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THE RACE TO NET ZERO

FUTURE ENERGY DECARBONISATION SCENARIOS

NORTHERN IRELAND

MARCH 2021

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EXECUTIVE SUMMARY

FUTURE ENERGY DECARBONISATION SCENARIOS - THE RACE TO NET ZERO

Executive Summary

No-one can predict the future of Northern Ireland's energy system out to 2050. There are a wide range of approaches that could be taken over the next three decades to deliver a net zero carbon energy mix.

In this report, we present a range of illustrative scenarios to demonstrate what our energy systems might look like in the future. To do this, we have developed a range of potential scenarios using a new publicly-available and open-source Energy Transition Model built specifically for Northern Ireland.[1]

None of these scenarios are an expected outcome of the Energy Strategy and we have not developed these scenarios in order to choose a preference. The scenarios outlined here have been informed by the Call for Evidence and visualise what different energy systems of the future might look like. **They are not forecasts of the future, nor do they represent any statement of policy intent.** They can provide indications of the scale and type of actions required to achieve certain goals, such as decarbonisation.

We have made two key decisions in developing these scenarios:

1. **They align with net zero carbon energy emissions by 2050.** We have not run high, medium and low scenarios looking at achieving net zero by different dates; with the exception of the 'Business As Usual' scenario, we are using the model to outline potential approaches to achieving the outcome of 'net zero carbon and affordable energy' proposed in this consultation document.
2. **They represent broadly realistic pathways for the future.** Whilst some scenario modelling may seek to test extreme approaches for the future to push the boundaries of different decisions, we have constrained the scenarios to focus on those we consider will be most relevant for Northern Ireland. This means there is overlap across the scenarios.

The scenarios have been created using the Northern Ireland Energy Transition Model (NI ETM), recently been developed. The NI ETM is the first NI regional initiative to create an energy model representing major energy sectors and sub-sectors and to assess their impacts on the current and future regional energy demand and associated carbon (CO_2) emissions.

This is an open source interactive simulation model that allows users, which could be anyone – from industry to businesses to researchers to the public, to explore future changes to the energy system. The ETM provides a holistic view on the energy system.

1 https://pro.energytransitionmodel.com/; under the heading Start a new scenario you can select from a range of countries, including Northern Ireland, and in the other drop down box you can select the future year you wish to create a scenario in. Click START and this should take the user into the NI ETM.

Future Energy Decarbonisation Scenarios

Scenario 1: Business As Usual - built on current trends and no further policy interventions to estimate what future CO_2 emissions in Northern Ireland (NI) could be for each sector to 2050, if no further energy sector action is taken beyond today.

The net zero carbon scenarios:

Scenario 2: High Electrification - builds on the existing success of the renewable electricity sector, with high levels of electrification to take advantage of a substantially larger renewable electricity base. Increased capacity is met through a combination of solar photovoltaic (PV), offshore wind and marine technology. In addition there is an expansion of onshore wind, aligned with improved demand-side management and flexibility measures.

Scenario 3: High Gasification - a greater focus on gas. Gas is imported for flexible electricity generation alongside the large renewables base. The gas network is fully decarbonised with a mix of hydrogen and biomethane and is expanded to reach a larger percentage of the population. Demand for hydrogen and biomethane is high.

Scenario 4: Diverse - takes into account the considerable regional differences in Northern Ireland and includes higher levels of local involvement as well as local responses to the low-carbon transition. Heat and transport have quite different solutions depending on location and geography, and for power it may imply a more decentralised system.

The three net zero scenarios reflect alternative futures from a combination of key policy areas. In all scenarios, significant change is required to achieve a net zero carbon energy system by 2050.

Comparing the Scenarios

The scenarios in this report are purely illustrative and are not expected outcomes of the Energy Strategy.

By visualising what a range of potential scenarios could be, it demonstrates that under any combination of policy decisions, **the energy system in 2050 will be radically different to how it is today.** Even under the Business As Usual scenario, which does not have additional policies over and above those already announced, oil is no longer the dominant energy source and energy demand is lower.

The additional three scenarios go much further than this, reducing energy demand further and leaving oil with less than a 5% contribution across each scenario. Key differences include:

- The **High Electrification** scenario has the lowest final demand of all scenarios due to higher energy efficiency required for heat pumps and relies mostly on electricity with 60% of final demand.
- The **High Gasification** scenario has the highest proportion of gas demand (network gas and hydrogen) with 46% of final demand, compared to the high electrification (22%) and diverse scenarios (37%).
- The **Diverse** scenario has a broader energy mix with 2050 energy demand being quite balanced, albeit higher overall than the other two.

In the Business As Usual scenario, **Northern Ireland falls significantly short of meeting net zero energy CO_2 emissions without new policies being introduced.** Carbon emissions will decrease based on a minimum 40% renewable electricity share of a larger electricity sector through Electric Vehicles replacing petrol and diesel cars, but 45% of 1990 emissions still remain by 2050.

The other three scenarios, by comparison, all achieve net zero carbon, a reduction of 100% of CO_2 emissions from 1990.

We have not sought to model the potential costs of any of these scenarios, none of which are expected outcomes from the Energy Strategy. Our approach to measuring and monitoring costs will be focused on actual policies and pathways we are proposing.

Comparison of scenarios across selected metrics in 2050

Criteria	Business As Usual	High Electrification	High Gasification	Diverse
Final energy demand (TWh)	35.1	19.1	21.5	22.1
Final energy demand change from 2018	-29%	-61%	-56%	-55%
Renewable energy share	27.5%	93.6%	95.9%	96.0%
Renewable electricity share	40%	100%	100%	100%
Energy Imports	83.8%	14.4%	21.7%	17.6%
Hydrogen demand (TWh)	2.4	2.8	6.7	5.1
CO_2 emissions relative to 1990	-55%	-100%	-100%	-100%
Paris Agreement Compatible 1.5 oC	No	Yes	Yes	Yes

INTRODUCTION

SECTION 1

INTRODUCTION

Looking at the state of Northern Ireland's energy system in 2018, it is still at the early stages of its energy transition. To become net zero in carbon emissions by 2050, NI must transition from today's decoupled state of power, heat and transport sectors, largely based on non-renewable energy sources, towards an integrated energy system with renewable sources at its core.

There are a wide range of approaches that could be taken over the next three decades to deliver a net zero carbon energy mix. This Future Energy Decarbonisation Scenario report describes four possible Northern Ireland (NI) energy futures up to 2050. They are not forecasts of the future, nor do they represent any statement of policy intent; they set out a range of possible futures.

This report describes different plausible energy system transition pathways for NI. This report analyses the development of the NI energy system across four scenarios:

1. Business As Usual
2. High Electrification
3. High Gasification
4. Diverse

The Business as Usual scenario is created to act as a baseline scenario (no further climate action beyond today) to illustrate if no further intervention occurs, how far away NI would be from net zero in 2050. The remaining scenarios all have a single objective of net zero carbon emissions by 2050.

This report focuses on the primary and final energy demands, fuel mix, the sectors demanding energy and the supply of the energy by fuel type. This report does not consider international aviation or shipping energy consumption or emissions as these are reported at a UK level. In addition, any potential costs associated with each of these scenarios are not determined within this report.

Why are we doing this? Climate change

The Earth's average temperature is about 15ºC but has been much higher and lower in the past. There are natural fluctuations in the climate but scientists have demonstrated that temperatures are now rising faster than at many other times. The world is about one degree Celsius warmer than before widespread industrialisation, according to the World Meteorological Organization (WMO). It says the years, 2015–2019, were the warmest on record. Across the globe, the average sea level increased by 3.6mm per year between 2005 and 2015. Most of this change was because water increases in volume as it heats up.

The rising global temperature will be increasingly prevalent and will lead to wider changes to our weather. Additionally, many impacts of climate change are already being detected, including:

- warming of the troposphere (the lower part of the atmosphere)
- acidification of the oceans
- rising sea levels
- declining glaciers and sea ice
- slowing of increases to crop productivity

Scientists believe we are enhancing the natural greenhouse effect, with gases released from industry and agriculture trapping more energy and increasing the temperature. This is known as climate change or global warming.

There is no clear threshold where climate change moves from safe to dangerous. We can expect some disruptions and irreversible losses of natural habitats and resources, even with a 1.5 or 2°C temperature rise. However, with rapid global action to cut greenhouse gas emissions, we can still reduce the likelihood of global temperatures increasing by more than 1.5 – 2°C. On the other hand, if we take no action, global temperatures could increase by 4°C or more by the end of the century.

Greenhouse Gases

The greenhouse gas with the greatest impact on warming is water vapour. However, it remains in the atmosphere for only a few days.

Carbon dioxide (CO_2) persists for much longer. It would take hundreds of years for a return to pre-industrial levels and only so much can be soaked up by natural reservoirs such as the oceans.

Most man-made emissions of CO_2 come from burning fossil fuels. When carbon-absorbing forests are cut down and left to rot or burned, that stored carbon is released, contributing to global warming.

Since the Industrial Revolution began around 1750, CO_2 levels have risen more than 30%. The concentration of CO_2 in the atmosphere is higher than at any time in the last 800,000 years.

Other greenhouse gases such as methane and nitrous oxide are also released through human activities but they are less abundant than carbon dioxide.

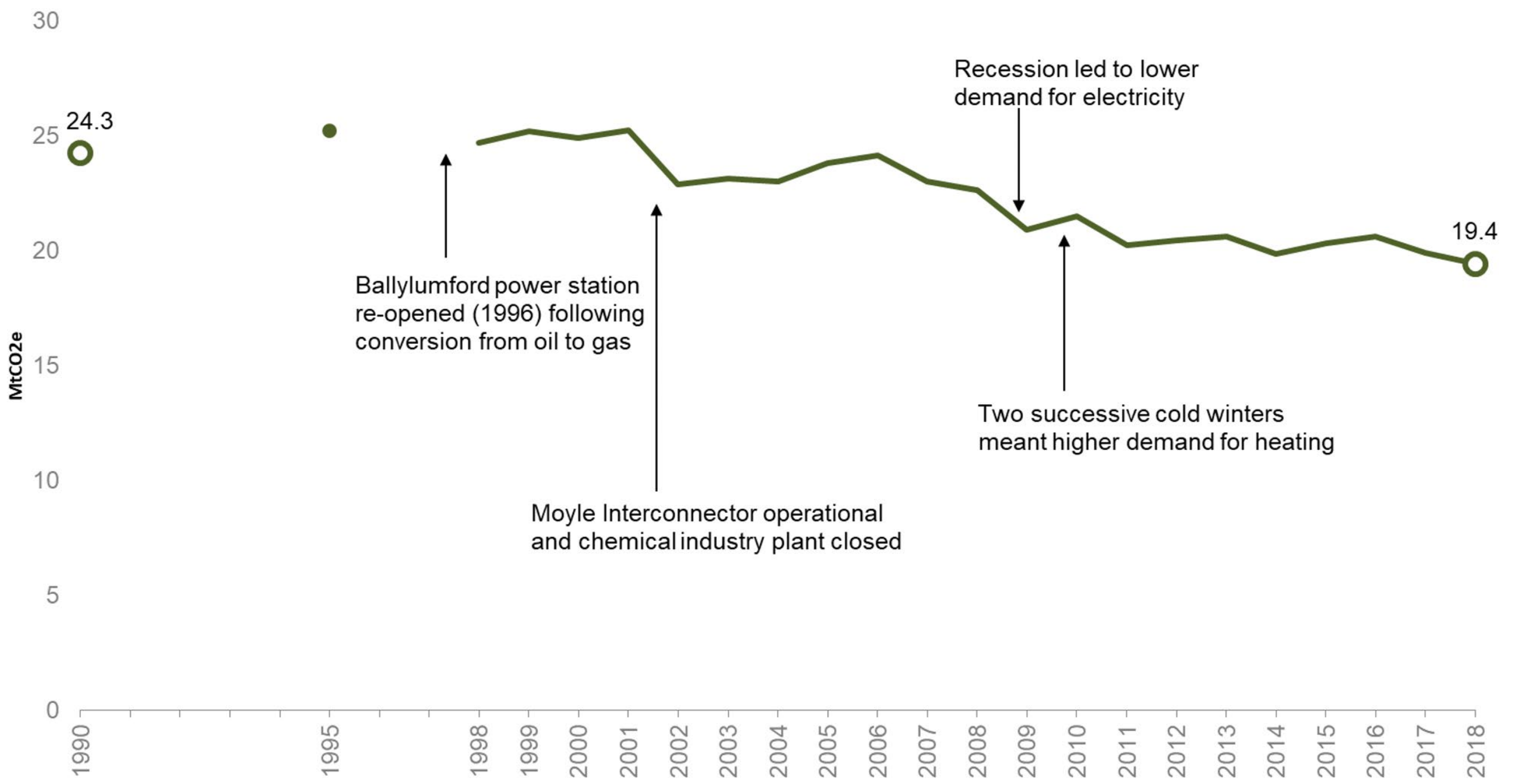
100% reduction of Greenhouse Gas

The UK Climate Change Act 2008 (2050 Target Amendment) Order 2019, which is the basis for the UK's approach to tackling and responding to climate change, was amended in 2019 to require the UK to have a 100% reduction in Greenhouse Gas (GHG) emissions by 2050 from 1990 levels. This 'net zero' target represents a significant step-change in the commitment to addressing the climate crisis. Net zero means GHG emissions are reduced to zero in total. This can only happen with a combination of both lowering baseline emissions linked to the things we do (including transport, energy, agriculture, our built environment) as well as removing any remaining emissions with schemes that offset an equivalent amount from the atmosphere. Such as planting trees or using technology like carbon capture and storage.

This includes reducing emissions from the devolved administrations. Northern Ireland accounts for about 4% (estimated 19.4 million tonnes of carbon dioxide equivalent [$MtCO_2e$]) of the UK's emissions (451.5 $MtCO_2e$) in 2018.

As shown in Figure 1.1, in 2018, Northern Ireland's GHG emissions were estimated to be 19.4 $MtCO_2e$. This was a decrease of 2% compared with 2017. The longer term trend showed a decrease of 20% compared to the base year (1990).

Figure 1.1: Greenhouse gas emissions for Northern Ireland, 1990, 1995, 1998 to 2018



Source: Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 - 2018

Climate Change Committee

The Climate Change Committee (CCC) recently conducted a comprehensive analysis[2] of different pathways to reach net zero to underpin their advice on the UK Sixth Carbon Budget. In December 2020, the CCC provided advice on the appropriate trajectory for emissions in Northern Ireland between now and 2050 for a fair contribution to the UK net zero target.

The CCC recommendation is that deep emissions reduction in Northern Ireland are still crucial if the UK is to reach net zero overall. On the basis of CCC's analysis, their Balanced Net Zero Pathway, which meets net zero by 2050 at a UK level and on which their recommended Sixth Carbon Budget is based, Northern Ireland would reach at least an 82% reduction in GHG emissions by 2050 compared to 1990 levels.

In addition, the CCC stated Northern Ireland could achieve net zero carbon (CO_2) emissions by 2050 as part of the Balanced Pathway to UK net zero

How Energy fits into the picture?

In 2018, energy-related emissions[3] accounted for approximately two thirds (66%) of all GHG emissions in NI. Estimates in 2018 for energy-related emissions have decreased from 1990 levels of 16.7 to 12.8 $MtCO_2e$ (23%).

It is important to note that GHG emissions are reported for seven greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3)[4].

2 https://www.theccc.org.uk/publication/sixth-carbon-budget/
3 Defined as GHG emissions assigned to Business; Energy Supply; Industrial Process; Public; Residential and Transport. Source: Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2018. http://naei.beis.gov.uk/reports/reports?section_id=4
4 https://public.flourish.studio/visualisation/5697342/ - interactive data visualisation showing GHG emissions for Northern Ireland in 2018 by sector and gas

Of the 12.8 $MtCO_2e$ energy-related GHG emissions in 2018, the majority (12.3 $MtCO_2e$; 96%) are carbon dioxide (CO_2). To achieve net zero CO_2 by 2050 there would need to be annual net decrease of 0.4 $MtCO_2$, based on current levels.

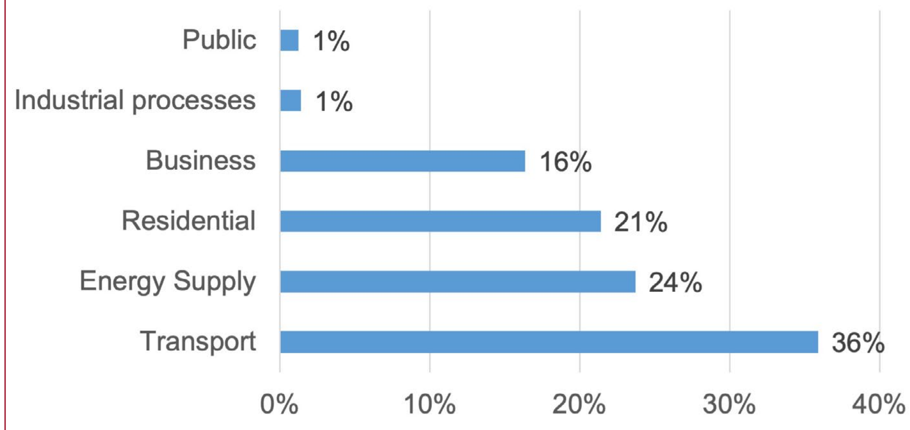
Table 1.1: Greenhouse gas and carbon emissions ($MtCO_2$) for Northern Ireland, 1990 and 2018

Greenhouse Gas Emissions ($MtCO_{2e}$)	1990	2018	Percentage change (%)
All sectors, All GHG	24.3	19.4	-20%
All sectors, CO_2 only	16.8	13.1	-22%
Energy-related, All GHG	16.7	12.8	-23%
Energy-related, CO_2 only	16.0	12.3	-23%

Source: Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 - 2018

In 2018, of the 12.3 $MtCO_2$, Transport had the largest share of CO_2 emissions with 36%, followed by Energy Supply at 24%. (Figure 1.2)

Figure 1.2: Energy-related carbon emissions ($MtCO_2$) by sector in 2018



ENERGY MODELLING APPROACH

SECTION 2
ENERGY MODELLING APPROACH

Introduction

The UK Climate Change Act 2008 (2050 Target Amendment) Order 2019 commits the UK to a 100% reduction in GHG emissions by 2050 from 1990 levels. In this context there needs to be an assessment of the potential pathways to reach a net zero carbon 2050 target for the energy sector in NI, whilst meeting the energy needs of the population sustainably and cost-effectively.

A whole systems approach, across key issues including: the role of the consumer; energy efficiency; energy for heat, power and transport; and other issues such as security of supply, data, the economy and new skills and technologies, will be required to transition towards a net zero carbon energy sector.

Currently our energy sector has many interdependencies but is not an integrated system. By adopting a whole systems approach we can integrate the energy system's supply and demand with other sectors such as domestic, services, transport & industrial sectors as well as new fuels such as hydrogen and increase overall system flexibility.

Data, analysis and modelling

'All models are wrong, but some are useful…' — George Box (1978)

To implement the energy transition to meet carbon reduction targets, it is crucial to understand the costs and benefits of different technologies, system designs and decarbonisation pathways.

Achieving net zero carbon requires an in-depth understanding of the existing energy use, costs and benefits of different options and choices from a whole sector perspective, to aid policy and investment decisions, as well as the impact of the transition.

Whole sector modelling and analysis is required to understand how the entire energy system, and the constituent parts within it, might interact and collectively contribute to delivering lowest-cost overall energy system transitions.

The Energy Transition Model

The Future Energy Decarbonisation Scenarios have been created using the Northern Ireland (NI) Energy Transition Model (ETM), which has recently been developed. The NI ETM is the first NI regional initiative to create an energy model representing major energy sectors and sub-sectors and to assess their impacts on the current and future regional energy demand and associated CO_2 emissions. The NI ETM is available at: https://pro.energytransitionmodel.com/ under the heading **Start a new scenario** you can select from a range of countries, including Northern Ireland, and in the other drop down box you can select the future year you wish to create a scenario in. Click **START** and this should take the user into the NI ETM.

This is an open source interactive simulation model that allows users, this could be anyone – from industry to businesses to researchers to the public, to explore future changes to the energy system. The ETM provides a holistic view on the energy system. The ETM is a simulation or 'what if' type model rather than an optimisation type such as TIMES (The Integrated MARKAL-EFOM System). ETM outputs include key indicators such as primary and final energy demand and CO_2 emissions.

