pre-assessed areas for onshore wind from Future Wales[41].

Our modelling points to an extensive build out of ground PV, combined with battery storage as the most cost and carbon efficient way to meet projected energy demands. In the low demand scenario all of the area suitable for ground PV is utilised (see Figure 30). We suggest that the shaded yellow areas on the map would be priority locations for the development of this infrastructure.

Onshore wind is not built out to its theoretical maximum capacity. However, up to 43MW, or 17 turbines, are deployed in the high demand scenario. We suggest that the shaded blue areas on the map would be the possible areas for the development of this infrastructure.

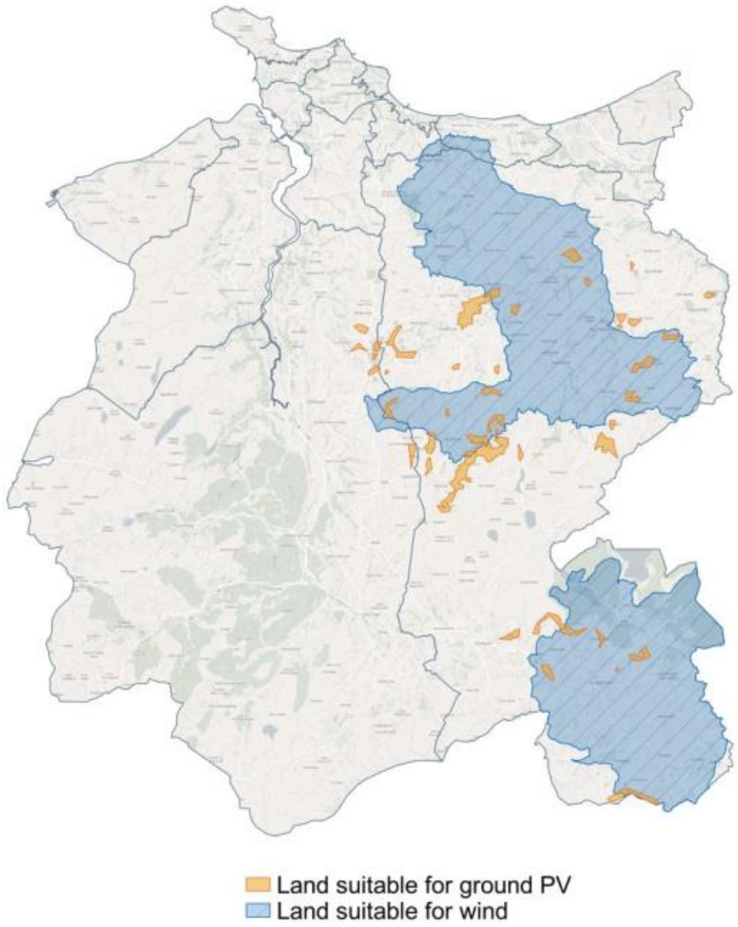



Figure 37: Suitable areas for wind and solar development, identified from Conwy's Renewable Energy Assessment and Future Wales

**Priority pilot areas for hydrogen for heating**

The availability and suitability of hydrogen for domestic heating remains a key uncertainty, with the UK government due to make a decision on its use in 2026.[31]

If the gas grid is repurposed to carry hydrogen, this will likely occur in areas where there is high demand, so that hydrogen production may benefit from economies of scale.

In Conwy, this is concentrated in MSOAs around the northern coast, as shown in Figure 38.

Non-domestic gas consumption follows a similar pattern of use.

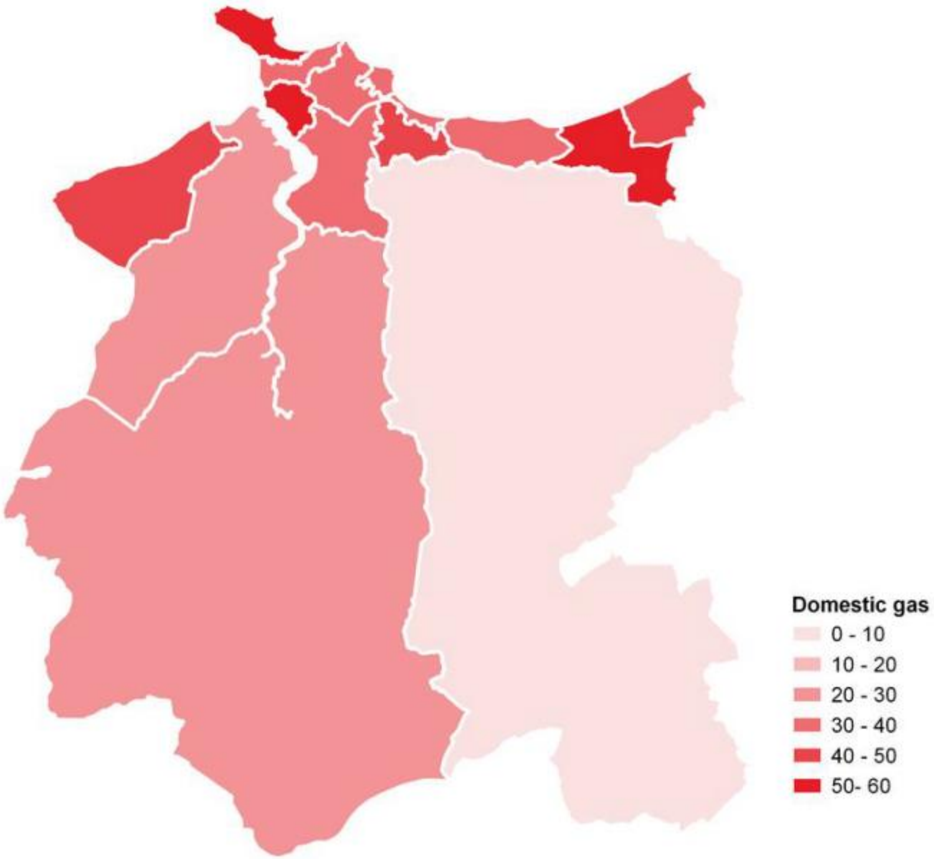



Figure 38: Domestic gas consumption (GWh/year)

**Levers of action – longlisting priority interventions**

We identified the key non-technical factors and conditions required for success by reviewing examples from city-scale decarbonisation plans. This was supplemented by the outputs of the 'roles and rules' workshop held with CCBC and the Conwy LAEP stakeholders.

We found that in order to be successful our 'implement – priority interventions' needed support from:

- actions to mobilise finance,
- a strong and consistent policy framework,
- accountable and committed delivery owners,
- a community engagement element.

The stakeholders best placed to support on these elements varied depending on the intervention, similar to the 'Team Wales' approach outlined in the Government's second carbon budget emissions reduction plan.[23]

This also holds true for the council's role. Some interventions called for council action in the material delivery of programmes, whilst other interventions required the council to act more as a facilitator for market driven change.