The NI ETM has been used to illustrate the broad impacts of different sectors and sub-sectors on regional demand and carbon emissions. The model visually reflects how changes in one sector can benefit from emissions reductions in other sectors. For example, electrification of transport and heat sectors will reach full decarbonisation only when full decarbonisation of the electricity sector is achieved. Such links can be easily observed and evaluated in the NI ETM.

The NI ETM also allows a high-level assessment of how policy instruments applied in one sector might impact other sectors. For example, how energy efficiency targets might reduce heat demand and as result then reduce electricity, bioenergy or hydrogen demand requirements.

In addition to this, the ETM has capacity to assess some behavioural impact on the energy transition, such as consumer prosperity and behavioural use. The ETM has the capability of simulating different scenarios concerning consumer engagement.

Finally, future net zero targets require a radically different approach for energy modelling to fully decarbonise each energy sub-sector. Only specific sub-sectors will benefit from the CO_2 sequestration and removal options. The NI ETM can identify potential sub-sectors and needs for CO_2 mitigation requirements.

The scope of ETM, in terms of CO_2 emissions, includes the following Intergovernmental Panel on Climate Change (IPCC) activities which result in carbon emissions:

Emissions Category	IPCC Code
Fuel Combustion by sector	1.AA
Ammonia Production	2.B.1
Metal Industry	2.C
Waste Incineration	5.C.1

Other emissions, such as other feedstock and fugitive emissions are out of scope of the ETM and therefore not part of the future energy scenario analysis. However, this does mean that CO_2 emissions over and above the energy-related sectors are included in the estimations of the ETM.

Table 2.1: Carbon emissions ($MtCO_2$) for Northern Ireland in 2018

Carbon Emissions ($MtCO_2$)	2018
All sectors	13.1
Energy-related	12.3
ETM IPCC codes only	12.6

Source: Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 - 2018

The coherence assessment of the estimated CO_2 emissions in 2018 is produced by comparing the ETM against the National Atmospheric Emissions Inventory (NAEI) estimates for NI CO_2 emissions within these IPCC categories.

Table 2.2: Carbon emissions ($MtCO_2$) by source for Northern Ireland in 2018

Carbon Emissions ($MtCO_2$) estimate source	2018
NAEI	12.58
ETM	12.57
Difference	0.01

Sources: Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 - 2018 and NI Energy Transition Model

Overall the difference between the two estimates of CO_2 emissions in NI for 2018 is minimal at 0.07%. This provides confidence in the ETM estimates for CO_2 emissions based on energy consumption data for 2018. In addition, if official NAEI methodology in estimating CO_2 emissions remains consistent, the ETM will provide consistent estimates for levels of CO_2 emissions out to 2050, relative to NAEI.

The ETM produces estimated cost figures for each scenario created. However, these costs are calculated within the default assumptions built into the model. No localised NI costs have been incorporated into the NI ETM. As a result no cost analysis is included within this report. Additional research, analysis and modelling projects involving local stakeholders will be required to fully assess potential costs associated with any future energy scenarios.

Data behind the ETM

The base year for the NI ETM is 2018. This year was selected as the most recent year comprehensive data for energy consumption and emissions was available for NI.

The ETM has specific data requirements to form a base year to work from, providing a high-level energy balance for NI. This data provides a high level overview of energy flows from primary energy supply down to final energy use. Primarily the energy balance data for NI has been sourced from national or official statistical data readily available through statutory agencies. However to build the energy model, more detailed information about regional characteristics was required. For example, how energy demand is split over various sub-sectors and/or applications within a sector down to what technologies are used.

An extensive consultation exercise was undertaken to engage with appropriate stakeholders including central & local government, industry representatives and academics. This was to ensure the data was as robust and reliable as possible and was incorporated into the ETM for NI. Further details on the sources of all data items utilised to build the base year for 2018 are available at https://refman.energytransitionmodel.com/publications/2140

Limitations of the energy data for Northern Ireland

There are over 300 separate data items required for the base year including an energy balance for NI. It is important to note that due to the detailed nature of the data requirements on the ETM that some of this data is not available at NI level. For example, there is no NI data for final energy consumption across technology and carrier application (how different energy types are used e.g. appliances, lighting, heating etc.). In such instances, an alternative has been incorporated utilising data from the Energy Consumption UK. The assumption is patterns of use are the same across the UK.

Data on energy use within industry is not available within each industrial sector, only at NI level. As a result any changes to energy use within industry is at this high level and not specific to each sector. In addition, there are a number of hourly profiles for electricity demand which are not available for NI. To ensure the ETM has sufficient data to produce scenarios, default profiles are utilised. This has the impact of affecting the hourly curves for electricity demand over the year and reduces the risk of a security of supply issue being identified within the future energy scenarios.

Limitations of the Energy Transition Model

The ETM, as with any other model, encompasses a certain level of limitations. The ETM has not been developed as a bespoke model for NI, therefore some elements of the future energy decarbonisation scenarios cannot be reflected within the ETM. On certain occasions a proxy has been used to represent, as closely as possible, the changes to the NI energy system which is intended to be portrayed. Any proxies selected have been dependent on the level of associated emissions of intended change for the energy sector. Further details on these proxies are presented in Annex F. There are some aspects of the scenarios which the ETM does not include, such as hybrid EV, hydrogen trains. These categories have been represented by aggregation with other technologies within the ETM.

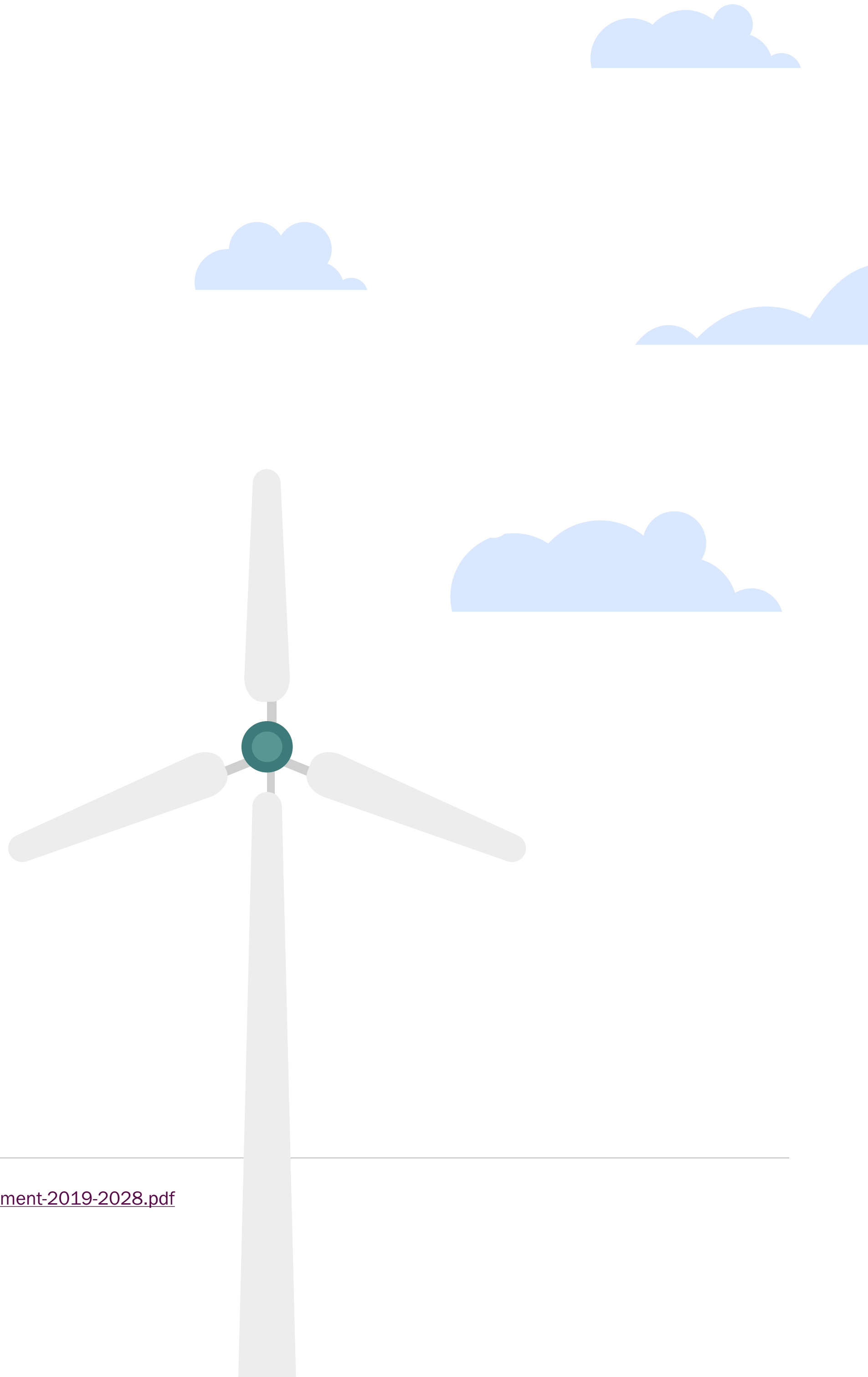
Technology efficiencies across power stations, space heating and transport are set to a default value for the starting year, within the model. On assessment, these values do differ (higher) from real technologies adopted by users or companies in NI. This has the effect of reducing final energy demand for specific technologies to deliver the energy required for certain applications. The base year (2018) data for the power stations generation has been adjusted to ensure it reflects the current efficiency levels in NI and keep the same level of CO_2 emissions.

In addition to this there are a number of technologies which are represented by the NI ETM model but their future potential and benefits are not fully quantified in the model. Among these are technologies representing flexibility services, such as energy storage and demand-side response. It should be stated that this limitation representing flexibility requirements is typical to any energy system model, this is well researched and highlighted by other studies. However, as flexibility may well play a crucial role in the future energy decarbonisation it is recognised as a limitation.

Within the ETM, interconnectors are modelled using economic dispatch. This simply means that power will flow from a less expensive region into a region where the price is higher. The North/South Interconnector functions as a tie line within the Single Electricity Market[5]. Flows on it are dictated by economic dispatch, reserve requirements, system security etc. Transfers on it vary somewhere between 350 MW North to South to 300 MW South to North following consideration of the noted constraints. It therefore cannot be represented as an interconnector in the ETM.

To represent North/South Interconnector we could have included additional capacity, based on the adequacy analysis used in the Generation Capacity Statement[6]. This reduction in capacity may result in system security issues, such as an increase in 'Blackout' hours, however no net zero scenario encounters this.

In addition, the reduction in capacity of the North/South Interconnector may result in slightly higher electricity prices as there is less availability of cheaper generation from the interconnector. However, as costs are not included in this analysis it does not affect the scenarios.



5 https://www.uregni.gov.uk/sem
6 https://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Group-All-Island-Generation-Capacity-Statement-2019-2028.pdf

FUTURE ENERGY DECARBONISATION SCENARIOS

SECTION 3

FUTURE ENERGY DECARBONISATION SCENARIOS

Introduction

Future scenarios can enable planning for varying visions of the future. They can also help to refine perceptions of existing or emerging problems and corresponding problem-solving strategies. In public policy-making scenarios may be most effective in early phases of the policy cycle and if used in a participatory manner they can generate and collect ideas, knowledge and views regarding possible futures and engage stakeholders.

The NI ETM was used to translate qualitative storylines into quantitative total energy future scenarios. The model ensures annual energy demand for all sectors, fuels and supply is balanced.

The quantitative translation of storylines into figures includes quantifying the energy demand and technology changes in domestic, services, transport and industrial sectors. The ETM provides annual energy volumes that are consistent with each scenario storyline.

What are future scenarios?

- A scenario is a coherent set of assumptions about a possible future
- It is a tool to allow story-telling about a variety of plausible long-term future occurrences or pathways in changing and uncertain environments
- Also called a narrative, they are a set of illustrative pathways that indicates how the future may unfold. They are not forecasts or predictions but alternative futures.
- Scenarios can provide indications of the degree of action required to achieve certain goals, for example decarbonisation
- The process is iterative, allowing for updates to assumptions and data as new information becomes available.

Building future energy scenarios for Northern Ireland

The Northern Ireland context for energy will by its nature reflect its geography, economy and historical energy environment. Future energy scenarios therefore take account of the unique characteristics of Northern Ireland, as scenarios developed for elsewhere will not necessarily be appropriate.

Some NI infrastructure elements considered in shaping the scenarios were:

- The **gas network** – of electricity connections, around 30% of households are connected to the gas grid based on the number in 2018 (although increasing), compared to 85-90% for the UK as a whole. For non-domestic this figure is around 19%. However, it is important to recognise that for non-domestic although there is a low proportion (5%) of all connections, it has a much higher proportion (approximately 47%) of all gas consumption[7]. Heat decarbonisation options that rely on the gas network will not be possible in these particular properties, and will require a greater use of other options such as heat pumps and smart storage heating.
- The **existing building stock** – 2016 estimates indicate less than half (49%) of homes are rated within band A-C in terms of energy efficiency[8] and in 2016/17 it is estimated 68% of homes use oil as their primary heating source while a high proportion (72%) use open/closed fires as secondary heating solutions[9].
- **Large point sources of emissions**. Existing fossil-fuelled power stations (Ballylumford, Collkeeragh and Kilroot) are large point-sources of emissions that will continue to pollute until effective measures to decarbonise them are put in place.

Further information about energy in NI is available through the Energy in Northern Ireland 2020 report. The report is produced by Northern Ireland Statistics and Research Agency (NISRA) statisticians within the Department for the Economy's Analytical Services Division (ASD). It provides a comprehensive and accessible overview of key statistics and information relating to energy in Northern Ireland.

Key Policy areas influencing scenario development

Through analysis of the call for evidence responses and consideration of key themes in the Energy Efficiency, Consumers, Heat, Power and Transport working groups, key decision points on behaviours, ambitions and technologies have been identified. Ultimately, a range of potential pathways to net zero energy exist based on combinations of each of these. The energy system in Northern Ireland in 2050 will therefore, reflect policy decisions made today and in the future. As well as consumer behaviours, the level of ambition in different sectors and the wider energy context. It is therefore impossible to predict the future of Northern Ireland's energy system, but it is possible to identify key issues that could lead to diverging and differentiated futures.

By considering key policy issues in the near-term and envisaging a future trajectory we frame the boundaries of what might be possible across each of the scenarios; an illustration of 'what if?'. They outline the scale of the challenge by modelling low or late action in one area to illustrate how other areas must compensate in order to reach the overall target of net zero.

While there is the potential to identify and model hundreds, if not thousands of energy futures, the focus here is on identifying a variety of direction of travel and to help demonstrate what can happen. They all illustrate the level of ambition that might be required and the scale of the challenge across the whole energy sector.

It is important to note that such futures will also be influenced by the likely impact of exogenous factors, such as policy decisions taken outside of NI, as well as expected cost trajectories of fuels and technologies.

7 https://www.uregni.gov.uk/sites/uregni/files/media-files/2019-08-30%20Annual%20Transparency%20Report%202018%20Final.pdf
8 https://www.nihe.gov.uk/Working-With-Us/Research/House-Condition-Survey Table 7.21
9 https://www.daera-ni.gov.uk/sites/default/files/publications/daera/CHS%20Heating%20Questions%20Report%20201617_0.pdf

Uncertainties

There are a range of uncertainties which are not possible to include in the model but will affect the choices available in decarbonisation; energy consumption levels and resultant CO_2 emissions. Some of these include the performance of the economy, sustained behavioural change post-COVID and forthcoming changes to the methodology for estimating emissions within the inventory:

- **The economy** – the level of economic activity, that could cause emissions, is always to some degree uncertain. At present, this uncertainty is much greater than usual, relating to how the economy will recover after the COVID-19 pandemic.
- **Sustained behavioural change post-COVID** - There have been some large changes in patterns of behaviour due to the COVID-19 pandemic and associated restrictions. For example, reduction in business aviation demand due to greater familiarity with videoconferencing. Other changes seen during 2020 (such as increased working from home, more walking and cycling) would tend to reduce overall emissions and also have positive co-impacts for health. Development of the scenarios began in late 2020 during the impacts of the COVID-19 pandemic. It is unclear the extent to which these changes will endure and effect energy demands and behaviours.
- **Changes to the UK Greenhouse Gas Inventory[10]** - There will be changes to how the UK and NI emissions are estimated. For example, seeking to increase the scope of the emissions inventory to count all emissions from wetlands.

Developing models for scenarios

Policy areas are often interdependent and any net zero carbon scenario must consider these connections. For example, continued use of fossil fuel generating plant will require consideration of the adoption of Carbon Capture Utilisation Storage (CCUS). In addition, increases in the use of heat pump technologies must be considered alongside the energy efficiency of buildings or significant electrification of transport can link to higher levels of demand-side flexibility.

With regards to the Energy Strategy and climate commitments we only model scenarios that can achieve a net zero carbon energy sector by 2050. This is in line with the Committee for Climate Change's analysis of the fair and equitable contribution that Northern Ireland can make to the UK's binding target contained within the UK Climate Change Act.

We have therefore identified two key technology uncertainties and used these to develop diverging scenarios. One is based on a high degree of electrification and the other on high usage of zero-carbon gas. The policy options identified through the working groups highlight that there are considerable opportunities for diversity of approach to decarbonisation of energy depending on geographical location, consumer engagement, population distribution, opportunities for local leadership and the availability of local renewable resources. Therefore a third scenario was developed which involves a more diverse set of technologies and views the energy transition through a more local lens.

10 https://naei.beis.gov.uk/

The three net zero carbon scenarios are illustrative and are not expected outcomes from the Energy Strategy. In all scenarios significant change is required to achieve a net zero carbon energy system by 2050. All scenarios have their own unique characteristics.

The scenarios outlined here have been informed by the Call for Evidence and visualise what different energy systems of the future might look like. They are not forecasts of the future, nor do they represent any statement of policy intent. They can provide indications of the action required to achieve certain goals, such as decarbonisation.

Outside the Business As Usual future energy scenario, we have made two key decisions in developing these scenarios:

1. They align with net zero carbon energy emissions by 2050. We have not run high, medium and low scenarios looking at achieving net zero by different dates. With the exception of the 'Business As Usual' scenario, we are using the model to outline potential approaches to achieving the outcome of net zero carbon by 2050.

2. They represent broadly realistic pathways for the future. Whilst some scenario modelling may seek to test extreme approaches to the future to push the boundaries of different decisions, we have constrained the scenarios to focus on those we consider will be most relevant for Northern Ireland. This means there is overlap across the scenarios.

Scenario 1: Business as Usual

A business as usual scenario for Northern Ireland examines the potential impact of maintaining the current range of energy policies and programmes (with the exception of any new policies already announced). Relevant UK-wide policy such as Road to Zero (low emission vehicles) is assumed to be adopted in Northern Ireland as required, although no additional measures are in place to speed up deployment.

Key assumptions are:

- Gradual move from oil to gas for home heating.
- Electricity demand increases due to more electric vehicles.
- Renewable electricity (RES-E) minimum 40% out to 2050 maintained.
- Lower final energy demand through:
  - Continuation of existing energy efficiency measures;
  - Increase in public transport usage, walking, wheeling and cycling; and
  - Some reduction in energy consumption due to increased awareness and behavioural change amongst the population.

Scenario 2: High Electrification

This scenario builds on the existing success of the renewable electricity sector, with high levels of electrification to take advantage of a substantially larger renewable electricity base. Increased capacity is met through a combination of solar photovoltaic (PV), offshore wind and marine technology. In addition there is an expansion of onshore wind, aligned with improved demand-side management and flexibility measures.

Heat pumps provide the majority of heat supplied in the domestic and services sector, and very high levels of energy efficiency are adopted. The existing gas network is not expanded and plays a small role to supplement heat pumps through decarbonised gas, including locally-produced biomethane and hydrogen. A combination of a ban on new petrol and diesel cars coupled with a charging infrastructure roll-out programme via public charging and new home standards drive a significant uptake in electric vehicles.

Key assumptions are:

- Home heating, transport and industry largely electrified
- Electricity demand is highest in this scenario
- RES-E target 70% in 2030 achieved, 100% in 2050
- Lowest final energy demand through:
    - Substantial increase in energy efficiency measures early in the pathway to 2050 due to requirements for heat pumps;
    - Reduction in industry energy demand through efficiency measures;
    - Increase in public transport usage, walking, wheeling and cycling; and
    - Some reduction in energy consumption due to increased awareness and behavioural change amongst the population.

Scenario 3: High Gasification

With a greater focus on gas, overall demand for electricity is lower meaning RES-E targets are higher due to the need for less additional generation capacity. This scenario has a target of 80% renewable electricity by 2030 and 100% by 2050. There is a large emphasis on off-shore wind mainly used for hydrogen production. Gas is imported for flexible electricity generation alongside the large renewables base. The gas network is fully decarbonised with a mix of hydrogen and biomethane and is expanded to reach a larger percentage of the population. As demand for hydrogen and biomethane is high, only some of which can be met locally due to the quantum need, there is considerable reliance on imports.

Energy efficiency improvements are supported consistently and the energy performance of buildings improves, however these measures are less ambitious than in the high electrification scenario, as thermal comfort can be provided without the high levels of energy efficiency required by heat pumps. The car and van fleet is powered by a mix of hydrogen and electrification with larger vehicles use mostly hydrogen. This is supported by significant investment in refuelling infrastructure.

Key assumptions are:

- Continued connect to existing gas network, with substantial amounts of hydrogen and biomethane injected by 2050.
- Off gas grid properties are heated using heat pumps and biofuels.
- Road vehicles decarbonised with a high percentage of electric cars and vans coupled with a high percentage of hydrogen-powered buses and HGVs.
- RES-E target 80% in 2030 achieved, 100% in 2050.
- Lower final energy demand through:
  - Substantial increase in energy efficiency measures across domestic and non-domestic sectors;
  - Increase in public transport usage, walking, wheeling and cycling; and
  - Some reduction in energy consumption due to increased awareness and behavioural change amongst the population.

Scenario 4: Diverse

This scenario takes in to account of the considerable regional differences in Northern Ireland and includes higher levels of local involvement as well as local responses to the low-carbon transition. Heat and transport have quite different solutions depending on location and geography and for power may imply a more decentralised system. There is an intermediate target of 80% renewable electricity by 2030. The power sector is fully decarbonised by 2050, through local ambition and public sector leadership this comprises a wide range of small, medium and large-scale renewable generation as local opportunities are maximised.

Investment in public transport, active travel and increased flexibility in working arrangements combined with place based solutions that are tailored to the locality and which involve the local people can address connectivity needs, particularly in rural areas, meaning that transport demand is significantly lower. Hydrogen is used for the ‘hard-to-electrify’ transport sector and for heating within domestic sector.

Energy efficiency improvements are supported consistently and the energy performance of buildings improves through the introduction of increasingly high standards for new builds as well as a comprehensive retrofit programme. There are higher numbers of off-grid energy solutions, particularly for heat. These include a significant focus on heat pumps and use of biofuels, such as Hydrogenated Vegetable Oil (HVO) fuel in earlier stages of transition. The existing gas network is decarbonised through the use of locally-produced biomethane and hydrogen.

Key assumptions are:

- Diverse mix of heating solutions.
- Heating oil displaced mainly through biofuel in early stages of transition before other technologies become more prevalent.
- Introduction of district heating.
- Electric and hydrogen powered cars, vans, HGV and public transport fleet.
- RES-E target 80% in 2030 achieved, 100% in 2050.
- Lower final energy demand through:
  - Substantial increase in energy efficiency measures across domestic and non-domestic sectors;
  - Increase in public transport usage, walking, wheeling and cycling; and
  - Larger reduction in energy consumption due to heightened awareness amongst the population from a more decentralised approach.

Table 3.1: Summary of general assumptions behind the storylines of the Future Energy Decarbonisation Scenarios

Theme	Business As Usual (BAU)	High Electrification (HE)	High Gasification (HG)	Diverse (D)
CO_2 Emissions	55% reduction from 1990	Net zero carbon emissions from energy by 2050		
Consumer	Gradual improvement in awareness of energy use and changes in behaviour affecting climate change.	Improved awareness of energy use and changes in behaviour affecting climate change.	Improved awareness of energy use and changes in behaviour affecting climate change.	Enhanced awareness of energy use and changes in behaviour affecting climate change.
Energy Efficiency	Existing programmes continue at the same rate.	Energy efficiency for new builds and retrofit is prioritised – High reduction in heat demand. Consideration given to accelerating retrofit rollout to support e.g. Heat Pump installation.	Energy efficiency for new builds and retrofit is prioritised –High reduction in heat demand.	Energy efficiency for new builds and retrofit is prioritised –High reduction in heat demand.
Heat	Limited further connections to gas network (0.5% per year transition from oil to gas).	High reliance on electric and hybrid heating. Limited further connections to gas network (continued expansion until not economically viable).	Continued connections to existing gas network. High use of hydrogen-enabled heating sources. Injection of hydrogen and biomethane into the network. Off gas grid properties to be heated using Heat pumps and biofuels.	Diverse mix of heating solutions as local and off-grid heating options are prioritised. Heating oil displaced mainly through biofuel in early stages of transition Small uptake in district heating and/or geothermal heating.

Theme	Business As Usual (BAU)	High Electrification (HE)	High Gasification (HG)	Diverse (D)
Power	40% RES-E target achieved out to 2050 Demand increases due to increase in EVs.	70% RES-E target in 2030 and 100% RES-E target in 2050. High production of offshore by 2050 and on-shore wind capacity. High production from solar PVs. High levels of household and large scale batteries. Demand almost doubles to high use of EVs and heat pumps.	80% RES-E target in 2030 and 100% RES-E target in 2050. Medium production of on-shore wind capacity. Very High production of offshore wind (mainly used to produce hydrogen). Medium production from solar PVs. Medium levels of household batteries. High level of large scale batteries. Lower demand than High Electrification due to less of an uptake of heat pump and EVs.	80% RES-E target in 2030 and 100% RES-E target in 2050. Medium production of on-shore wind capacity. High production of off-shore wind (low cost option). High production from solar PVs. Medium levels of household batteries. High level of large scale batteries. Slightly lower demand than High Electrification due to less of an uptake of heat pump and EVs.
Transport	Increase in public transport usage/walking/ bike increases. Sales of new Petrol and Diesel cars and vans stopped in 2030 (Hybrids in 2035) will see higher % of EVs. Introduction of the phase-out of new diesel heavy goods vehicles (HGVs) (date to be determined).	Demand reduction measures to reduce overall miles travelled by vehicles / Increase in public transport usage/walking/ wheeling/ cycling. Vehicle and fuel efficiency improvements to reduce vehicle emissions. Sales of new Petrol and Diesel cars and vans stopped in 2030 (Hybrids in 2035) will see high % of EVs. BEV for buses and HGVs. Low % of electrolysed hydrogen primarily in HGVs.	Demand reduction measures to reduce overall miles travelled by vehicles / Increase in public transport usage/walking/wheeling/ cycling. Vehicle and fuel efficiency improvements to reduce vehicle emissions. Sales of new Petrol and Diesel cars and vans stopped in 2030 (Hybrids in 2035) will see low % hydrogen powered cars and vans and high % EVs. Larger road vehicles decarbonised with high % hydrogen-powered buses and HGVs.	Enhanced demand reduction measures to reduce overall miles travelled by vehicles / Larger increase in public transport Usage/walking/wheeling/ cycling. Vehicle and fuel efficiency improvements to reduce vehicle emissions. Sales of new Petrol and Diesel cars and vans stopped in 2030 (Hybrids in 2035) will see both EVs and hydrogen powered car and van fleet. Initially higher % of electrolysed hydrogen long range HGVs but BEV vehicles increasingly used in short range buses/HGVs. BEVs become more cost effective but hydrogen remains.

Theme	Business As Usual (BAU)	High Electrification (HE)	High Gasification (HG)	Diverse (D)
Industry	Gradual decarbonisation of fuel usage moving from oil to gas or electricity. Small amount of coal use by 2050.	Decarbonisation of fuel usage moving away from coal, oil and natural gas to a mixture of low carbon fuels. No coal or oil use for heat and high proportions of electricity usage by 2050.	Decarbonisation of fuel usage moving away from coal, oil and natural gas to a mixture of low carbon fuels. No coal or oil use for heat and high proportions of hydrogen usage by 2050.	Decarbonisation of fuel usage moving away from coal, oil and natural gas to a mixture of low carbon fuels. No coal or oil use for heat and high proportions of hydrogen and biofuels by 2050.
Hydrogen	No change.	Demand is met with local production. Range of methods to production hydrogen including use of curtailed power, solar PV plant, steam methane reforming and biomass gasification.	Demand is met with local production. Range of methods to production hydrogen including use of curtailed power, solar PV plant, steam methane reforming and biomass gasification.	Demand is met with local production. Range of methods to production hydrogen including use of curtailed power, solar PV plant, steam methane reforming and biomass gasification.
Agriculture	No change.	Gradual decarbonisation of fuel usage for machinery and vehicles moving from oil to gas or biofuels (biomass). Low level of uptake of heat pumps.	Gradual decarbonisation of fuel usage for machinery and vehicles moving from oil to gas or biofuels (biomass). Low level of uptake of heat pumps.	Gradual decarbonisation of fuel usage for machinery and vehicles moving from oil to gas or biofuels (biomass and HVO). Low level of uptake of heat pumps.
Macro	Natural growth for population projections and estimated growth in dwellings. Moderate Economic growth.	Natural growth for population projections and estimated growth in dwellings. Moderate Economic growth.	Natural growth for population projections and estimated growth in dwellings. Moderate Economic growth.	Natural growth for population projections and estimated growth in dwellings. Moderate Economic growth.
Additional Consideration		Some Carbon Capture.	Some Carbon Capture.	Some Carbon Capture.

RESULTS

SECTION 4
SCENARIO RESULTS

Looking at Northern Ireland's energy system and associated emissions in 2018, it is clear that there is some way to go in transitioning to net zero carbon by 2050. To achieve this, Northern Ireland must transition away from the reliance on non-renewable energy sources. This section illustrates a resultant position of the NI energy sector across the four scenarios. The links to the NI ETM for each scenario and point in time are included in Annex G. All data behind the tables and figures in this report are available at Future Energy Decarbonisation Scenarios data.

Scenario 1: Business as Usual

Net zero carbon scenarios:

Scenario 2: High Electrification

Scenario 3: High Gasification

Scenario 4: Diverse

The scenario analysis presented here is divided into the following sections:

- CO_2 emissions trajectories
- Present and future energy flows
- Demand, and
- Supply.

Within each section there are focused analysis on consuming sectors, namely:

- Residences (domestic); and
- Across non-domestic:
  - Services
  - Industry
  - Agriculture, and
- Other, which includes energy used in the production of energy. Please note no separate analysis is provided for this sector.

In addition, there are focused analysis on fuel type in each section. Unless presented separately, there are seven main fuel categories, used within this analysis. These are:

- Oil: Oil and derivatives including transport fuels
- Coal: Coal and derivatives
- Electricity: Renewable and fossil fuel generated electricity
- Network gas: Natural gas and green gas
- Hydrogen: Locally produced and imported hydrogen, and
- Biofuels: Solid (wood, biomass) and liquid biofuels (Hydrogenated Vegetable Oil (HVO), Bio-Liquefied Petroleum Gas (Bio-LPG) and biofuel blend in transport),
- Other: district heating and solar thermal.

The three net zero carbon scenarios reflect alternative futures from a combination of assumptions. In all scenarios, significant change from the 2018 position is required to achieve a net zero carbon energy system by 2050.

CO_2 EMISSIONS

CO_2 Emissions

Northern Ireland reaching net zero carbon emissions by 2050 is an important contributing component in the overall goal of net zero GHG within the UK. Figure 4.1 presents the trajectory of CO_2 emissions over time for each scenario. They all show a decline in carbon emissions, only Business As Usual not reaching net zero carbon by 2050.

In the Business As Usual scenario, Northern Ireland falls significantly short of meeting net zero energy emissions without new policies being introduced. Carbon emissions will decrease based on a minimum 40% renewable electricity share of a larger electricity sector and through Electric Vehicles (EVs) replacing petrol and diesel cars, but 45% of 1990 emissions still remain by 2050.

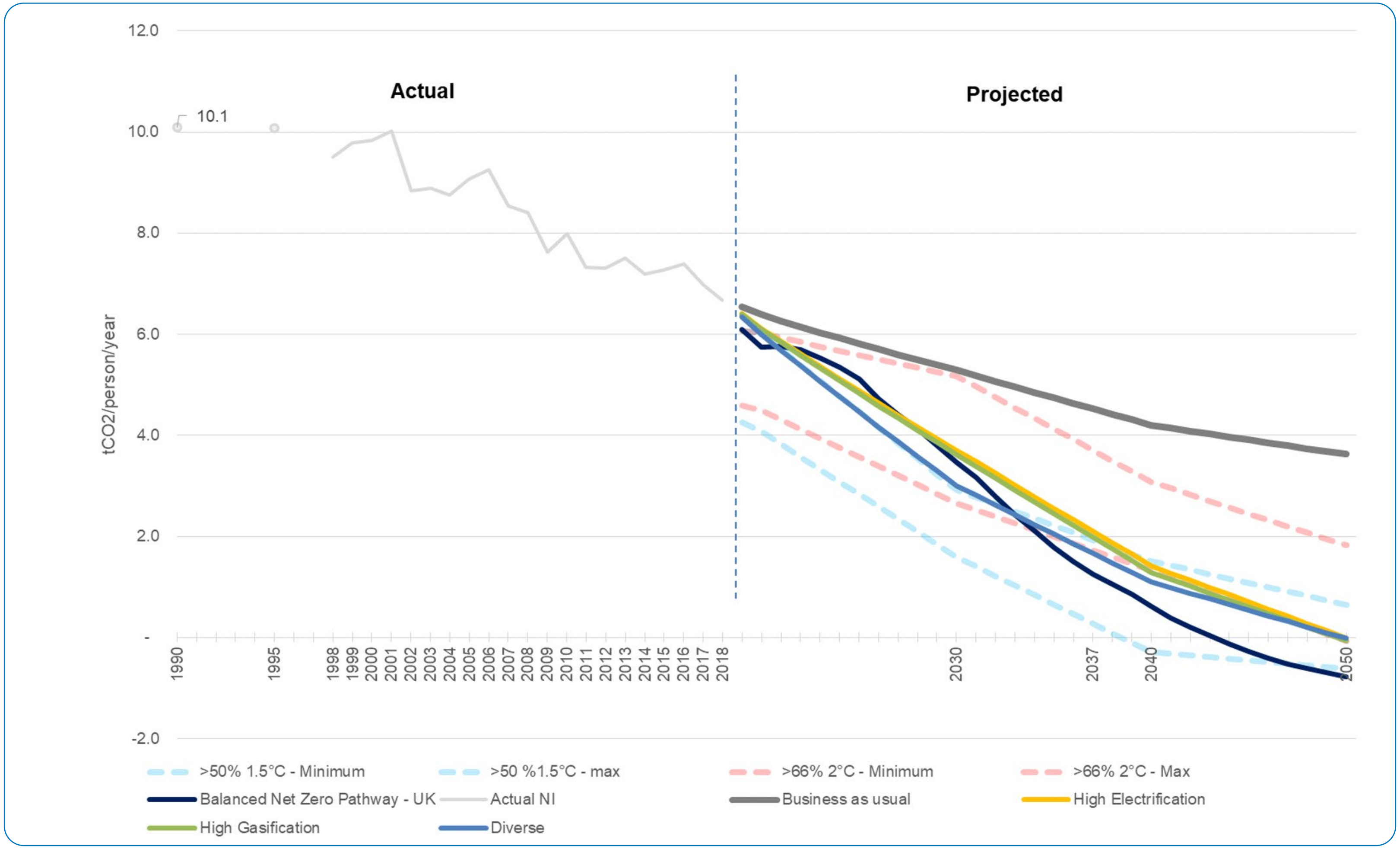
The three net zero scenarios all show different pathways to achieving 100% reductions of CO_2 compared to 1990. Whilst High Electrification and High Gasification scenarios have very similar pathways to reducing emissions, the Diverse scenario achieves a steeper reduction in emissions earlier in the journey to 2050. This is a result of increased use of biofuels in heating to displace heating oil as an interim solution.

In addition, the Diverse scenario reduces NI's annual per capita emissions by 2034 to under 2.4 tCO_2e per person, in line with global pathways consistent with meeting the Paris Agreement 1.5 °C goal[11] (light blue dotted line in Figure 4.1). The High Electrification and High Gasification) scenarios achieve this Paris Agreement 1.5 °C goal by 2039.

Please note that the phrases “carbon” and “CO_2” are used interchangeably throughout this analysis.

11 https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Figure 4.1: Carbon emissions (tCO_2 per person) over time by scenario compared to Paris Agreement of 1.5°C and 2.0°C goals



As referenced earlier, part of the Climate Change Committee (CCC) recommendations on the sixth carbon budget included a proposal for supplementary CO_2 only NI targets. For CO_2 emissions, the suggested targets for NI is net zero by 2050 with various percentage reductions at different points during the journey. These targets are part of the fair contribution for NI to Net Zero for the UK. Table 4.1 indicates the CCC suggested targets for NI in relation to CO_2 only and how each of the Future Energy Decarbonisation (FED) Scenarios compare to these.

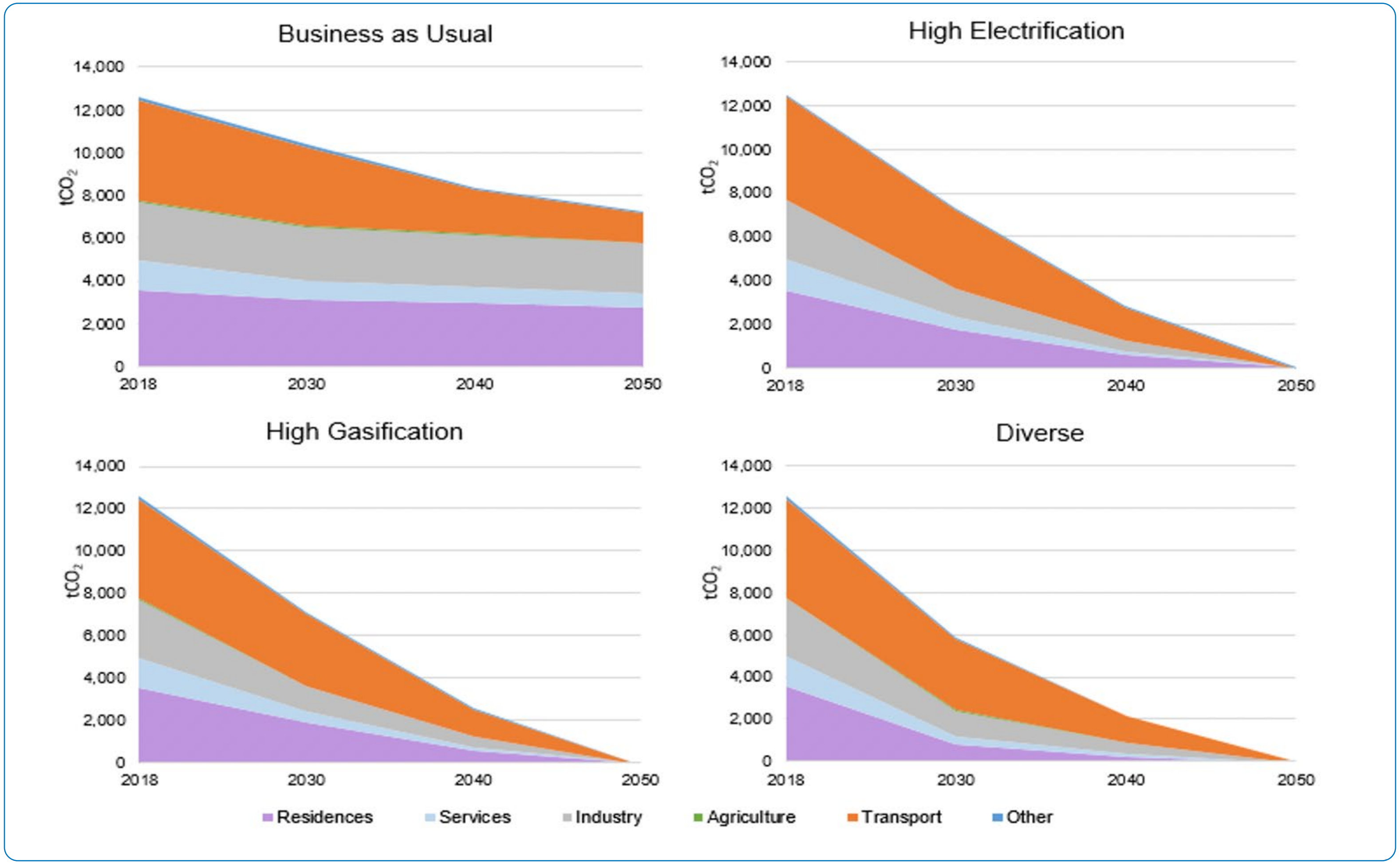
Table 4.1: Comparison of Climate Change Committee suggested targets and Future Energy Decarbonisation Scenarios, percentage reduction in CO_2 emission from 1990

Year	CCC	BAU	HE	HG	Diverse
2030	-56%	-36%	-55%	-56%	-63%
2037+	-70%	-44%	-74%	-76%	-80%
2040	-83%	-48%	-83%	-84%	-86%
2050	-100%	-55%	-100%	-100%	-100%

+ Year refers to UK 6th Carbon Budget period (2033-37)

For each scenario, Figure 4.2 presents the carbon emissions by sectors over time. The charts show that in 2018 the sectors with the largest emissions that need to be addressed are residences and transport. In 2018, the residences heating sector is dominated by oil, which is a vast contributor to emissions. In transport, the high reliance on internal combustion engine (petrol and diesel) vehicles, alongside the high use of cars in passenger transport are the key elements that need addressing. However, Figure 4.2 shows that addressing these issues within transport alone, as in Business As Usual scenario, will not get Northern Ireland to net zero carbon emissions by 2050 and a more detailed approach is needed.