Following outputs from the 'roles and rules' workshop, we further developed an action longlist which ensured each of our priority interventions were supported by at least one action to mobilise finance, one action to ensure committed delivery owners, one action which included community engagement, and one action that ensured the intervention was supported by a strong and consistent policy framework.

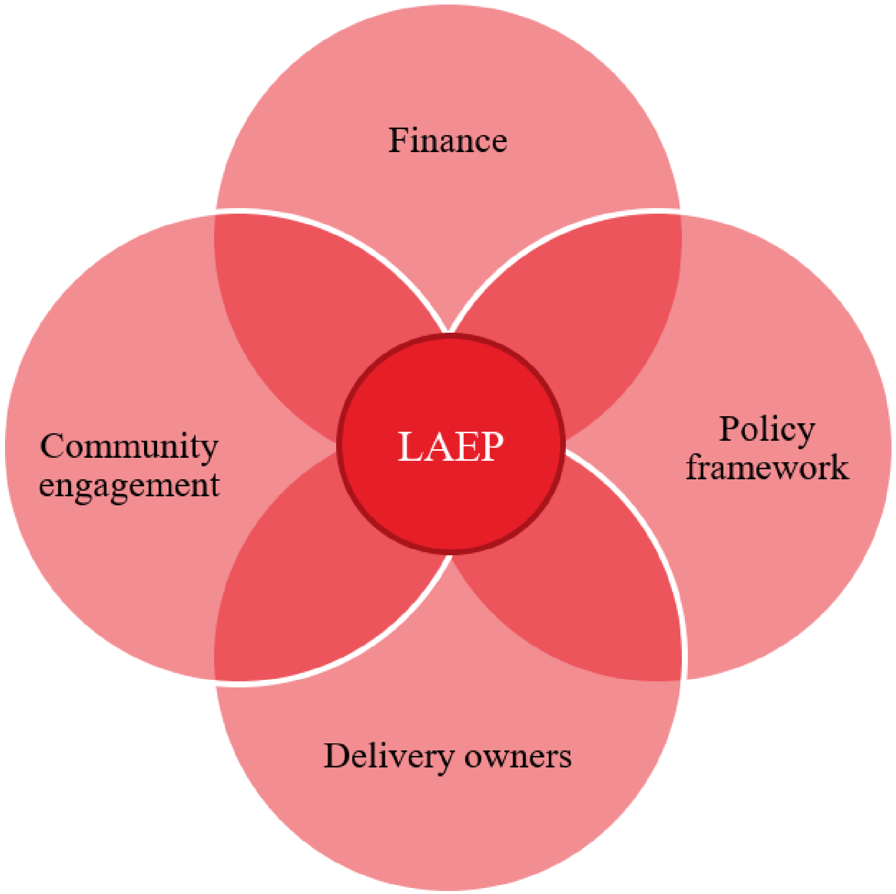



Figure 39: Key levers for action to deliver our priority interventions areas

# Conclusions

The LAEP process for Conwy has identified the need for an unprecedented scale of change and investment in buildings, transport and energy infrastructure. While some aspects of change – grid scale renewables and electric vehicles – are already happening at scale, many other areas continue to face significant barriers due to complexity, uncertainty and the high cost of delivery.

The Local Area Energy Plan represents the start of a process of accelerated and coordinated action to address these barriers at the local level. The Council cannot do everything on its own – indeed it will have only limited direct involvement in the investments envisaged in the plan. But it plays a critical role as the local champion and leader with both the power and opportunity to shape the agendas of energy actors as well as local property owners and the wider community.

Given we are on a nearly 30 year journey to net zero, the analysis and modelling captured in this report have sought to identify sectoral and spatial priority areas for action and investment, to help the Council and local actors focus limited resources first on the highest benefit and least regret measures, while still keeping an eye to the longer term goals to mitigate the risk of lock-in or plateauing of our emissions pathway.

Further and more detailed assessments will be needed for each of the actions identified in the plan, and regular reviews and refreshes of the plan will be needed as the wider policy and energy infrastructure context changes over the coming three decades.

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# Appendix 1: Policy Review

## 1. National context

### 1.1 UK policy context

The UK has had legally binding greenhouse gas reduction targets since 2008 when UK Parliament passed the Climate Change Act.[32] This legislation mandated a reduction in greenhouse gas (GHG) emissions of 80% compared to 1990 levels by 2050.

In 2019, the Climate Change Act was strengthened and the UK committed to a 100% reduction (i.e. reaching net zero carbon emissions) by 2050, with interim carbon budgets every five years. The Climate Change Act also created the UK Committee on Climate Change (UKCCC). This is an independent advisory body that advises the government on decarbonisation pathways, and reviews progress towards these targets.

In late 2020, acting on the advice provided by the UKCCC, the UK submitted an ambitious Nationally Determined Contribution (NDC) to the parties signatory to the Paris Agreement and the United Nations Framework Convention on Climate Change. This NDC committed the UK to reducing economy wide greenhouse gas emissions by at least 68% by 2030, compared to 1990 levels.[33]

In April 2021, the UK Government announced its climate change target for the sixth carbon budget period. This committed the UK to reducing emissions by 78% by 2035 compared to 1990 levels, including the UK's share of international shipping and aviation emissions.[34]

*Energy sector policy*

In December 2020, the UK Government released its Energy White Paper,[35] which set out their policies and commitments in the energy sector to set the UK on the path to net zero emissions. Commitments in the Energy White Paper included:

- targeting 40GW of offshore wind by 2030
- an investment of up to £1 billion to support CCUS clusters and establishment of a revenue mechanism to bring private sector investments into the sector, with the aim of capturing 10 $MtCO_2$ per year by 2030
- accelerating the installation of heat pumps, consulting on the end of new homes
- connecting to the gas infrastructure network developing 5GW of low carbon hydrogen production capacity by 2030.

The UK Government has committed to a ban on the sale of new petrol and diesel cars and vans by 2030, greening to public transport through investments in rail, bus, and active travel, with £2 billion of funding announced in May 2020 for walking and cycling.[36]

All reductions quoted in this piece are from a 1990 baseline. A very small minority of GHG gases, (such as hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride) are measured from 1995 levels. Carbon Dioxide, Methane and Nitrous Oxides are measured from a 1990 baseline

## 1.2 Welsh context

*Sustainable development*

The Well-being of Future Generations (Wales) Act 2015 provides the legally binding framework for public sector activities to be in line with sustainable development principles in Wales. The Act has seven overarching goals:

- A prosperous Wales
- A resilient Wales
- A more equal Wales
- A healthier Wales
- A Wales of cohesive communities
- A Wales of thriving culture and Welsh language
- A globally responsible Wales.

National, local and other specified public bodies must work, and made long term decisions, in such a way to improve the current and future well-being in Wales.

*Climate change and carbon budgets*

The Environment (Wales) Act 2016[37] requires the Welsh Government to set targets for reducing emissions of GHGs. When setting emissions targets, the Welsh Senedd (Parliament) considers the UKCCC recommendations, as well as a range of other factors and reports, including the future trends report prepared under provision of the Well-being of Future Generations Act 2015.[29]

The first carbon budget approved by the Senedd was a reduction in GHG emissions of an average of 23% in the period 2016-2020. Although there are no published emissions data from 2019 to 2020, Wales is likely to have met the first carbon budget.