Figure 4.2: Carbon emissions by sector (tCO_2) over time and scenario



The Business As Usual scenario was created to demonstrate that without major intervention NI does not reach net zero carbon by 2050. This is demonstrated in the CO_2 emissions Figure 4.2 and Table 4.1. Therefore the Business As Usual scenario is not included in the remaining analysis examining demand and supply. Only those deemed net zero carbon scenarios are included in the remaining analysis.

ENERGY FLOWS

Energy Flows

Within this section the energy flows in 2018 and for the three net zero carbon scenarios in 2050 are presented in the form of a Sankey diagram. This type of diagram visually represents the NI energy balances in showing how, where and how much energy is used, based on the assumptions made.

The flow of energy runs left to right. The energy commodities enter the energy balance on the left (mainly from production or imports), this is primary energy; and exit on the right (mainly through final consumption, exports and losses), where the energy is used.

The middle part of the diagram shows which energy commodities are used in their original form; and which go through the transformation sector to generate electricity and heat.

In the 2018 Sankey it shows natural gas being used for heating in the industrial sector, this is an example of a commodity being used in its original form (i.e. “Direct carry-over”). By contrast, natural gas is also transformed into electricity in a thermal power plant, this is an example of an energy commodity going through the transformation sector.

In the Sankey diagram, the width of the bar represents the size of the energy quantity. All flows are measured in GWh. For example, oil primary energy consumption was 29,518 GWh, while Residences (Households) final energy demand was 14,739 GWh during 2018 in NI.

Interactive versions of these Sankey diagrams are available at the following links:

- Present 2018 energy flows
- High Electrification future 2050 energy flows
- High Gasification future 2050 energy flows
- Diverse future 2050 energy flows

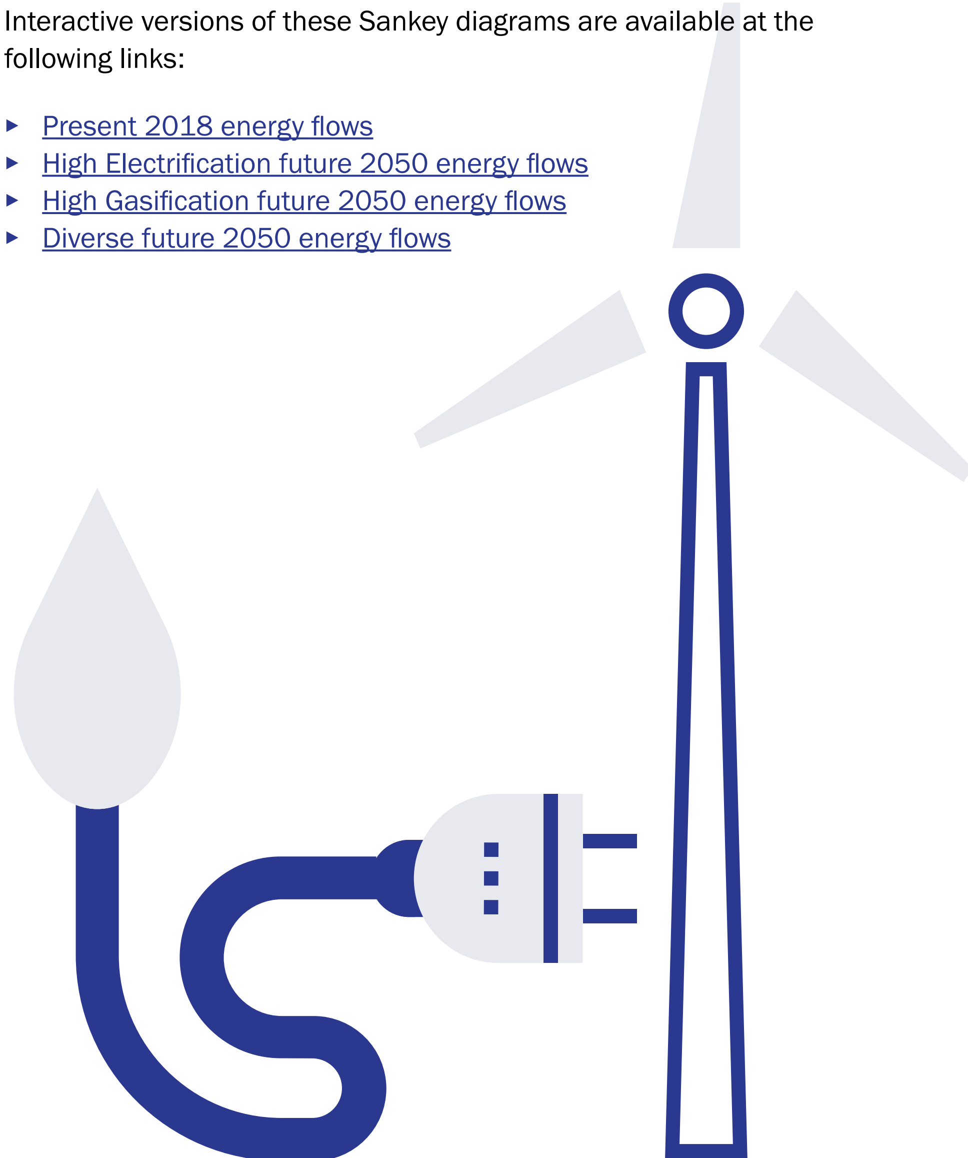


Figure 4.3 Energy flows: Base Year 2018

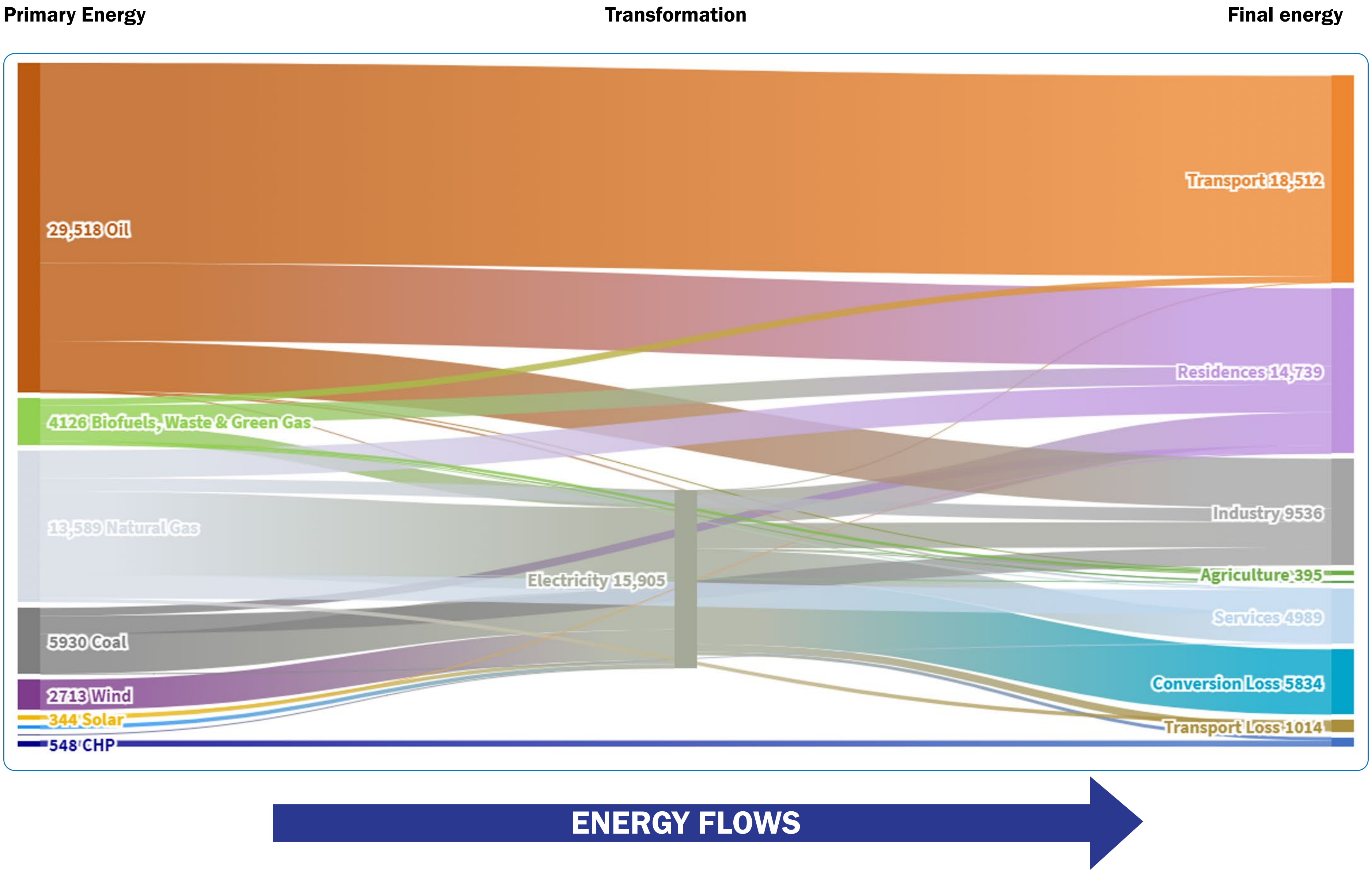


Figure 4.4: Energy flows: High Electrification 2050

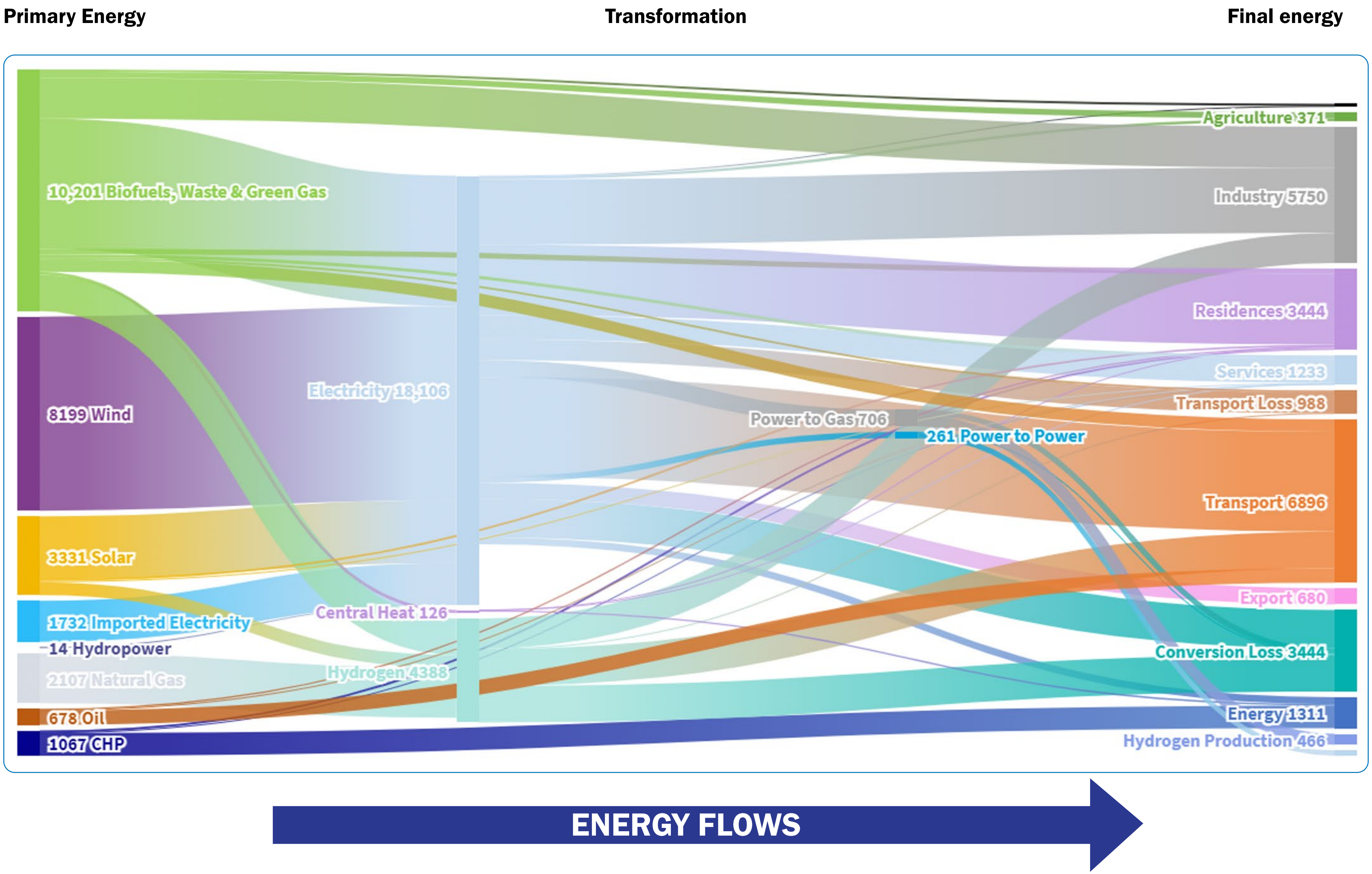


Figure 4.5: Energy flows: High Gasification 2050

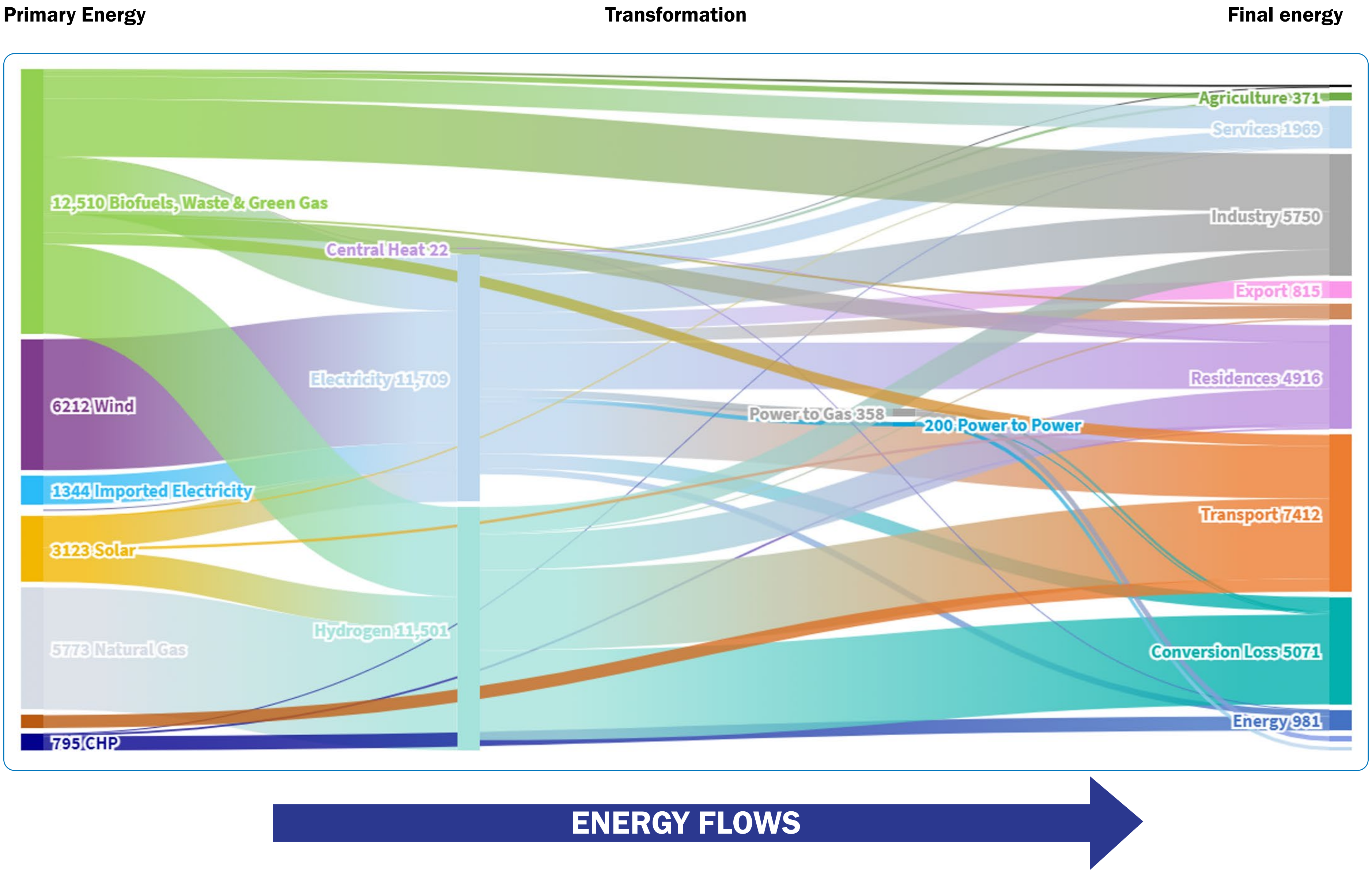
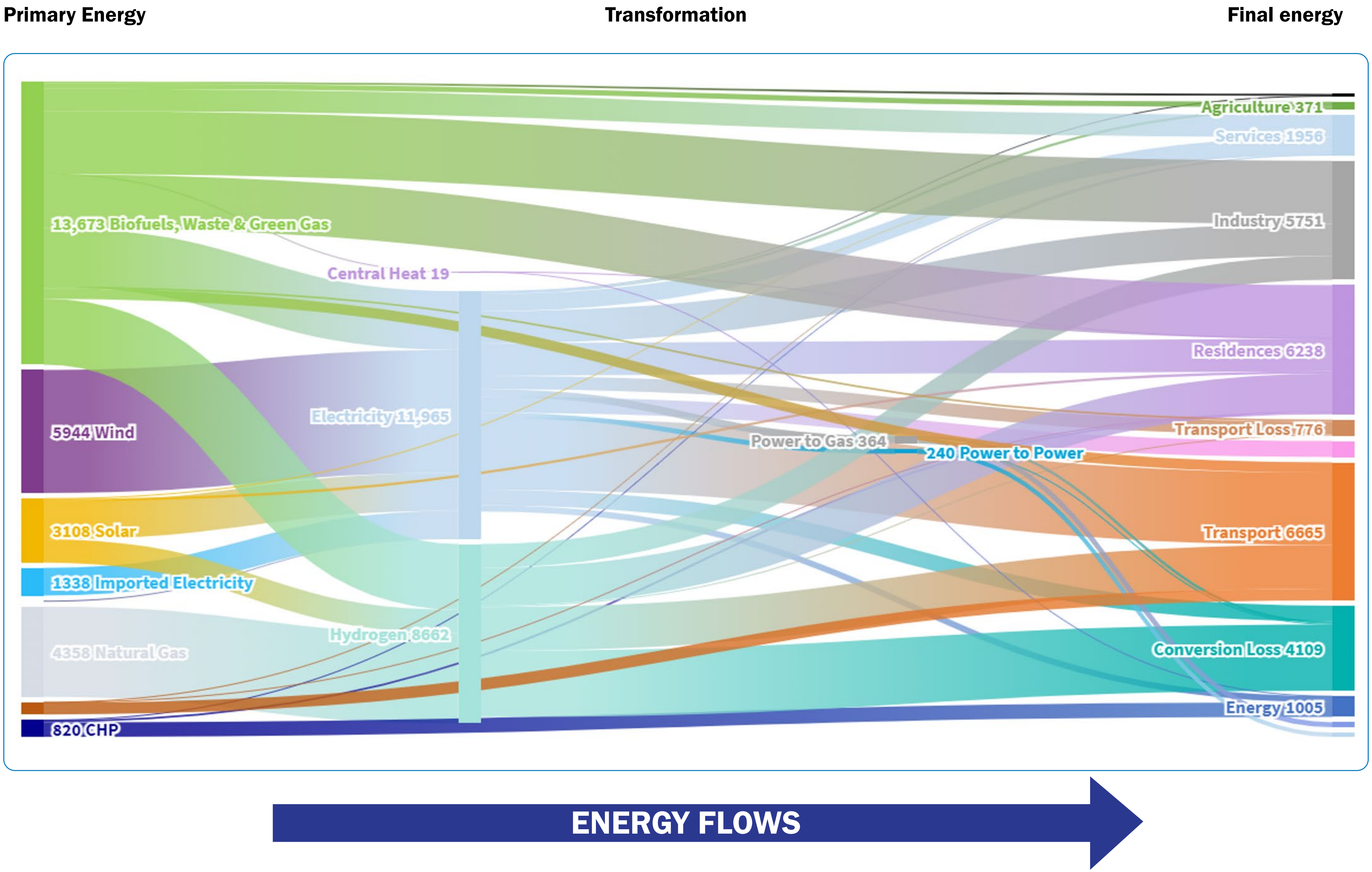


Figure 4.6: Energy flows: Diverse 2050



DEMAND

Consumer demands

The energy supply system alone cannot deliver decarbonisation. The system exists to serve consumers (domestic and non-domestic). This is why we are exploring the future of energy from an end-user (consumer) perspective, using societal change as one of the groups of assumptions behind the development of the future energy decarbonisation scenarios.