Under the Environment (Wales) Act 2016, the Welsh Government is obligated to publish a report for each budgetary period which sets out proposals and policies for meeting that period's carbon budget. The first of these, *Prosperity for all: A low carbon Wales*, was published in March 2019. The second, corresponding to the second carbon budget, is due to be published in November 2021.

In late 2020, the UKCCC presented to Welsh ministers their recommendations on targets and carbon budgets based on the latest evidence and analysis. This supported a recommendation to reduce all GHG emissions to Net Zero by 2050. Further recommendations on targets on the pathway to net zero included interim targets for 2030 and 2040, which were reductions of 63% and 89% respectively. Finally, The Committee recommended that the second carbon budget (2021-2025) should be tightened to a minimum reduction of 37%.[19]

The advice stressed that although good progress had been made in reducing emissions and meeting the first carbon budget, this was almost entirely due to reductions in fossil fuel fired electricity generation. Gaps remain in a cohesive economy wide strategy for 2050, and significant policy progress needs to be made, utilising the full range of devolved and reserved policy leavers to deliver emissions reductions other sectors, particularly buildings, industry (manufacturing and construction), transport and agriculture.

In March 2021, the Senedd approved a net zero target for Wales by 2050, going beyond the previous target of an 80% reduction, set in 2016. In addition, the Senedd approved the second and third carbon budgets, as well as targets for 2030 and 2040. The Senedd also confirmed their ambition in delivering the second carbon budget through action taken within Wales, without relying on international offsets. These developments are summarised in Table 1.

The Senedd have accepted the UKCCC advice and support their conclusions that this ambitious decarbonisation can be delivered at minimal negative cost to the economy, as well as offering co-benefits to societal health through improved air quality, healthier modes of travel and diets, sustainable employment models that promote wellbeing, and more comfortable homes. However, the largest driver of health outcomes in the UK remains economic inequality. Therefore, the Senedd recognises that a just transition is an essential part to any climate policy.[38]

*Planning Policy*

Planning policy is one of the most important levers that Welsh Government has to influence the energy transition.

*Planning Policy Wales, edition 11*

The principle objective of Planning Policy Wales, edition 11 is to ensure that the planning system contributes to sustainable development and improves the well-being of Wales as required by the Well-being of Future Generations (Wales) Act 2015.[29]

PPW presents a transport hierarchy for planning. It states that the planning system should enable people to access their jobs and services through shorter, sustainable journeys by prioritizing sustainable and active, and public transport travel choices. Through the advice in this document, The Welsh government is committed to reducing reliance on the private car and supports a modal shift to walking, cycling and public transport.

PPW presents an energy hierarchy for planning. The highest priority is to reduce energy demand, where it is possible and affordable, followed by using energy efficiently, and increasing renewable generation. These are followed by minimising the carbon emissions impact of other energy generation, and to minimise extraction of carbon intensive energy materials. Further, the planning system should secure an appropriate mix of energy provision, and PPW envisions that the future energy supply mix will depend on a range of established and emerging low carbon technologies.

| Time period | Reduction in emissions compared to 1990 baseline |
|---|---|
| Carbon budget 2 (2021-2025) | Average 37% reduction |
| Carbon budget 2 international offset limit | 0% |
| Carbon budget 3 (2026-2030) | Average 58% reduction |
| 2030 target | 63% reduction |
| 2040 target | 89% reduction |
| 2050 target | At least 100% reduction (net zero) |

Table 1: Targets and Carbon Budgets approved by Senedd Cymru in March 2021[19]

Planning authorities should plan positively for grid infrastructure, optimise energy storage, ensure sustainable design principles in new developments are met, optimise the location of new developments to allow the efficient use of resources, including local energy sources such as heat networks, and maximise renewable and low carbon energy generation.

PPW also states that planning authorities should facilitate the development of renewable and low carbon energy relevant and feasible for the area. It tasks local authorities to create local development plan policies that enable these contributions, in a way that is consistent with obligations at the national and international level.

*Future Wales, National Development Framework*

The Welsh Government published in February 2021 a development plan for Wales: *Future Wales – the National Plan 2040.* It sets the direction for where investment is needed to contribute to the improving the economic, social and environmental well-being of Wales. It recognises the key importance of key future sectors, including renewable energy technologies, and supports the development of energy infrastructure and advanced manufacturing in each region.

Table 2 overleaf provides an overview of the key commitments outlined in *Prosperity for all: A low carbon Wales*, *Future Wales – The National Plan 2040, Planning Policy Wales edition 11* and other key Welsh policies and commitments.

Table 2: Targets and Carbon Budgets approved by Senedd Cymru in March 2021

| Sector | Policy and proposals |
|---|---|
| **Power** | 70% of Welsh electricity consumption to be generated from renewables by 2030.<br>1GW of renewable energy capacity to be owned locally by 2030.<br>All new renewable energy projects to have an element of local ownership from 2020<br>Ministers do not intend to authorise new or variations to coal mining licences. Coal for power generation will not be permitted, the use of coal for any other thermal purpose to be avoided. |
| **Buildings** | Funding and delivery of the Warm Homes Programme, which addressed fuel poverty and improved 45,000 homes with an investment of £240 million. An additional 20,000 homes to be improved with £106 million of funding from March 2018 to March 2021.<br>Optimised retrofit programme (ORP) aims to deliver building upgrades upgrades to at least 1,000 homes between from November 2020 to March 2021.<br>Large-scale mixed-use development should where feasible, have a heat network with heat from a low carbon source.<br>By 2035, no households to be living in severe or persistent fuel poverty.[28] Fabric first approach.<br>Innovative Housing Programme – Using modern methods of construction to deliver 1,000 of the 20,000 affordable homes target.<br>Secure zero carbon buildings whilst promoting a range of technologies to achieve this.<br>Within priority areas for district heat networks planning authorities should identify opportunities for district heating.<br>Participation in the Heat Network Innovation Programme. |
| **Transport** | Reduce GHG emissions through planning for better connectivity, active travel, and decreased reliance on the private car.<br>Proposed investment of £30 million over five years to aid in the delivery of a vision that 'by 2025, all users of electric cars and vans in Wales are confident they can access charging points'.<br>30,000 to 55,000 EV 'fast charging' points available to use by 2030, up to 4,000 rapid charging points.<br>Sustainable transport hierarchy (PPW, objective 10) prioritises walking, cycling and public transport.<br>Reducing greenhouse gas emissions from transport by reducing demand, supporting low-carbon services and infrastructure and through modal shift.<br>Targets for transport mode shift are set out in 'Llwybr Newydd – New Path', 45% of journeys to be made by public transport, walking and cycling by 2040 |
| **Cross cutting** | Welsh public sector carbon neutral target 2030. |

## 2. Local context

### 2.1 Climate change commitments

In May 2019, Conwy County Borough Council passed unanimously a resolution that declared a climate emergency. It called on the Welsh Government to commit to reducing carbon emissions and to provide the necessary support and resources to enable emissions reductions across Wales. In line with the Future Generations Act, it committed to the local authority being a lively and sustainable home for future generations.