This chapter covers consumer and energy demands across the scenarios.

It looks at:

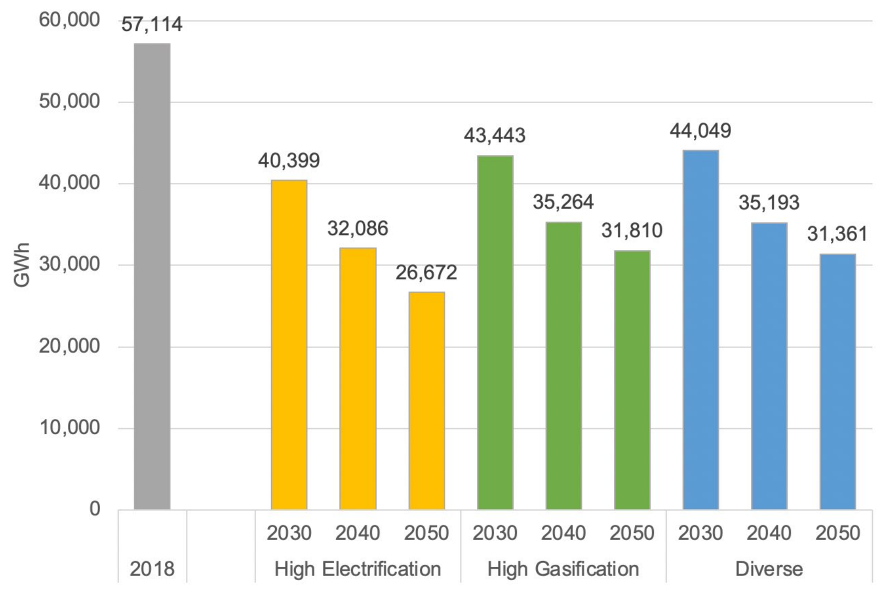
- Primary energy demand
- Final energy demand across:
  - Residences
  - Services
  - Industry
  - Agriculture, and
  - Transport
- Fuel demands covering:
  - Electricity
  - Gas and
  - Heat

Primary energy demand

Primary energy demand is the total input energy required to meet consumer demand and includes, consumption of the energy sector itself and losses during transformation & distribution of energy. In this analysis, primary energy figures do not include primary demand for exports or curtailment.

Figure 4.7 illustrates that all three scenarios show significant decreases in primary energy demand from 2018 to 2050. They all decline with similar rates. The High Electrification scenario reflects the largest decrease (53%) in primary energy use from 2018 to 2050.

Figure 4.7: Primary energy demand in 2018 and by scenario across time



The reduction in primary energy demand is based on assumptions associated with the growth of energy efficient technologies and systems, coupled with an increased awareness of energy use and changes in behaviour affecting climate change within society. To better understand this, figures 4.8 and 4.9 illustrate primary energy demand broken into fuel use and sector, respectively.

Figure 4.8: Proportions of fuel within primary energy demand 2018 and by scenario in 2050

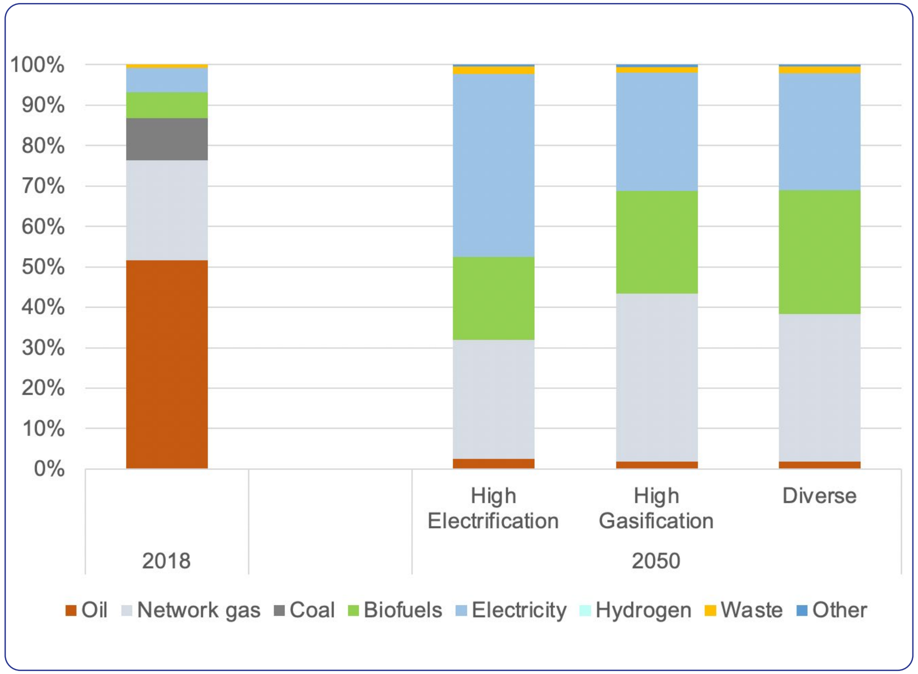


Figure 4.8 shows the change in the proportions of fuels within primary energy demand across all scenarios in 2050 compared to 2018:

- By 2050 coal is removed entirely and oil falls from over half (52%) of primary energy in 2018 to less than 3% in each scenario by 2050
- Electricity reduces the reliance on fossil fuels; making up almost half (45%) of primary energy demand in High Electrification and 29% in the High Gasification and Diverse scenarios by 2050.
- Biofuels become more important as a primary fuel source with the Diverse scenario seeing the largest increase from 7% in 2018 to 31% in 2050.

Figure 4.9: Primary energy demand by sector in 2018 and by scenario in 2050

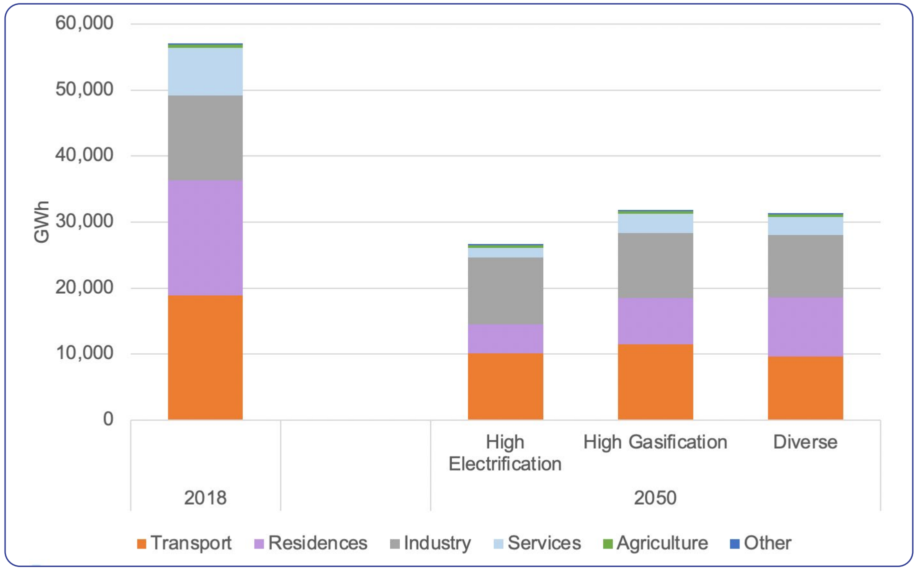


Figure 4.9 shows how the primary energy demand across each sector changes from 2018 to 2050 across the three scenarios:

- Residences and Services both have large reductions in primary energy demand from 2018 across all scenarios in 2050. This is most prominent in the High Electrification scenario with reductions of 75% and 79%, respectively. This is largely due to the assumptions made regarding changing technologies used for space heating and ambitious energy efficiency measures to reduce heat demand.
- There is also a decrease in primary energy demand within Transport across all scenarios, due to an assumed shift away from internal combustion engines (diesel and petrol) vehicles, as well as an overall reduction in miles travelled.
- The Industry sector also reduces by around 25% across the scenarios due to assumptions of improvements to resource and energy efficiency in industrial processes.

Final Energy demand

Final energy demand represents the total energy consumed by end users. This does not include energy associated with losses and exports.

Figure 4.10 shows how the final energy demand reduces from the 2018 position, across all scenarios. Similar to primary energy, the High Electrification scenario reflects the largest decrease (61%) in demand from 2018 to 2050.

Figure 4.10: Final energy demand in 2018 and by scenario over time

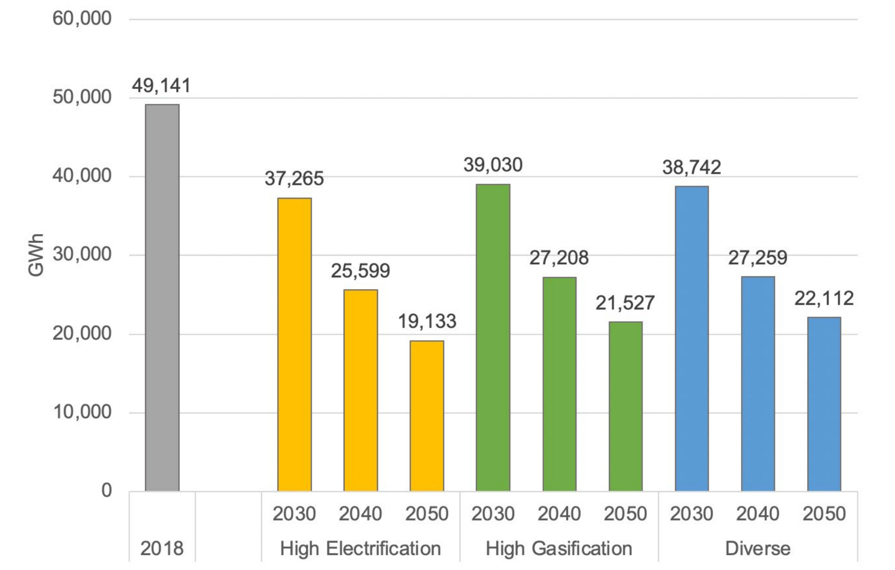


Figure 4.11: Proportions of fuel within final energy demand in 2018 and by scenario in 2050

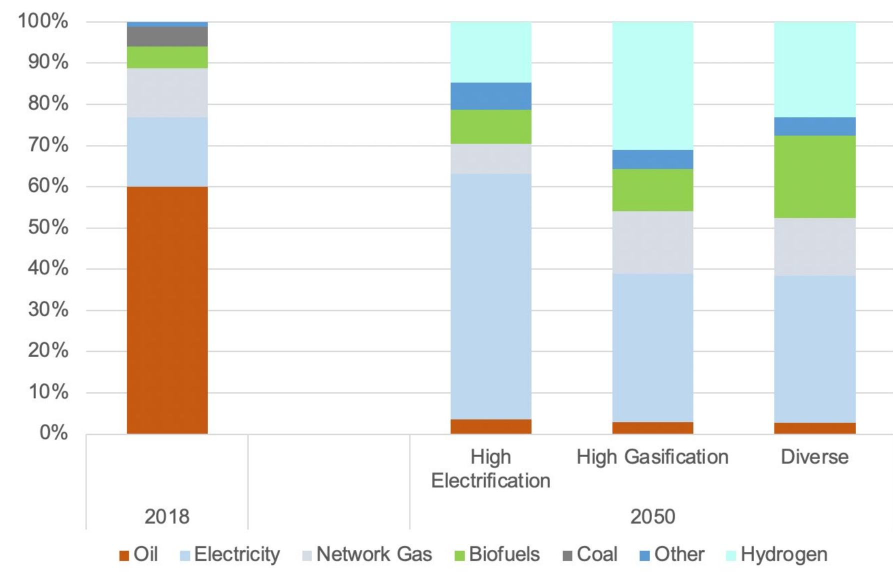


Figure 4.11 shows how the proportions of fuel within final energy demand changes over time for each scenario. It illustrates Northern Ireland's reliance on oil in 2018, with 60% of final energy demand. This is due to the large amount of heating oil and the prevalence of petrol and diesel cars. The figure shows that in 2050 oil demand is 4% or less in all scenarios. There are also some key points that reflect the differing assumptions across the scenarios:

- High Electrification relies mostly on electricity with 60% of final demand.
- High Gasification has the highest proportions of network gas (15%) and hydrogen (31%) of final demand, Diverse is not far behind at 14% and 23%, respectively.
- Diverse has a more varied and balanced final energy demand by fuel with electricity being its largest contributor at 36%.

Figure 4.12: Final energy demand by sector in 2018 and by scenario in 2050

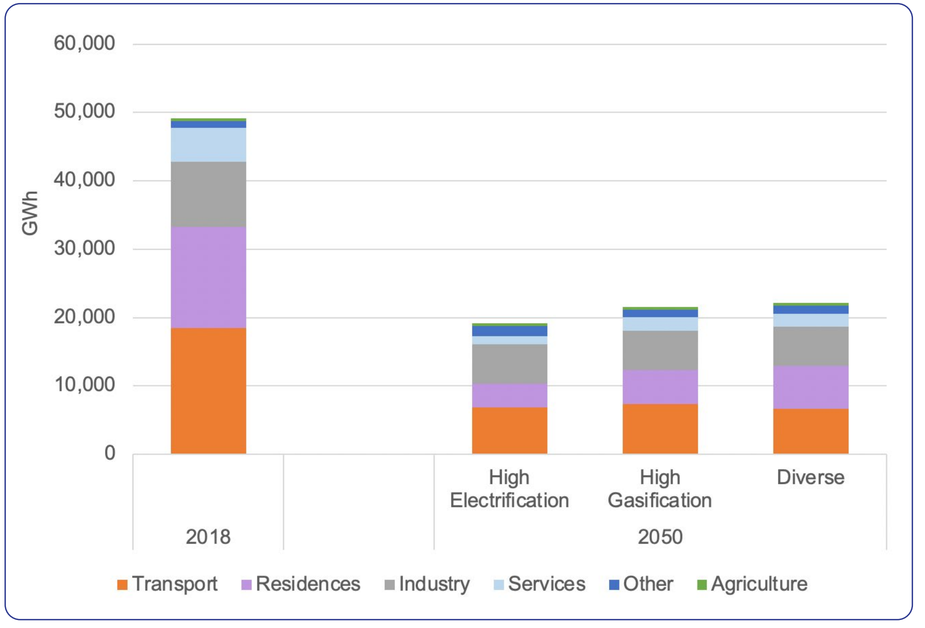


Figure 4.12 illustrates the breakdown of final energy demand by sector which indicates:

- The largest reduction by 2050, in final energy demand, from 2018 is in the transport sector. Demand reduces by over 11,000 GWh (over 60%) across all three scenarios.
- Residences and Services also see large reductions across scenarios. The largest in High Electrification with reductions of 77% and 75%, respectively. This can largely be attributed to the greater use electricity for space heating and the associated higher efficiency of the technology in this scenario.
- The Industrial sector falls by 40% across all scenarios, due to assumptions of resource and efficiency improvements in industrial processes.
- Final demand in the Other sector increases as this includes energy production which increases for NI through all scenarios.

Figure 4.13: Electrification rate per scenario over time

The electrification rate represents the amount of electricity demanded as a proportion of final demand. In 2018 the electrification rate was 17%:

- High Electrification unsurprisingly has the highest rate of electrification in 2050 (60%).
- High Gasification and Diverse scenarios have the same rate by 2050 (36%), and take similar paths of electrification.

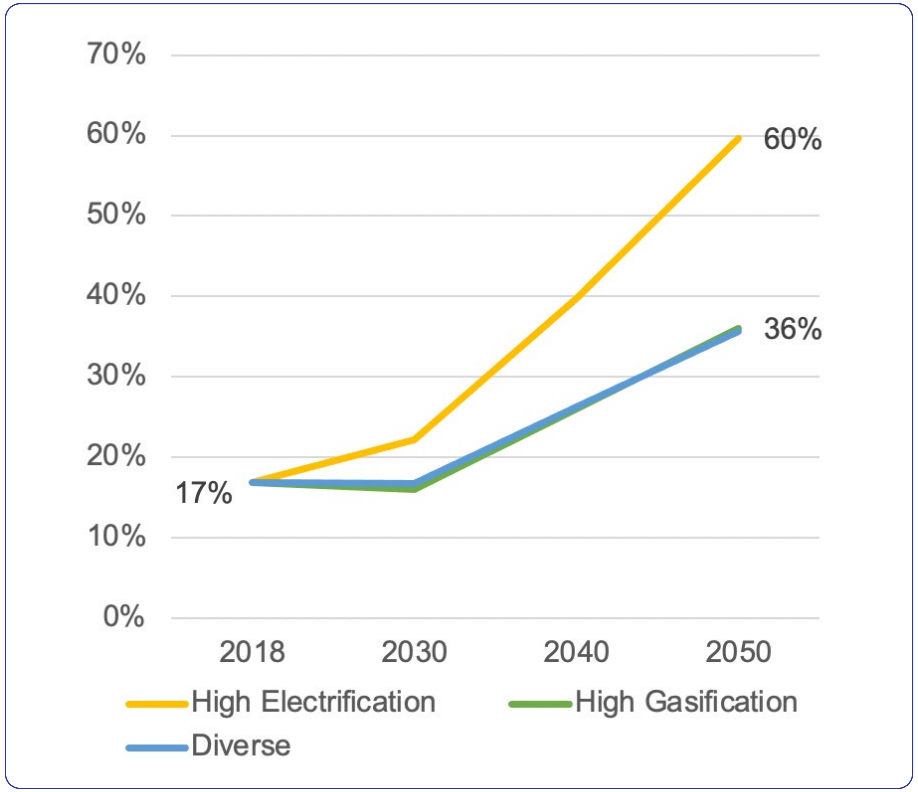
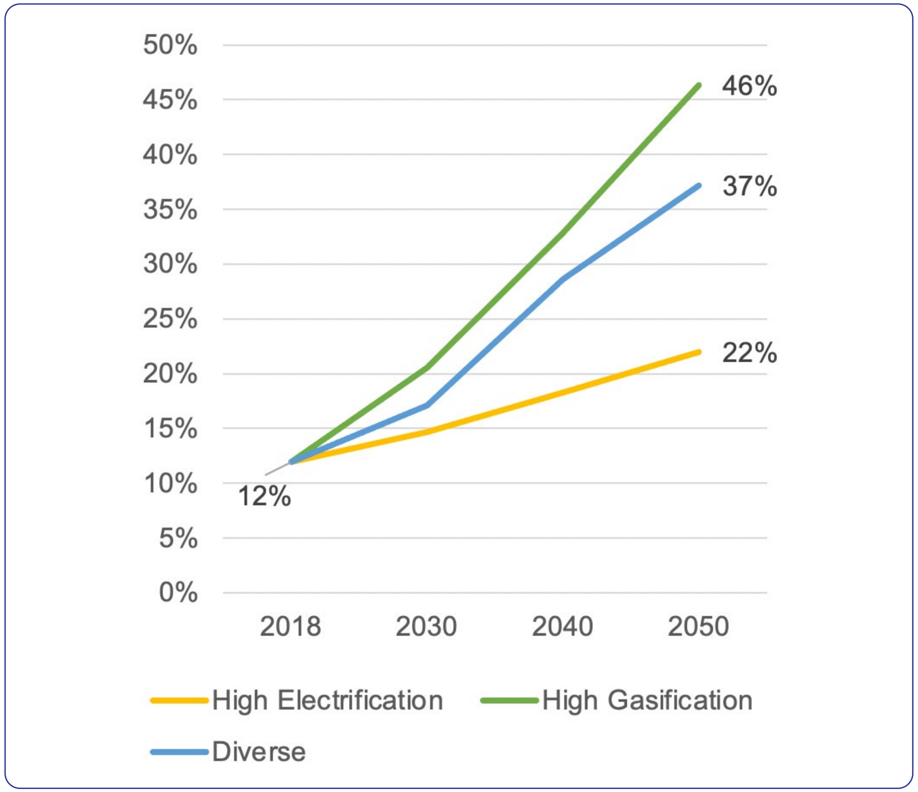


Figure 4.14: Gasification rate per scenario over time

The gasification rate represents the amount of gas (including natural gas, green gas and hydrogen) demanded as proportion of final demand. In 2018 the gasification rate was 12%:

- High Gasification has the highest rate of gasification (46%) across all scenarios in 2050.
- The Diverse scenario has a similar level of gasification to High Gasification in 2030, however by 2050 it is lower at 37%.
- High electrification has the lowest gasification rate throughout the transition, and is less than half of High Gasification in 2050 (22%).