The Council at this time also tasked the local Green Programme Board to develop a clear plan for the local authority that sets out a route to it becoming zero carbon in its operations, designed to be fully implemented by the end of the decade.

Conwy's Carbon Management Plan for 2019-2024 presents the principles for limiting the Council's negative impact on the environment, and the Council has implemented the Green Dragon Environmental Standard across the range of Council services (excluding schools), to accurately monitor and improve their environmental performance. This represents 65% of the GHG emissions from Council activities.

### 2.2 Local Development Plan

The Council adopted their current local development plan in 2013, and it is currently undergoing full review. The council is at the fifth and final stage of this review, which sees them producing a 'deposit plan', which integrates comments received during the consultation phase of the councils 'Preferred Strategy', the Replacement Local Development Plan (RLDP).

The Council's current 'Preferred Strategy' RLDP, which is due to go to consultation, sees adding 4,300 new homes, of which 1,800 homes will be affordable housing. The Preferred Strategy aims to add 1,800 jobs. It envisions 90% of growth within the Coastal Development Strategy area, and 10% of growth in the Rural Development Strategy Area. All development proposals should mitigate carbon and other GHG emissions across their lifecycle and include features for effective adaptation to and resilience against current and projected future climate and events. The RLDP supports district heating and local low carbon energy generation schemes.

The council has aspirations to deliver a tidal lagoon project along its northern coastline, and early scoping and feasibility work is currently underway. Land at Gofer will be allocated for a 4MW PV solar array, and additional onshore wind capacity within the SSA of up to 30MW will be supported, with review. Appropriate grid development schemes will be supported in principle, where they avoid areas of landscape, ecological and archaeological sensitivity.

### 2.3 Local Well-being Plan

The Conwy and Denbighshire five-year local well-being plan was published in April 2018. It prioritises mental wellbeing at all ages, supports community empowerment and environmental resilience. Within this, it seeks to improve the energy efficiency of buildings, seek sustainable procurement. The local well being plan mirrors what LAEP 'done well' looks like, as it considers it important to engage with individuals and communities in the creation of community plans.

### 2.4 Regional Energy Strategy

The Welsh Government Energy Service developed a Regional Energy Strategy with government and regional stakeholders. It identified a number of key interventions for the decarbonisation scenario consistent with a net zero energy system by 2050, and to ensure the region benefits from the energy transition.

North Wales seeks to become a net exporter of low carbon electricity. Priorities identified where offshore wind and marine energy technologies (including tidal), energy efficiency and decarbonisation of the building stock and shift to low carbon transport.

According to their modelling, achieving their target of a 55% reduction in emissions from the energy system by 2035 requires domestic heating emissions to fall to 499 kt $CO_2e$ (57% reduction), commercial and industrial emissions to fall to 781 kt $CO_2e$ (54% reduction) and road transport to fall to 660 kt $CO_2e$ (55% reduction).

### 2.5 Other investment plans

The North Wales Economic Ambition Board proposal for a North Wales Growth Deal was signed in December 2020. This puts into motion 14 investment projects. The deal seeks to establish North Wales as a leading location for low carbon energy generation and related supply chain investment, improvement to transport and digital connectivity, including a metro and rail program. Funding from the Welsh and UK governments in the order of £340 million (capital) is being sought to secure £1bn of private sector investment in the next 15 years, along the principles of ‘smart, resilient and connected’. Among the 14 projects include The Llysfasi Carbon Neutral Centre, constructing infrastructure that connects the Morlais Zone to the grid, and enabling infrastructure for the development of a SMR/AMR nuclear reactor at Trawsfynyyd.

## 3. Energy system actors

### 3.1 Utilities

The primary utility companies, National Grid (Electricity Transmission and Gas Transmission), Wales and West Utilities, and SP Energy Networks all recognise the need to decarbonise the energy system.

National Grid has pledged to achieve Net Zero.[39] ScottishPower was the first integrated energy company to generate 100% green electricity, and SP Energy Networks is active in broadening its service provision to heat and transport. Utilities' strategic focus lies in increasing electric vehicle connections, deploying decarbonisation technologies such as heat pumps, smart meters, and connecting more renewable energy sources to the grid.

Wales and West Utilities sees the gas network as critical to the secure and sustainable supply of energy.

*Future energy scenarios*

National Grid publishes Future Energy Scenarios (FES)[40] annually to inform future planning of energy networks nationally. FES 2020 shows that reaching net zero carbon emissions by 2050 is achievable, but requires significant investment in new capacity, energy efficiency measures (particularly in domestic housing), vehicle to grid services and deployment of emerging technologies like hydrogen, hybrid heat pumps, bioenergy and carbon capture and storage.

### 3.2 Ofgem

Ofgem has identified the following key challenges for decarbonisation:

- decarbonisation of heat for homes
- decarbonisation of transport
- decarbonisation of industrial use of energy.

Addressing these requires large increases in low carbon and renewable electricity, and an energy system which is robust and can supply energy when consumers need it. This needs large increases in investment, both in strengthening existing infrastructure and investment in new technologies. At the same time, energy users, particularly those who are vulnerable need to be protected against price increases. Ofgem recognises the trade-offs between consumers today and consumers tomorrow, as well as between different consumer groups, but also stresses that delaying action will lead to higher future costs.

Within this context, Ofgem is actively encouraging networks to invest – and is developing guidance to networks to ensure that proposals for investment are justified and manage uncertainty with regards to uncertain future needs. It recognises fast moving technological and economic contexts and the necessity to develop adaptive regulation. For example, in fostering a more coordinated regulatory approach to offshore wind, making it easier and cheaper to bring electricity on shore, and in engaging customers in energy services that provide simple ways to use less energy, and at different times.

### 3.3 Community energy groups

*Community Energy Wales*

Community Energy Wales is an overarching organisation that represents the community energy sector at the national level. Community Energy Wales could be a key stakeholder in achieving the requirement under Planning Policy Wales for all new energy projects to have an element of local ownership. For example, it has set up a new Special Purpose Vehicle (SPV) - YnNI Hiraethog - for a community shared ownership opportunity for a 33MW commercial wind farm developed by energy company RWE at Clocaenog, Denbighshire. Community Energy Wales have the option to acquire up to a 15% stake in the wind farm. Similar SPVs might be set up for the development of solar and onshore wind in Conwy.

*Datblygiadau engi Gweldig*

Datblygiadau engi Gweldig (DEG) is active in Conwy and focuses on community owned renewable energy. They have been active in over 50 projects in Northwest Wales, covering wind, solar PV and hydroelectricity. They were active in the Sustainable Communities Wales programme, which offered free support to communities across the country to improve the energy efficiency of their buildings.

*Menter Siabod*

Menter Siabod is a community action group, founded in 2003, which aims to improve the well-being of Doleyddelan through strengthening community engagement, education and employment. It has a history of working on community owned renewable energy feasibility studies. Previously, they have also set up a SPV to support community ownership of small-scale renewable electricity schemes.

*Menter Iaith Conwy*

A community organisation to promote and develop the Welsh language locally. Previously, they have secured funding to employ an energy officer to support the development of locally owned renewable energy projects.

*Other Community groups*

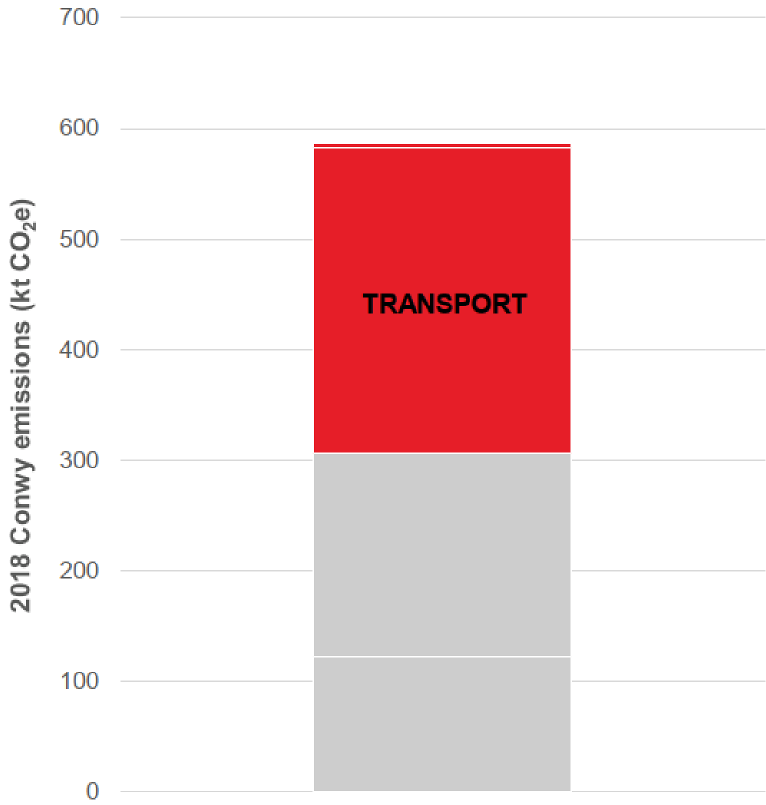
A number of other community groups have expressed interest in investigating opportunities for community owned renewable energy schemes, including Llysfaen Community Council, Conwy Local Action Group, and in the Capel Curig area.

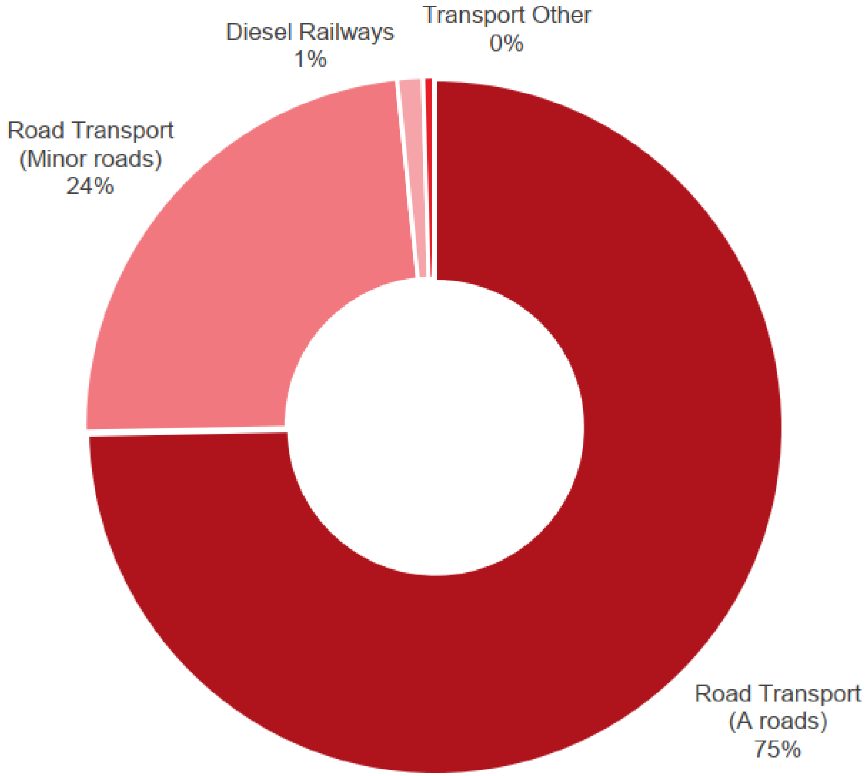
*Gwynt y Mor Community Fund.*

Community groups in Conwy are eligible to apply for the Gwynt y Mor community fund from the GYM offshore wind farm operated by RWE. This fund is offering a total of £19 million for communities in Conwy, Denbighshire and Flintshire

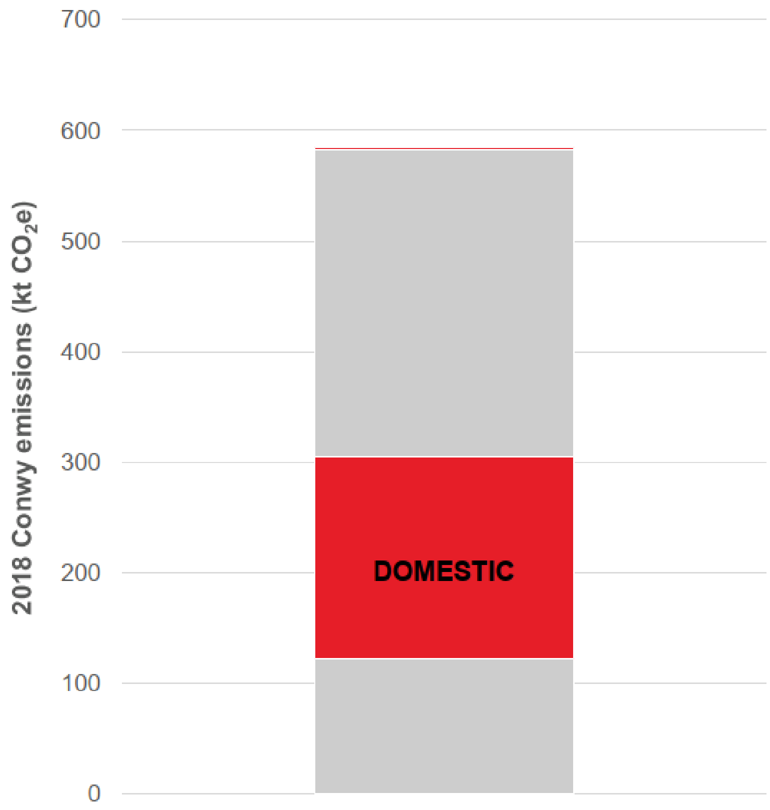
## Appendix 2: GHG emissions inventory breakdowns