RESIDENCES

Energy Demand in Residences Sector

The residences sector covers all energy consumed within domestic households. This includes heating, hot water, ventilation, household appliances, cooking and lighting. This sector also includes an element of consumer behaviour and its ability to affect final energy use. Each scenario illustrates potential different pathways of reducing energy demand and transition away from fossil fuel use. Each scenario has ambitious energy efficiency improvements, which reduces the final energy demand, particularly for space heating. There is also an assumption of a move to smarter technology for lighting and appliances across all scenarios.

Figure 4.15: Residences final energy demand in 2018 and by scenario over time

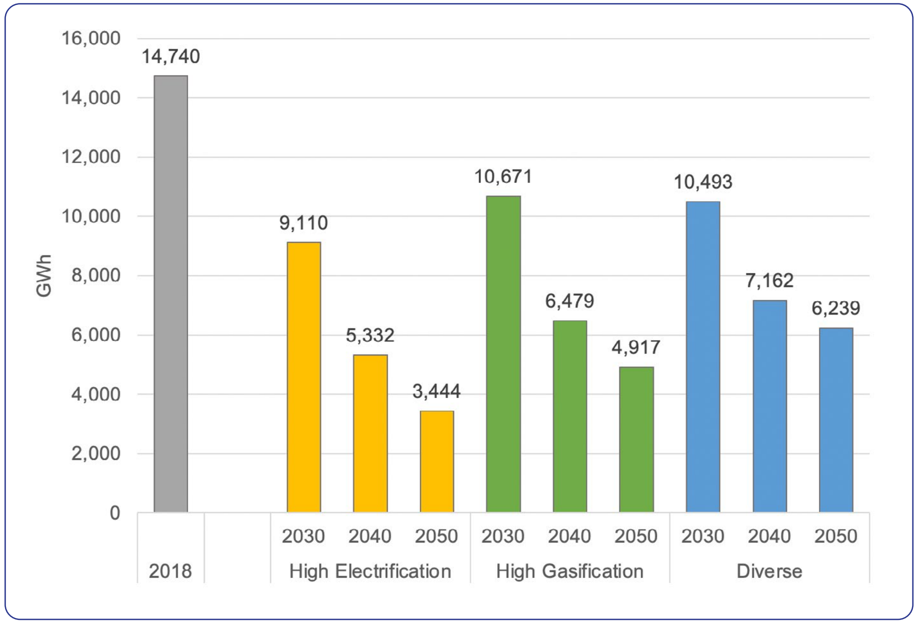


Figure 4.15 shows how final energy demand in the residences sector decreases across all scenarios. All scenarios have the same ambitious assumptions regarding energy efficiency measures introduced before 2050. High Electrification follows an accelerated path to reaching this due to a higher volume of heat pumps being utilised. The main contribution to differences in demand is divergence in the fuels and technologies used for space heating:

- In 2050, High Electrification has the lowest demand (3,444GWh), largely due to the greater use of heat pumps for space heating, which have higher efficiency levels.
- Diverse has the highest demand, which is primarily driven by the different combination of technology used in space heating. In particular the Diverse scenario uses HVO, which are not used in the other scenarios as well using more as hydrogen than elsewhere.

Figure 4.16: Proportion of residences final energy demand by fuel type in 2018 and by scenario over time

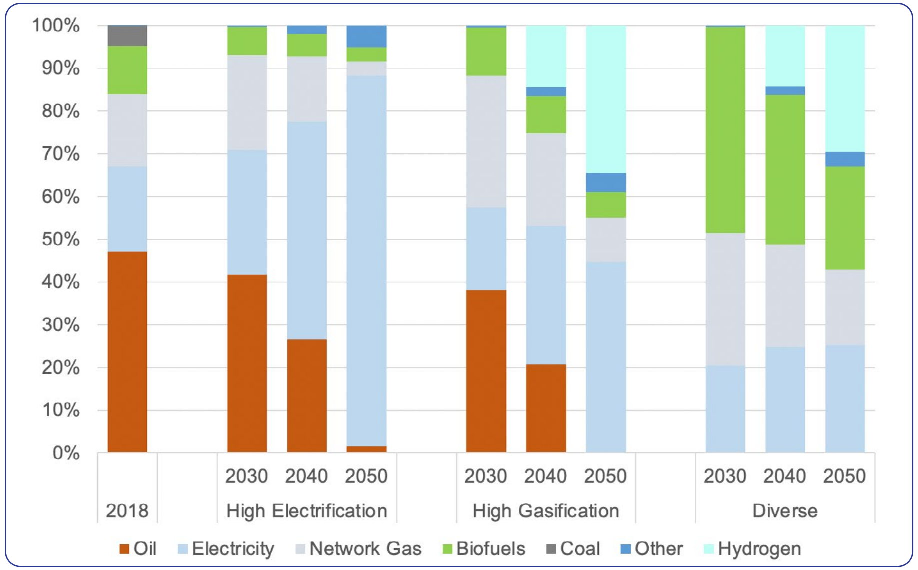


Figure 4.16 shows the proportion of residences final energy demand by fuel type in 2018 and across all three scenarios and time.

- High Electrification relies heavily on electricity with 87% of final residences demand in 2050.
- Hydrogen (34%) is demanded most in the High Gasification scenario, however it is still reliant on electricity (45%).
- The Diverse scenario has a much more even mix of fuel type, split across final energy demand in the residences sector [electricity (25%), biofuels (24%), hydrogen (30%) and network gas (18%)].
- The Diverse scenario assumes the use of biofuels, in the form of HVO and Bio-LPG, as a replacement for heating oil (kerosene). This transition to biofuels does not require major technology changes within the domestic sector, making it easier to implement. Therefore the move across fuels is assumed to be much faster, creating a sharper reduction in CO_2 emissions between 2018 and 2030.

SERVICES

Energy Demand in Services

The service sector covers both commercial and public sectors, such as, Wholesale and retail trade; Accommodation and food service activities, Public administration, Education, Human health and social work activities and Arts, entertainment and recreation. It is identified through the classifications as defined International Standard Industrial Classification (ISIC) of All Economic Activities. Further details on this can be found in Annex D.

Each scenario illustrates a different way to transition from fossil fuels across a range of applications, such as heating, hot water, ventilation, appliances and lighting. Similar to the residences sector, each scenario has ambitious energy efficiency improvements, which reduces the final energy demand for space heating.

Figure 4.17: Services final energy demand in 2018 and by scenario over time

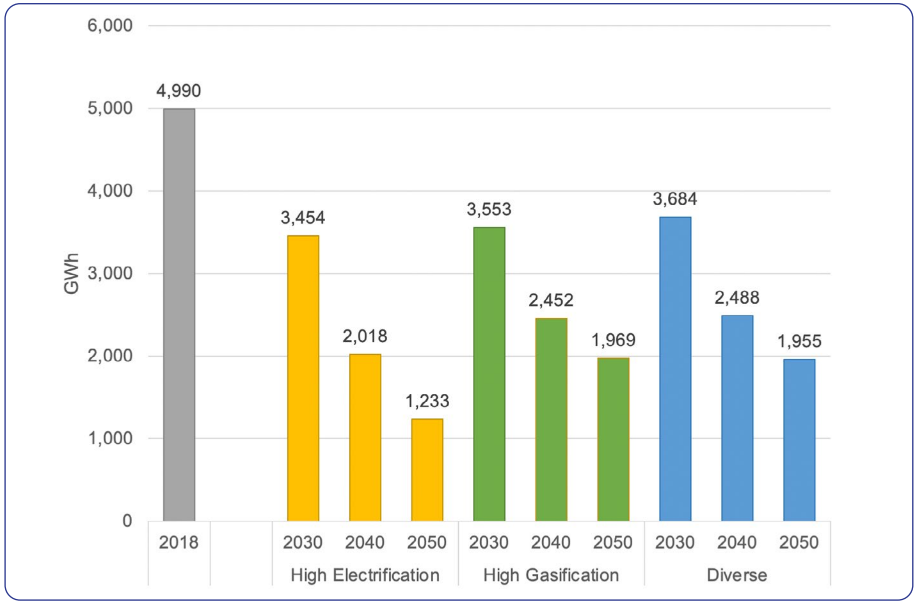


Figure 4.17 shows how final energy demand in the services sector decreases across all scenarios:

- In 2050 High Electrification has the lowest demand (1,233GWh), largely due to the greater use of heat pumps for space heating and associated efficiency of the technology.
- Diverse and High Gasification have similar levels of demand in 2050, with the latter having a higher reliance on gas technologies for space heating. Diverse however, is more reliant on biofuels by 2050 for the same purpose.

Figure 4.18: Proportion of services final energy demand by fuel type in 2018 and by scenario over time

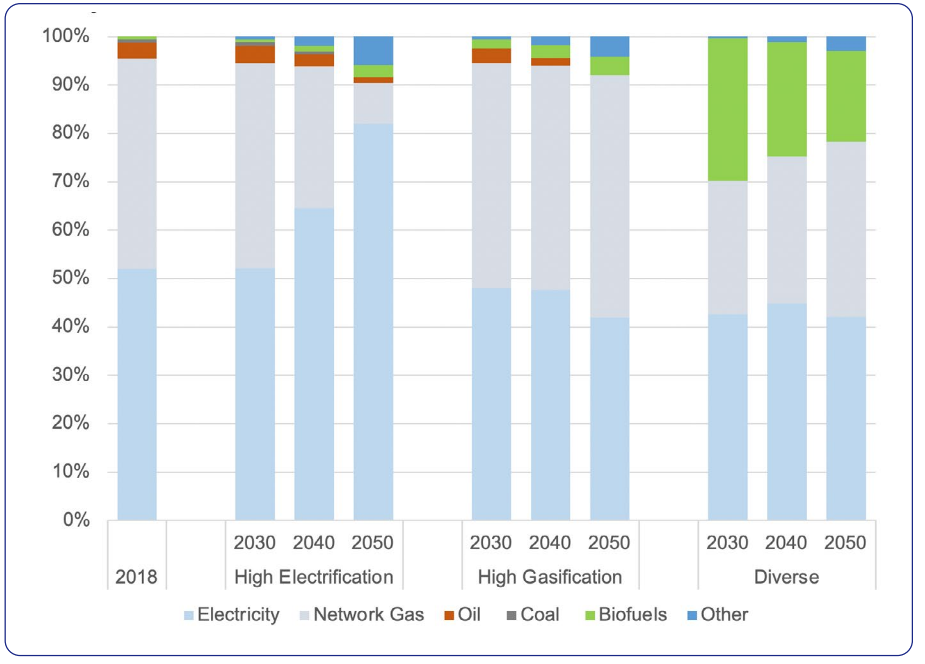


Figure 4.18 shows that within the services sector:

- High Electrification relies heavily on electricity with 82% of final demand in 2050.
- In 2050, the fuel type demanded most in the High Gasification scenario is network gas (50%), but it is still heavily reliant on electricity (42%).
- The Diverse scenario has a faster transition away from oil due to the use of HVO in space heating. In this scenario the proportion of biofuels of services final demand reduces over time. However there is still a larger demand in 2050 (19%) compared to High Electrification (3%) and High Gasification (4%).

INDUSTRY

Energy Demand in Industry

Industry sector includes all energy used for industrial processes across industry in Northern Ireland. It is predominately concerned with the energy consumed within the manufacturing and construction sector. Energy demand in off road mobile machinery (such as forklifts) are reflected in the transport sector demand.

Figure 4.19: Industry final energy demand in 2018 and by scenario over time

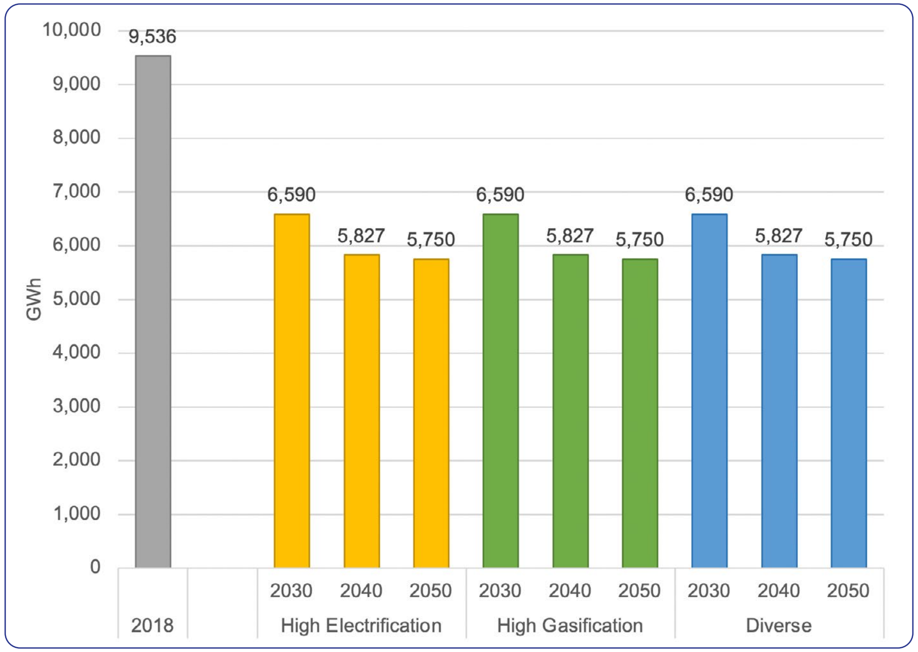


Figure 4.19 shows how the reduction in final energy demand for industry is the same across all scenarios. This decrease is driven by the improvements in resource and energy efficiency, which is assumed the same across scenarios. Within each scenario there is a move away from coal and oil to a different mix of electricity, gas, hydrogen and biofuels, which is shown in Figure 4.20.

Figure 4.20: Proportion of industry final energy demand by fuel type in 2018 and by scenario over time

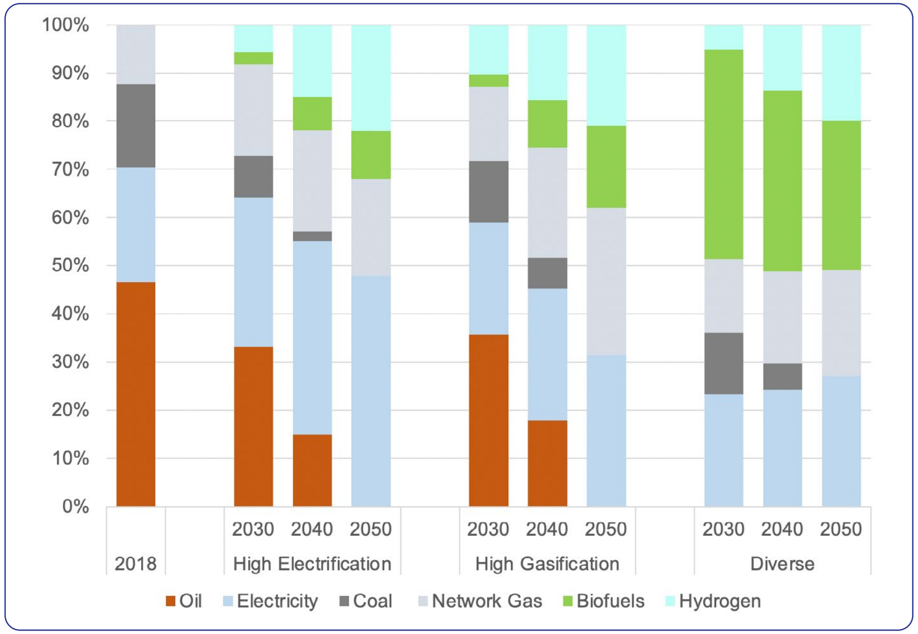


Figure 4.20 shows the proportion of fuels used to meet final demand within industry. Each scenario assumes no future use of oil and coal entirely but have different resulting fuel mixes:

- High Electrification shows a gradual increase in the share of electricity out to 2050, when it is nearly half of final energy demand (48%).
- There is no hydrogen demand in 2018, however over time it plays an increasingly import role in industry and by 2050 accounts for approximately a fifth of demand within each scenario.
- Biofuels play a major role in meeting demand in 2030 within the Diverse scenario (43%) but a slight decrease to 31% in 2050, as hydrogen becomes more prominent.

AGRICULTURE

Energy Demand in Agriculture

The agriculture sector is primarily focused on energy used for heating with agriculture. The NI ETM does not include aspects associated with variations in land use as it is an energy related model. Energy demand for agricultural vehicles is reflected in the transport sector. Agriculture sector energy demands are the smallest of the sectors assessed. Due to the typical rural setting and more remote buildings, it is assumed this limits the options to displace carbon intensive heating solutions to decarbonise.