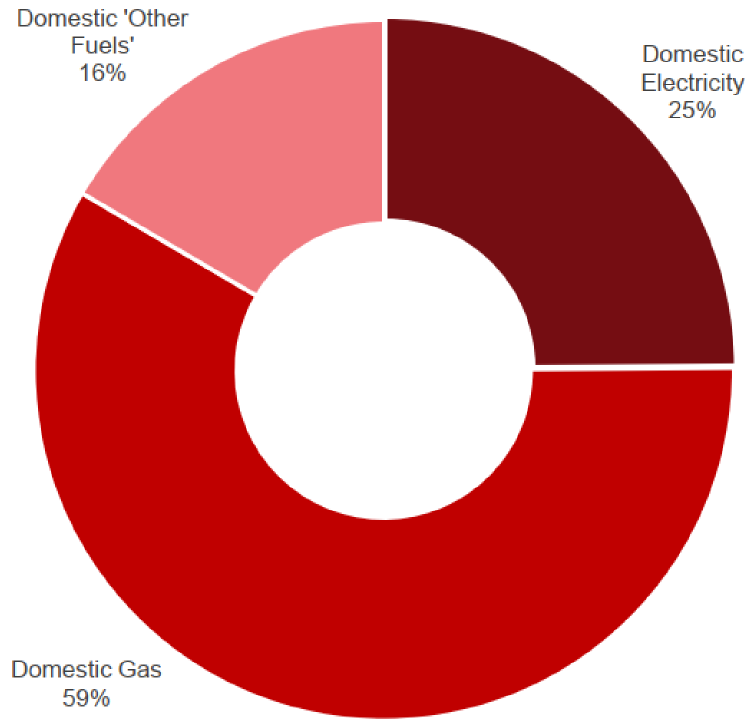
Transport emissions



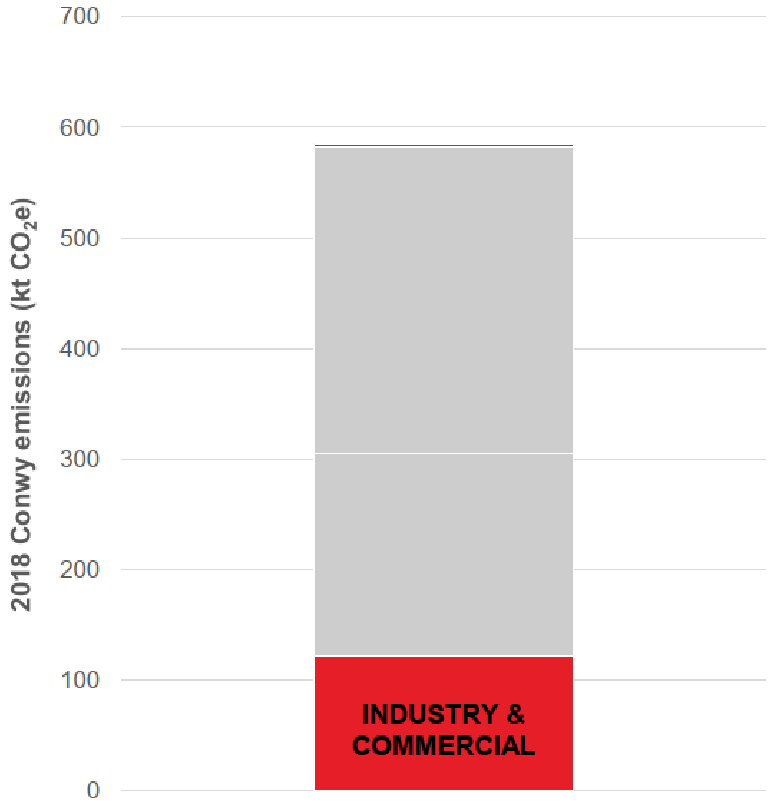



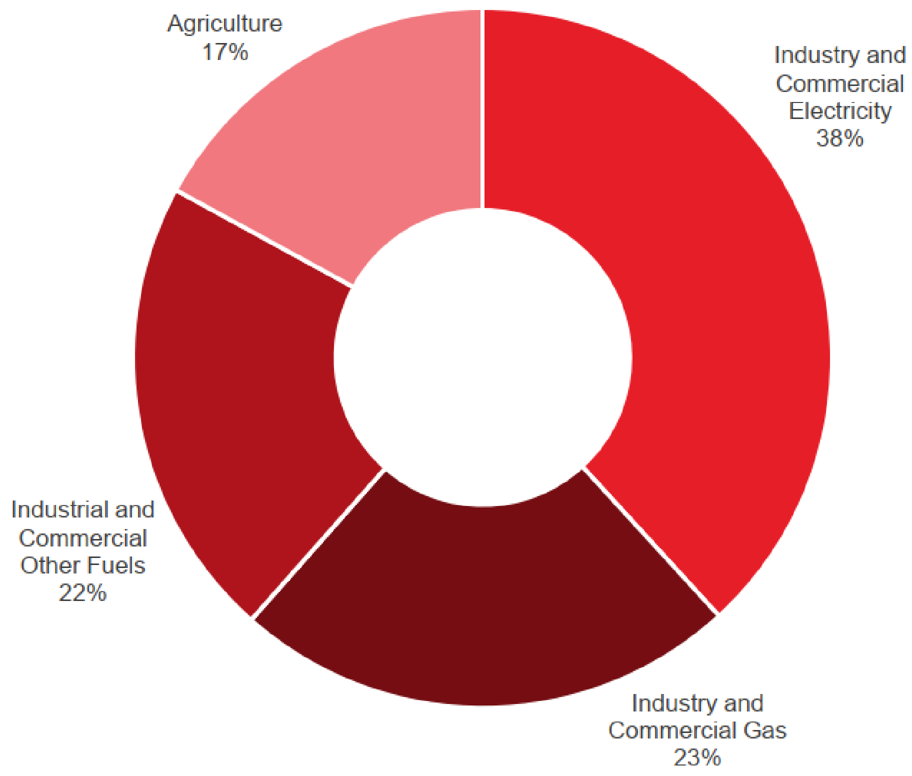
Domestic emissions



Industry and commercial emissions



# Appendix 3: Assumptions log

Assumptions register

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| Anaerobic digestion | Energy CAPEX | 4,760.0 | £ / kW | BEIS (2020) BEIS Electricity Generation Costs (2020). https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020 | CAPEX includes Pre-development cost (medium scenario) in £/kW, Construction cost (medium scenario) in £/kW and Infrastructure cost. Infrastructure cost (£'000) is converted to £/kW by dividing by reference plant size (MW*1000). Assumed price in 2020 is equivalent to projected 2025 price. No change across years | All |
| Anaerobic digestion | Energy efficiency | 0.3 | fraction | BEIS (2020) BEIS Electricity Generation Costs (2020). https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020 | From the BEIS electricity generation costs 2020. This is the load factor multiplied by the plant efficiency to account for the fact that the plant cannot operate at full load throughout the year. | All |
| Anaerobic digestion | Operational cost of production | 0.1 | £ / kWh generated | BEIS (2020) BEIS Electricity Generation Costs (2020). https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020 | OPEX includes Fixed O&M, Variable O&M, Fuel Costs, Decommissioning and waste, Steam Revenue, Additional Costs (all provided in £/MWh). No change across years | All |
| Anaerobic digestion | Lifetime | 20.0 | years | BEIS (2020) BEIS Electricity Generation Costs (2020). https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020 | | All |
| Anaerobic digestion | Operational fuel consumption cost | 0.0 | kgCO2e / kWh fuel in | BEIS (2020). Greenhouse gas reporting: conversion factors 2020. https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020 | Biogas scope 1 emissions factor used | All |
| Battery | Annual operational cost | 3.0 | £ / kW/ year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/upl | | 2050_high_hydrogen |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| | | | | oads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | |
| Battery | Annual operational cost | 7.3 | £/kW/year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | OPEX includes Operation, Inspection, Maintenance, Replenishment / refurbishment of consumables, Insurance, Security. Medium Value | All |
| Battery | Energy CAPEX | 197.6 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | 2050_high_demand |
| Battery | Energy CAPEX | 474.5 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | CAPEX includes infrastructure costs, design costs, capital costs and installation costs. Medium value | All |
| Battery | Energy efficiency | 0.9 | fraction | https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | JR - Changed energy_eff to 0.92 this means a round trip efficiency of 0.85 | All |
| Battery | Lifetime | 15.0 | years | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | | All |
| Battery | Annual operational cost | 3.0 | £ / kW/ year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/stor | | 2050_high_hydrogen |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| | | | | age-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | |
| Battery | Annual operational cost | 7.3 | £/kW/year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | OPEX includes Operation, Inspection, Maintenance, Replenishment / refurbishment of consumables, Insurance, Security. Medium Value | All |
| Battery | Energy CAPEX | 197.6 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | 2050_high_demand |
| Battery | Energy CAPEX | 474.5 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | CAPEX includes infrastructure costs, design costs, capital costs and installation costs. Medium value | All |
| Battery | Energy efficiency | 0.9 | fraction | https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | JR - Changed energy_eff to 0.92 this means a round trip efficiency of 0.85 | All |
| Battery | Lifetime | 15.0 | years | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | | All |
| Battery | Annual operational cost | 3.0 | £ / kW/ year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/stor | | 2050_high_hydrogen |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| | | | | age-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | |
| Battery | Annual operational cost | 7.3 | £/kW/yea r | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | OPEX includes Operation, Inspection, Maintenance, Replenishment / refurbishment of consumables, Insurance, Security. Medium Value | All |
| Battery | Energy CAPEX | 197.6 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | 2050_high_demand |
| Battery | Energy CAPEX | 474.5 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | CAPEX includes infrastructure costs, design costs, capital costs and installation costs. Medium value | All |
| Battery | Energy efficiency | 0.9 | fraction | https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | JR - Changed energy_eff to 0.92 this means a round trip efficiency of 0.85 | All |
| Battery | Lifetime | 15.0 | years | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | | All |
| Battery | Annual operational cost | 3.0 | £ / kW/ year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/stor | | 2050_high_hydrogen |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| | | | | age-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | |
| Battery | Annual operational cost | 7.3 | £/kW/year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | OPEX includes  Operation, Inspection, Maintenance, Replenishment / refurbishment of consumables, Insurance, Security. Medium Value | All |