Figure 4.21: Agriculture final energy demand by fuel type in 2018 and by scenario over time

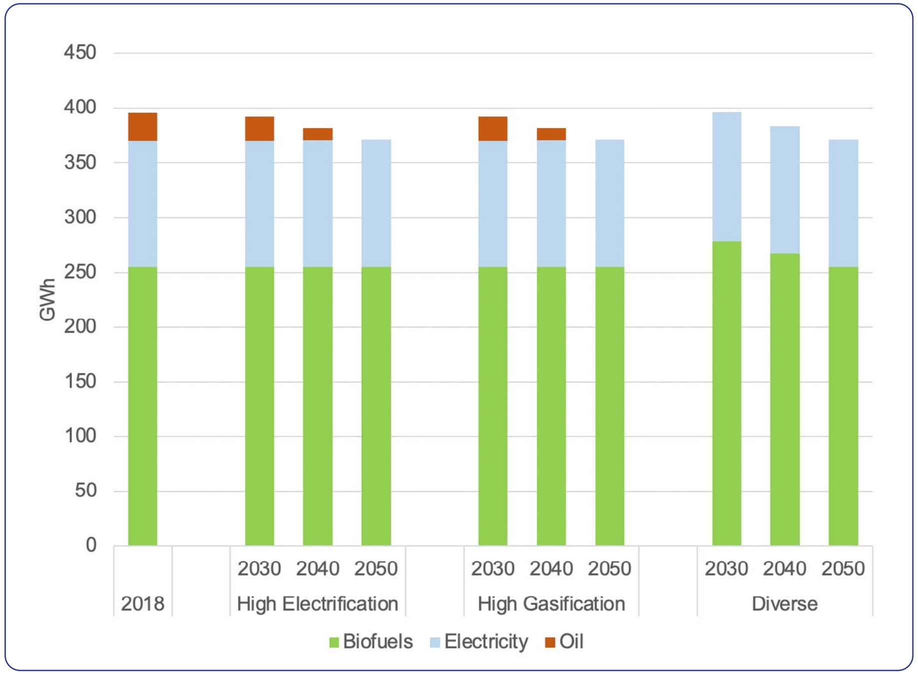
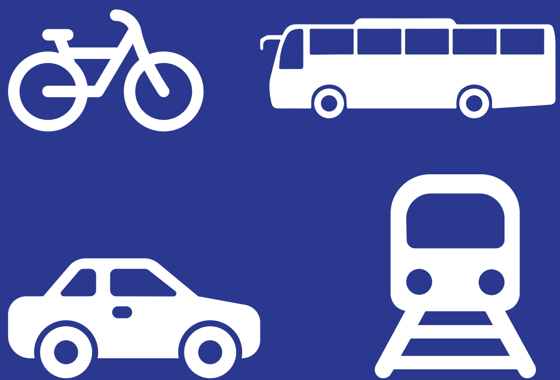


Figure 4.21 shows how the reduction in final energy demand for agriculture in 2050 is the same across all scenarios. This slight reduction is the result of shifting away from oil in space heating. The main difference across the scenarios is Diverse has an assumed shift to HVO and Bio-LPG, which results in marginally higher final demand in 2030. Each scenario displaces the use of oil in slightly different ways, resulting in different fuel mixes across scenarios earlier in the transition to 2050:

- Each scenario has the same positon in 2050 where all of the oil demand is replaced by electricity in the form of heat pumps. High Electrification transitions directly to this position, whereas the other scenarios use elements of biofuels in transition.
- The High Gasification and Diverse both include an element of Bio-LPG meeting final energy demand within Agriculture in 2030 (3%) and 2040 (1.5%).
- Diverse transitions away from oil quickly through a switch to Bio-LPG and HVO, which results in lower CO_2 emissions.

TRANSPORT



Energy Demand in Transport

The transport sector includes all passenger transport (includes road, rail and domestic aviation), freight transport (includes trucks and ships) and all off road industrial and agriculture vehicles. International transportation energy demands are not included in this analysis.

Figure 4.22: Transport final energy demand in 2018 and by scenario over time

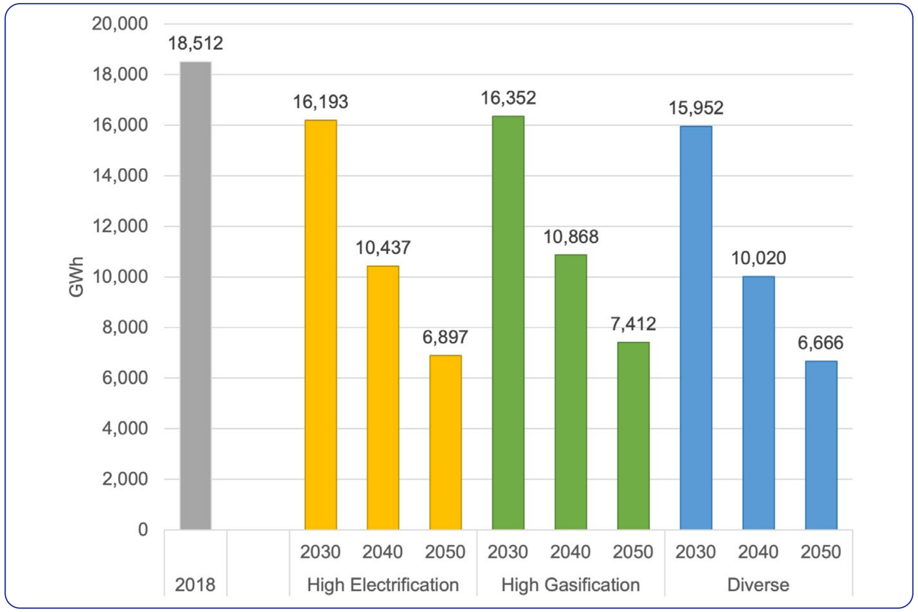


Figure 4.22 shows a large reduction in final demand across all scenarios, mainly due to the ban on the sale of new petrol and diesel cars in UK from 2030. This requires a fundamental shift of fuel technologies used in the transport sector:

The largest reduction is in the Diverse scenario, which assumes enhanced demand reduction measures to reduce overall miles travelled and sees a greater increase in public transport.

- High Gasification and High Electrification have the same assumptions around demand reduction, therefore any difference is due to the fuel technologies used for transport.
- High Gasification has the highest final demand due to greater reliance on hydrogen vehicles and less on EVs compared to the other scenarios.

Figure 4.23: Proportion of Transport final energy demand by fuel type in 2018 and by scenario over time

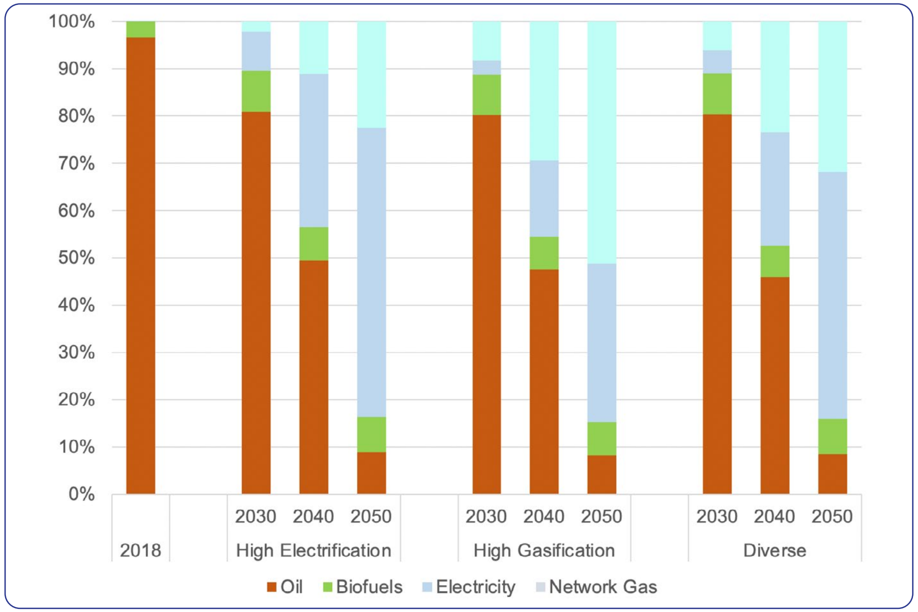


Figure 4.23 reflects how within each scenario the transport sector transitions away from oil (petrol and diesel):

- High Electrification has the greatest emphasis on EVs with electricity making up 61% of the final energy demand.
- The majority of demand in High Gasification is Hydrogen (51%) for larger sized vehicles but there is still over a third (34%) demand for electricity due to the importance of this in cars and Light Goods Vehicles (LGVs).
- Diverse has a more even mix of the two main fuel types but still over half of its demand is for electricity (52%).

The most common mode of transport in 2018 was a car or LGV (the model groups these due to the similar size and fuels types utilised). It is estimated in the data collected for base year of this model that this 90% of passenger transport was a car or LGV. Figure 4.24 provides a focused look at cars and LGVs in terms of how many miles are travelled by each fuel type. It illustrates how each scenario transitions away from Internal-Combustion Engines (ICE) to 2050:

- High Electrification has assumed 95% of all cars and LGVs miles travelled will be fuelled by electricity and 3% hydrogen.
- High Gasification has the largest amount of miles travelled by hydrogen cars and LGVs of all scenarios with 25% and 73% EVs.

Figure 4.24: Proportion of miles travelled for cars and LGVs by fuel and scenario over time

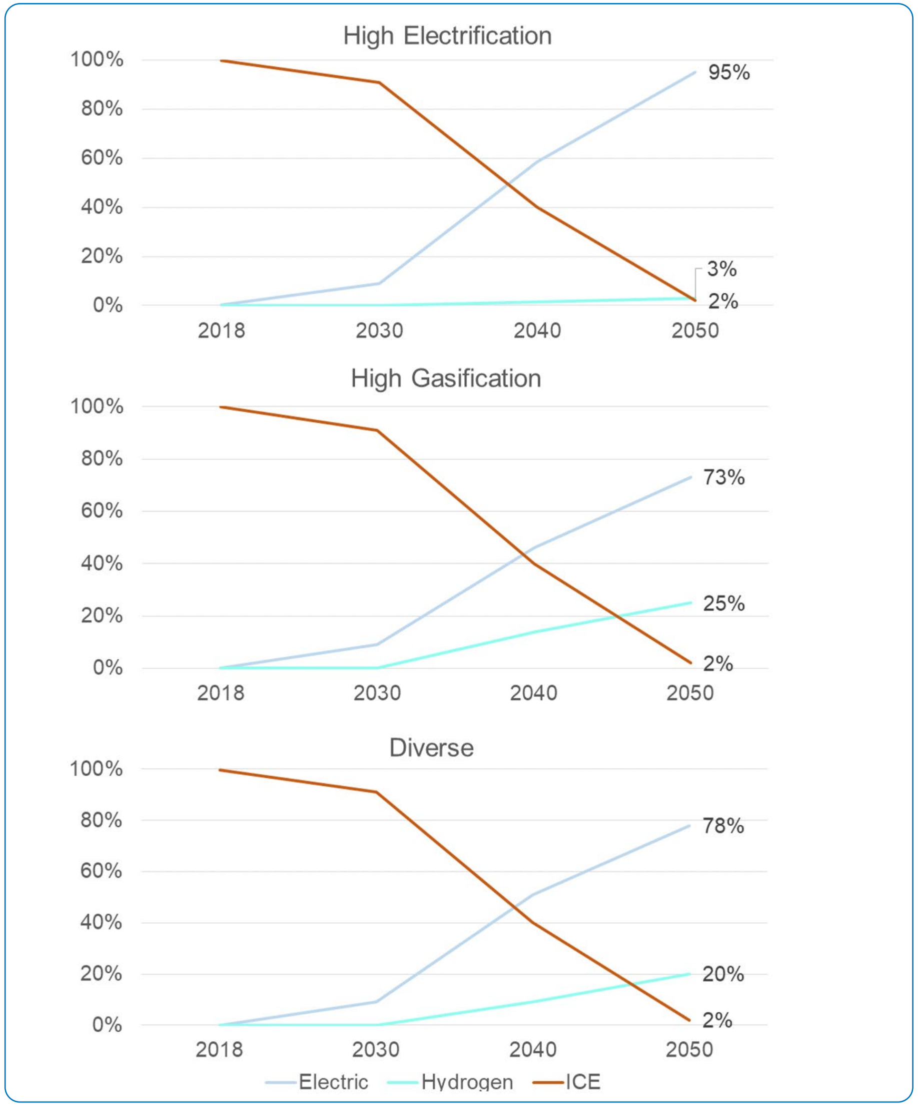
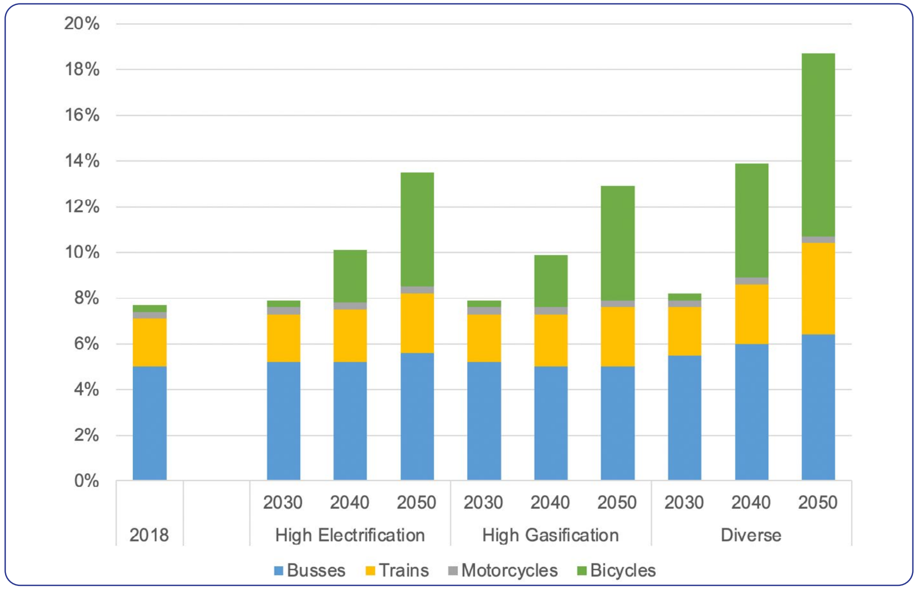


Figure 4.25 illustrates the proportion of distance travelled for the other modes of surface vehicles, which include trains, busses, motorcycles and bicycles:

- The Diverse scenario assumes an enhanced demand reduction position, through the changes in the world of travel. This sees the largest proportion of miles travelled by bicycle of 8% compared to High Electrification (5%) and High Gasification (5%).
- The proportion of miles travelled by trains is highest in the Diverse scenario with 4% compared to 2.6% in the other scenarios.
- The Diverse scenario also has the highest proportion of miles travelled by busses with 6.4%, compared to High Electrification and High Gasification that have 5.6% and 5.5%, respectively.

Figure 4.25: Proportion of distance travelled by mode of transport (excluding cars and LGVs) in 2018 and by scenario over time



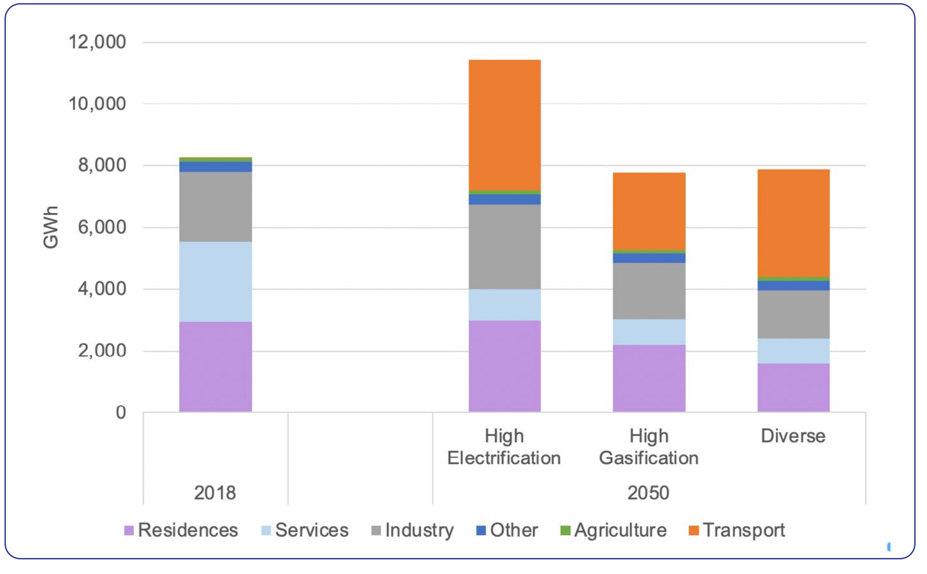
FUEL DEMANDS

Final Energy Demand for Electricity

This section examines the final energy demand for electricity across sectors within each scenario. As previously discussed, the High Electrification scenario has the largest demand for electricity with the other two scenario's having similar levels of demand. However, Figure 4.26 shows how this consumption is made up differently across sectors:

- The largest amount of demand in High electrifications in 2050 is in the transport sector (4,218 GWh) with residences (2,987 GWh) and industry (2,760) the other largest sectors.
- Diverse has a greater amount of electricity used in transport (3,487GWh) than High Gasification, whereas High Gasification demands more electricity in Residences and Industry.

Figure 4.26: Final energy demand for electricity by sector in 2018 and by scenario in 2050



Final Energy Demand for Gas

The level of demand for gas (natural, green and hydrogen) varies across the scenarios but also the make-up of gas demanded changes across time. Figure 4.27 shows how hydrogen and green gas replaces natural gas by 2050 in all scenarios. Hydrogen production is assumed to be either "green hydrogen" or accompanied by carbon capture to ensure it is carbon neutral. This results in a fully decarbonised gas sector by 2050.

Figure 4.27: Proportion of final demand for gas by natural gas, green gas and hydrogen in 2018 and by scenario in 2050

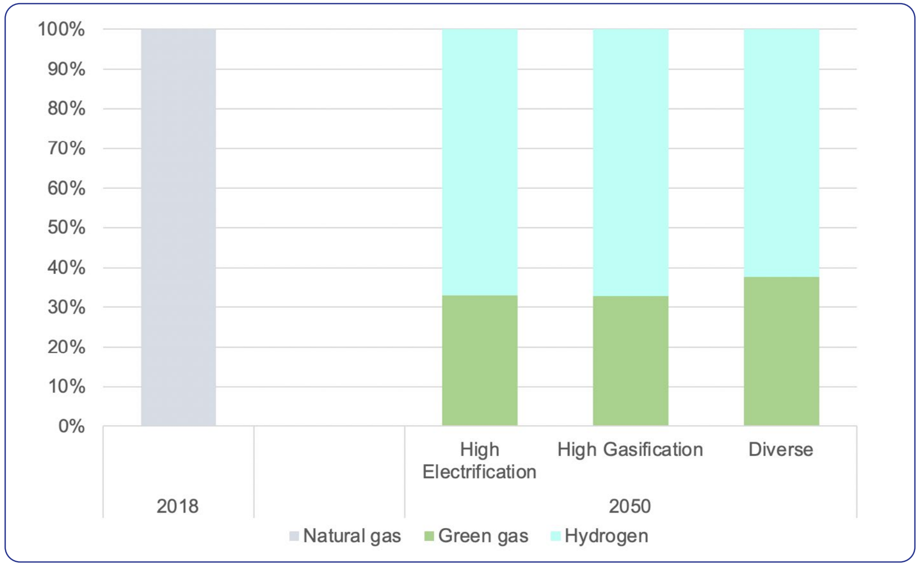
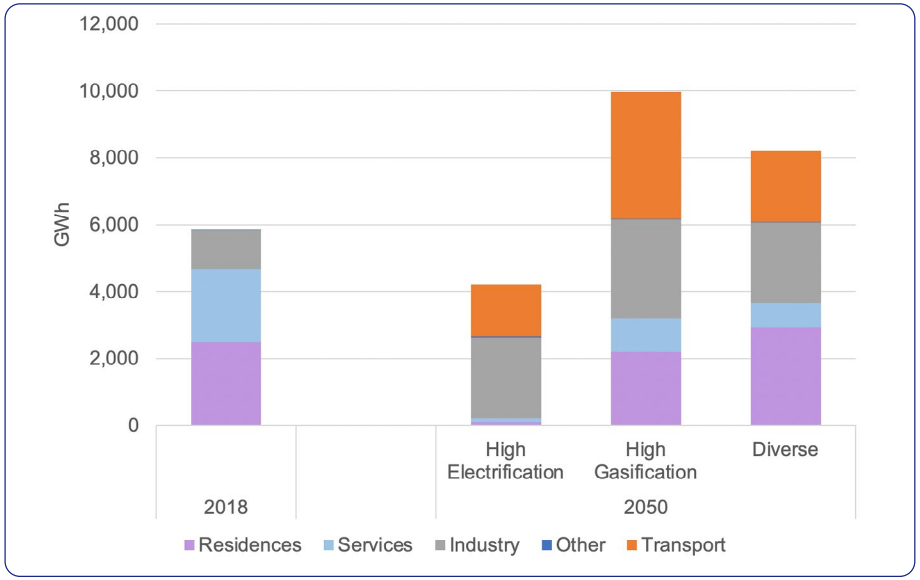


Figure 4.28 presents levels of gas demand across sectors for each scenario. This shows that:

- Apart from the residences sector in the Diverse scenario, High Gasification has a greater demand for all gases (green gas & hydrogen) across all sectors. This is due to a greater emphasis on hydrogen.
- High Electrification demands a relatively small amount of gas in residences and services due to the focus on air source heat pumps for space heating.
- The use of gas in industry is consistent across all scenario's with High Gasification (2,961 GWh) demanding slightly more than other scenarios (both 2,415 GWh).