| Battery | Energy CAPEX | 197.6 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | 2050_high_demand |
| Battery | Energy CAPEX | 474.5 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | CAPEX includes infrastructure costs, design costs, capital costs and installation costs. Medium value | All |
| Battery | Energy efficiency | 0.9 | fraction | https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | JR - Changed energy_eff to 0.92 this means a round trip efficiency of 0.85 | All |
| Battery | Lifetime | 15.0 | years | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | | All |
| Battery | Annual operational cost | 3.0 | £ / kW/ year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/stor | | 2050_high_hydrogen |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| | | | | age-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | |
| Battery | Annual operational cost | 7.3 | £/kW/year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | OPEX includes Operation, Inspection, Maintenance, Replenishment / refurbishment of consumables, Insurance, Security. Medium Value | All |
| Battery | Energy CAPEX | 197.6 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | 2050_high_demand |
| Battery | Energy CAPEX | 474.5 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | CAPEX includes infrastructure costs, design costs, capital costs and installation costs. Medium value | All |
| Battery | Energy efficiency | 0.9 | fraction | https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | JR - Changed energy_eff to 0.92 this means a round trip efficiency of 0.85 | All |
| Battery | Lifetime | 15.0 | years | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | | All |
| Battery | Annual operational cost | 3.0 | £ / kW/ year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/stor | | 2050_high_hydrogen |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| | | | | age-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | |
| Battery | Annual operational cost | 7.3 | £/kW/year | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | OPEX includes  Operation, Inspection, Maintenance, Replenishment / refurbishment of consumables, Insurance, Security. Medium Value | All |
| Battery | Energy CAPEX | 197.6 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | | 2050_high_demand |
| Battery | Energy CAPEX | 474.5 | £ / kW | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf 50MW Frequency Management battery | CAPEX includes infrastructure costs, design costs, capital costs and installation costs. Medium value | All |
| Battery | Energy efficiency | 0.9 | fraction | https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | JR - Changed energy_eff to 0.92 this means a round trip efficiency of 0.85 | All |
| Battery | Lifetime | 15.0 | years | Mott MacDonald for BEIS (2018) Storage cost and technical assumptions for BEIS. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910261/storage-costs-technical-assumptions-2018.pdf | | All |
| EV chargers | Energy CAPEX | 817.0 | £ / kW | https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf Calculations: https://arup.sharepoint.com/:x:/t/prj-28041700/EZof4JF_CH5HngEuZKZWJ5gBSDd8irdD4zCUWBIbznK54A?e=vjQttT | Networked 50 kW Rapid DC charger - Capex includes hardware, labor and materials (3-5 chargers per location) | All |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| EV chargers | Energy efficiency | 1.0 | fraction | | selected to have no effect | All |
| EV chargers | Lifetime | 12.0 | years | https://www2.deloitte.com/uk/en/pages/energy-and-resources/articles/uk-ev-charging-infrastructure-update-show-me-the-money.html | | All |
| Ground PV | Energy CAPEX | 531.3 | £ / kW | BEIS (2020) BEIS Electricity Generation Costs (2020). https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020 | Large-scale Solar. CAPEX includes Pre-development cost (medium scenario) in £/kW, Construction cost (medium scenario) in £/kW and Infrastructure cost. Infrastructure cost (£'000) is converted to £/kW by dividing by reference plant size (MW*1000). | All |
| Ground PV | Operational cost of production | 0.0 | £ / kWh generated | BEIS (2020) BEIS Electricity Generation Costs (2020). https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020 | OPEX includes Fixed O&M, Variable O&M, Fuel Costs, Decommissioning and waste, Steam Revenue, Additional Costs (all provided in £/MWh) | All |
| Ground PV | Operational cost of production | | kgCO2e / kWh fuel in | | | All |
| Ground PV | Lifetime | 35.0 | years | BEIS (2020) BEIS Electricity Generation Costs (2020). https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020 | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |
| Heat network | Operational cost of production | 0.1 | £ / kWh generated | Varies per network - so this shouldn't be used | | All |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |
| Heat network | Operational cost of production | 0.1 | £ / kWh generate d | Varies per network - so this shouldn't be used | | All |
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| Heat network | Operational cost of production | 0.1 | £ / kWh generated | Varies per network - so this shouldn't be used | | All |
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |
| Heat network | Operational cost of production | 0.1 | £ / kWh generated | Varies per network - so this shouldn't be used | | All |
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |
| Heat network | Operational cost of production | 0.1 | £ / kWh generate d | Varies per network - so this shouldn't be used | | All |
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |
| Heat network | Operational cost of production | 0.1 | £ / kWh generate d | Varies per network - so this shouldn't be used | | All |
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |
| Heat network | Operational cost of production | 0.1 | £ / kWh generate d | Varies per network - so this shouldn't be used | | All |
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |
| Heat network | Operational cost of production | 0.1 | £ / kWh generate d | Varies per network - so this shouldn't be used | | All |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |
| Heat network | Operational cost of production | 0.1 | £ / kWh generate d | Varies per network - so this shouldn't be used | | All |
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| Heat network | Operational cost of production | 0.1 | £ / kWh generated | Varies per network - so this shouldn't be used | | All |
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
| Heat network | Lifetime | 40.0 | | Standard Arup approach | | All |
| Heat network Duffyn | Energy efficiency | 0.9 | fraction | Arup approach is energy_eff of 0.95. but changed to 0.9 to account for the use of a heat pump in this particular heatnetwork | | All |
| Heat network Duffyn | Lifetime | 40.0 | years | Arup experience | | All |
| Heat network | Energy CAPEX | 1,500.0 | £ / kW | Varies per network - so this shouldn't be used | | All |
| Heat network | Energy efficiency | 1.0 | | Standard Arup approach | | All |
| Heat network | Operational cost of production | 0.1 | £ / kWh generated | Varies per network - so this shouldn't be used | | All |
| Heat network | Operational cost of production | 0.0 | kgCO2e / kWh | Assumed free because | | All |
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| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| Nuclear SMR | Energy CAPEX | 7,500.0 | £ / kW | £10k comes from the ETI paper, if you then apply the learning rate for small SMR from the EY paper, you get £7.5k for 2050 and 2040. This assumes that the first small SMRs are built in 2030, and the learning rate is applied over the first 10GWe. | | 2050_low_demand |
| Nuclear SMR | Energy CAPEX | 10,000.0 | £ / kW | £10,000 comes from ETI (2015) "The role for nuclear within a low carbon energy system" https://www.eti.co.uk/insights/the-role-for-nuclear-within-a-low-carbon-energy-system (accessed 04/01/2021) apply the learning rate from EY for DECC (2016) Small modular reactors: Can building nuclear power become more cost-effective?. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/665300/TEA_Projects_5-7_-_SMR_Cost_Reduction_Study.pdf | LCOE taken as £100/MWh, based on Figure 7. Operating costs are the smaller part of the cost of generation, circa 25% of LCOE (p.38). | All |
| Nuclear SMR | Energy efficiency | 1.0 | | | Selected to have no effect | All |
| Nuclear SMR | Operational cost of production | 0.0 | £ / kWh generated | EY for DECC (2016) Small modular reactors: Can building nuclear power become more cost-effective?. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/665300/TEA_Projects_5-7_-_SMR_Cost_Reduction_Study.pdf | LCOE taken as £100/MWh, based on Figure 7. Operating costs are the smaller part of the cost of generation, circa 25% of LCOE (p.38). | All |
| Nuclear SMR | Operational cost of production | 0.0 | kgCO2e / kWh | NEA (2020) The Role of Nuclear Energy in a Low-carbon Energy Future. https://www.oecd-nea.org/nsd/reports/2012/nea6887-role-nuclear-low-carbon.pdf | 42% of the lifecycle carbon assessment is during the operational phase. Lifecycle emissions based on Figure 2.2. | All |
| Nuclear SMR | Lifetime | 60.0 | | EY for DECC (2016) Small modular reactors: Can building nuclear power become more cost-effective?. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/665300/TEA_Projects_5-7_-_SMR_Cost_Reduction_Study.pdf | | All |
| Nuclear SMR | Energy CAPEX | 7,500.0 | £ / kW | £10k comes from the ETI paper, if you then apply the learning rate for small SMR from the EY paper, you get | | 2050_low_demand |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| | | | | £7.5k for 2050 and 2040. This assumes that the first small SMRs are built in 2030, and the learning rate is applied over the first 10GWe. | | |
| Nuclear SMR | Energy CAPEX | 10,000.0 | £ / kW | £10,000 comes from ETI (2015) "The role for nuclear within a low carbon energy system" https://www.eti.co.uk/insights/the-role-for-nuclear-within-a-low-carbon-energy-system (accessed 04/01/2021) apply the learning rate from EY for DECC (2016) Small modular reactors: Can building nuclear power become more cost-effective?. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/665300/TEA_Projects_5-7_-_SMR_Cost_Reduction_Study.pdf | LCOE taken as £100/MWh, based on Figure 7. Operating costs are the smaller part of the cost of generation, circa 25% of LCOE (p.38). | All |
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| Nuclear SMR | Energy CAPEX | 7,500.0 | £ / kW | £10k comes from the ETI paper, if you then apply the learning rate for small SMR from the EY paper, you get £7.5k for 2050 and 2040. This assumes that the first | | 2050_low_demand |

| Technology | Setting | Value | Units | Reference | Notes | Scenario |
|---|---|---|---|---|---|---|
| | | | | small SMRs are built in 2030, and the learning rate is applied over the first 10GWe. | | |
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| Nuclear SMR | Energy CAPEX | 10,000.0 | £ / kW | £10,000 comes from ETI (2015) "The role for nuclear within a low carbon energy system" https://www.eti.co.uk/insights/the-role-for-nuclear-within-a-low-carbon-energy-system (accessed 04/01/2021) apply the learning rate from EY for DECC (2016) Small modular reactors: Can building nuclear power become more cost-effective?. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/665300/TEA_Projects_5-7_-_SMR_Cost_Reduction_Study.pdf | LCOE taken as £100/MWh, based on Figure 7. Operating costs are the smaller part of the cost of generation, circa 25% of LCOE (p.38). | All |
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