Figure 4.28: Final energy demand for gas by sector in 2018 and by scenario in 2050



HEAT DEMAND

Heat Demand

Heat demand is the demand for space and water heating and cooling across all sectors and is correlated directly with the level of insulation and energy demand growth or decline. As each scenario has the same assumptions on change in demand, they show similar trends.

Figure 4.29: Heat demand in 2018 and by scenario over time

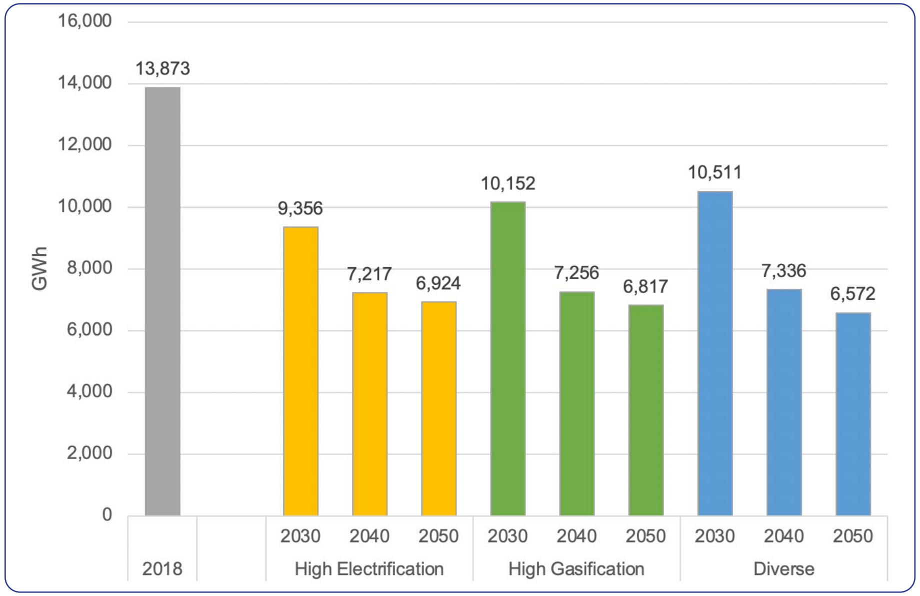


Figure 4.29 shows the heat demand reduces over time in all scenarios, this is due to assumptions around the ambitious energy efficiency saving in residences and services:

- High Electrification shows a lower level in 2030 compared to the other scenarios, due to the accelerated retrofit rollout to support a high volume of heat pump.
- In 2050 all scenarios show at least a 50% reduction in heat demand and are at very similar levels.

Figure 4.30: Proportion of heat production by fuel in 2018 and by scenario over time

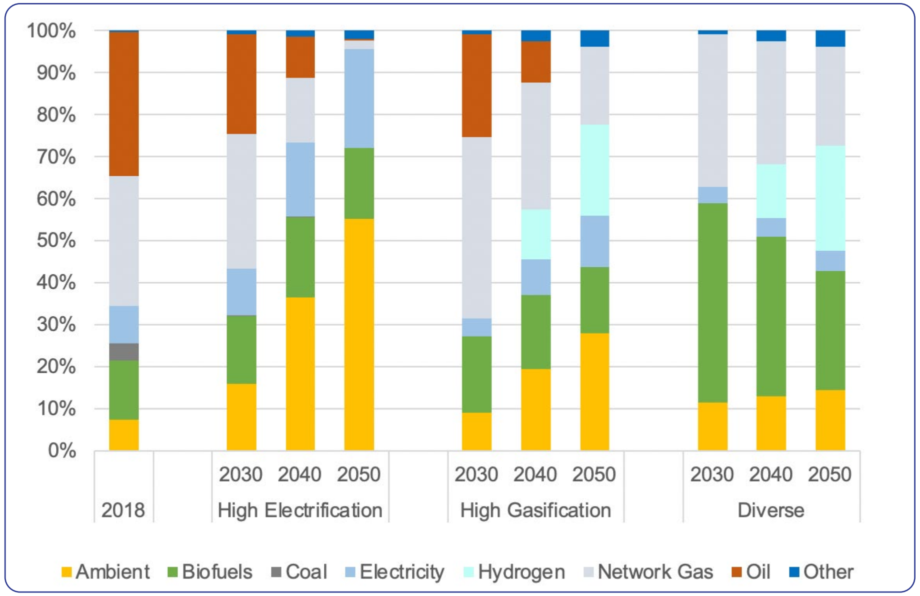


Figure 4.30 shows the proportions of fuel type used to produce the heat in 2018 and across each scenario:

- High Electrification has a large dependence on heat pumps, which can be seen in the Ambient heat production making up 55% of production in 2050.
- High Gasification has moderate use of heat pumps, which accounts for its 28% Ambient heat but also sees the use of hydrogen (22%) and network gas (18%).
- Diverse assumes no oil used for heat in the transition to 2050 due to its fast switch over to HVO instead of oil.

SUPPLY

Energy Production

In order to facilitate the changes in energy demand required to reach net zero by 2050, energy production must evolve in a safe and reliable manner over the coming decades. This is a complex process that involves increasing scale and interdependency of energy conversions from one fuel to another.

This chapter covers the fuel production requirements needed to meet the demands of the NI consumer across the high level narratives.

It looks at:

- Local production/Imports
- Electricity supply
- Network gas supply
- Hydrogen Supply
- Renewable energy share

Figure 4.31: Primary energy supply by source in 2018 and by scenario over time

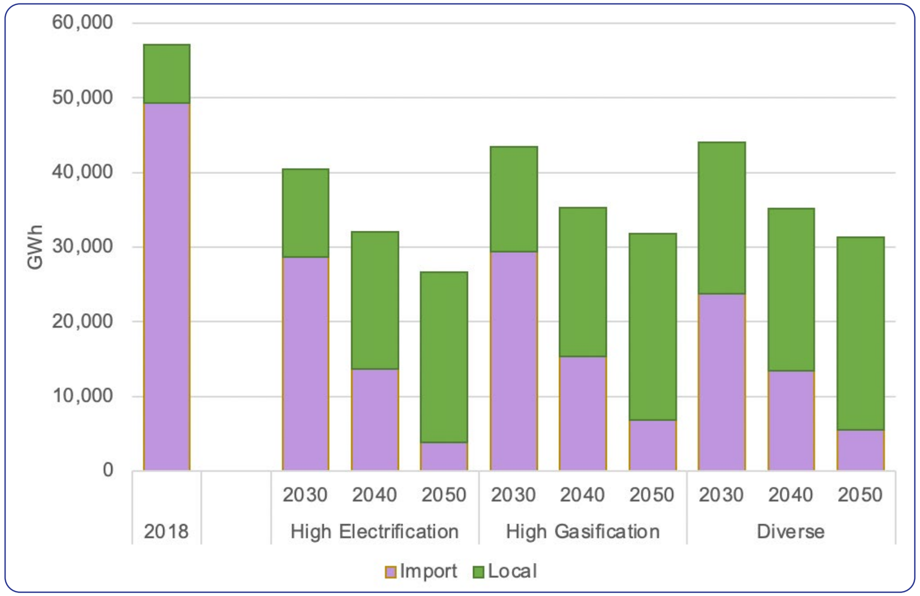


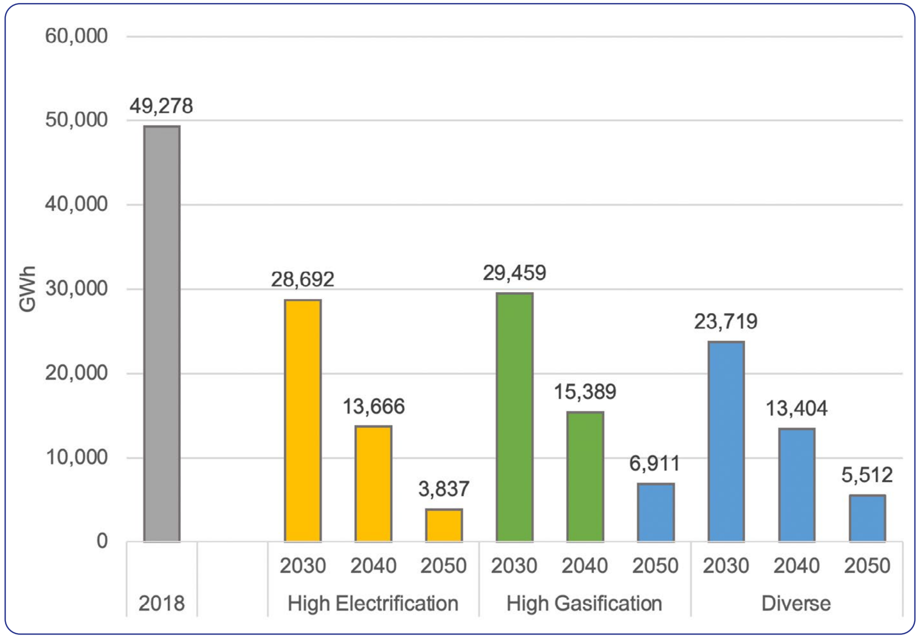
Figure 4.31 shows the level of locally produced and imported primary energy into NI:

- In 2018, imports held an overwhelming majority (86%) of primary energy supply in NI.
- The remaining generation mix (14%) was made up of locally produced energy, including biofuels, electricity and waste products.
- It is assumed that over the next three decades the energy supply will encounter a major shift, with locally produced energy assuming the role that was previously dominated by imports.
- By 2050 each scenario sees above 78% of all primary energy demand being produced locally. This is due to the increased production of renewable energy and hydrogen in Northern Ireland.

IMPORTS

Imports

Figure 4.32: Energy imports in 2018 and by scenario over time



To meet fluctuating energy demand in Northern Ireland in a given year, certain fuels have to be imported. The ETM calculates how much energy is locally produced and determines what level of imports are required to meet demand. This section looks at the how imports change due to the changing reduction in demand and the change of fuel technologies over time.

Figure 4.32 highlights the falling dependency on imports in NI by 2050;

- The sharpest drop in import reliance is clearly shown in the Diverse scenario, within the initial decade, imports fell by 52%.
- However by 2050 the reduction in imports is most prominent in High Electrification, reaching a 92% fall. The remaining imports are a combination of oil, network gas and electricity.
- Between the net zero scenarios, High Gasification has the highest remaining import dependencies by 2050 (22%). This is largely due to the volume of imported network gas.

Please note on the 5th May 2021 Figure 4.32 has been updated to show the correct imports data, previously this was a duplicate of Figure 4.34 and showed electricity production data.

Figure 4.33: Proportion of primary energy imports by fuel type in 2018 and by scenario over time

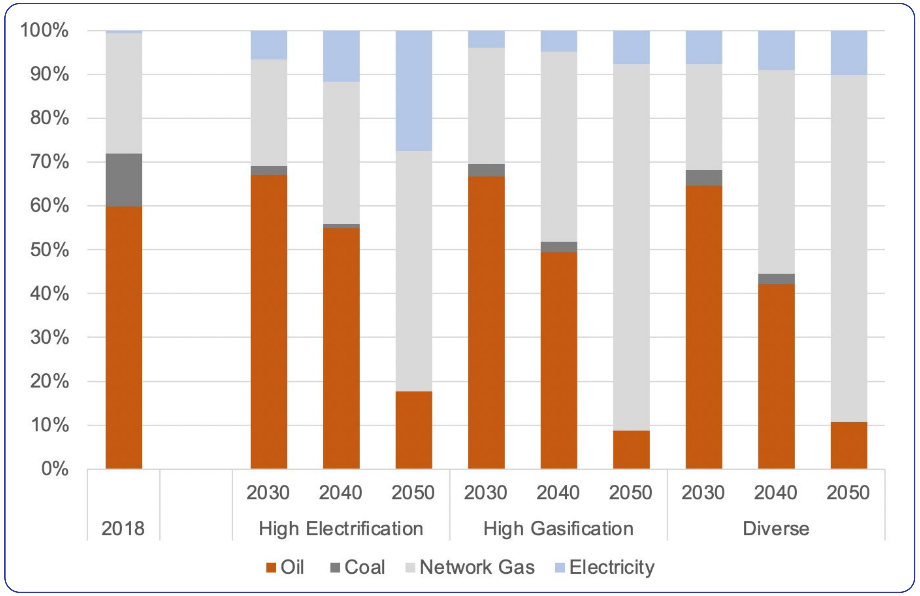


Figure 4.33 illustrates the change in fuels that NI will need to import across each scenario:

- There is a shift away from an energy system that is dependent on oil and coal imports across all scenarios, with imported coal being removed entirely by 2030.
- Although the volume of demand for imports of network gas decreases across all net zero scenarios (57-84% decrease from 2018) it becomes a critical element of the imports required to meet demand. In 2050 across all scenarios, network gas accumulates more than half of all imports, peaking at 84% in High Gasification. In comparison to 2018, the share of network gas imports was 27%.
- In comparison to 2018, electricity plays a larger role by 2050, both in terms of magnitude and share of imports in all net zero scenarios, In the High Electrification scenario electricity imports in 2050 nearly quadruple (1,052 GWh) compared to 2018 (353 GWh). In addition, it makes up just over a quarter (27%) of all energy imports in order to meet the increased demand. This is large increase on the 2018 baseline, in which electricity share equalled 1% of total imports.

ELECTRICITY

Electricity Production (Generation)

Electricity production is a fundamental element of the overall energy supply mix in Northern Ireland. Across all scenarios, whether it is a dominate force or a fuel to facilitate production of other fuels, electricity supply plays a central role in the pathway to reaching net zero by 2050.

Figure 4.34: Electricity production in 2018 and by scenario over time

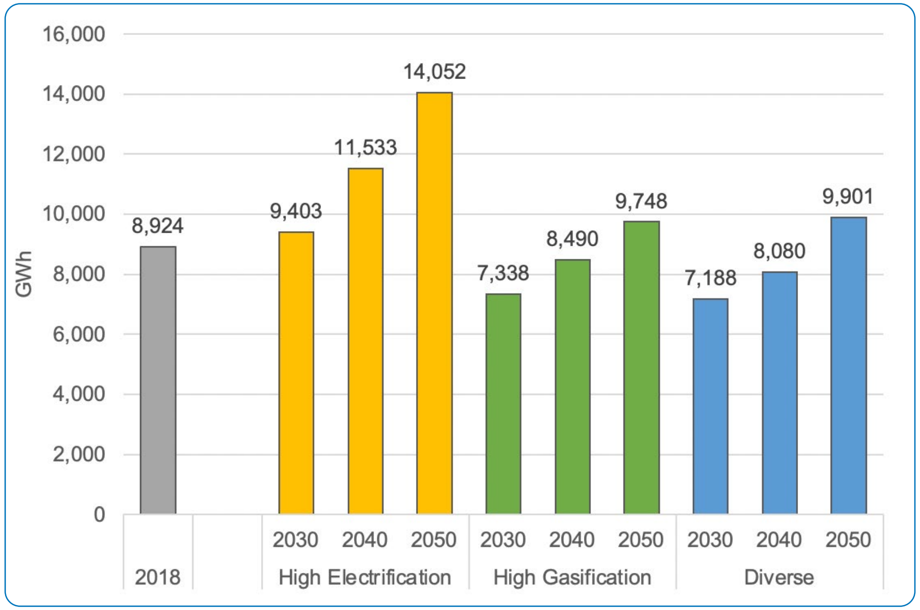
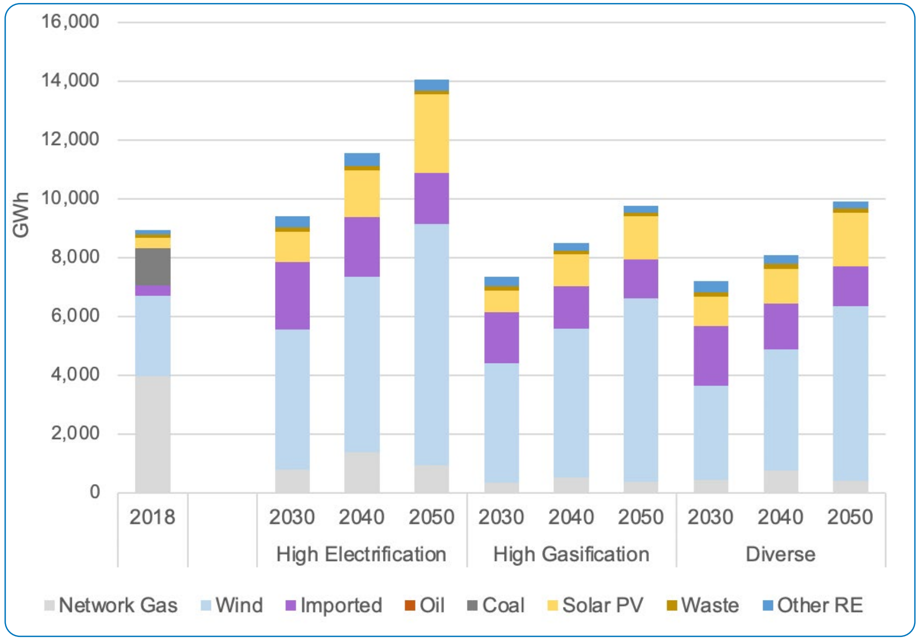


Figure 4.34 highlights a number of key points that reflect the different approaches across each scenario:

- High Electrificiation will require siginifcantly higher levels of electricity generation, which in 2050 has 57% higher total generation compared to 2018.
- Across the High Gasification and Diverse scenarios electricity production falls in 2030, due to the reliance on other energy sources.
- By 2050, electricity generation is assumed to rise above 2018 levels by a small amount in both High Gasification and Diverse, however this energy source will not dominate the overall supply mix.

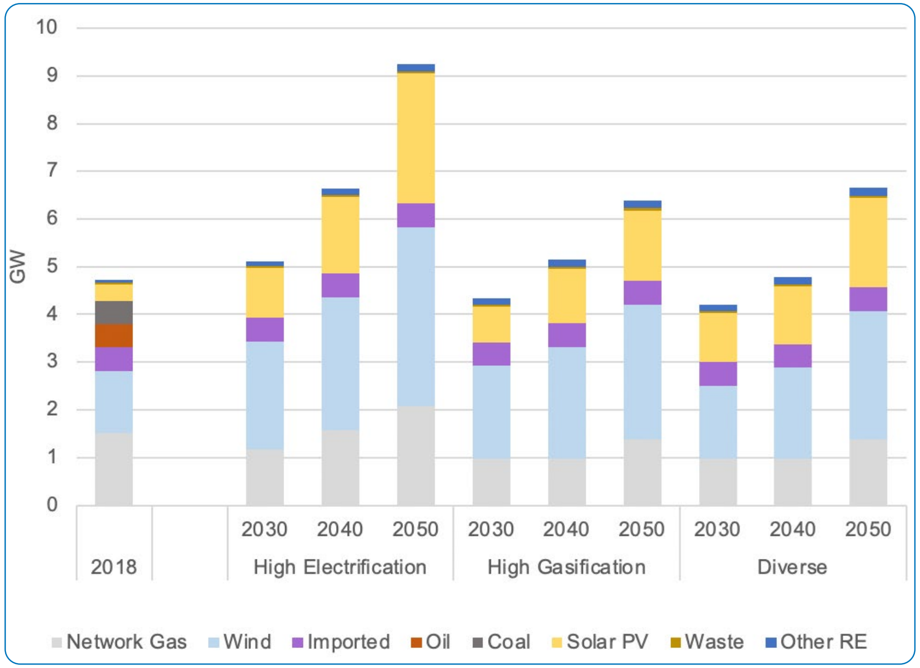
Figure 4.35: Electricity production by fuel in 2018 and by scenario over time



In the net zero scenarios most electricity generation will come from three sources: wind, solar, network gas. The flow of electricity supplied through imports remains consistent across all scenarios:

- Electricity generated through wind and solar technologies dominates the generation mix.
- The volume of electricity produced by wind in 2050 peaks in High Electrification, at 8,199 GWh, which is three times generation in 2018.
- High Gasification has the largest proportion of generation produced through wind in 2050, making up 64%.
- Across both High Gasification and Diverse scenarios electricty generated through renewable technologies accumlate to 82%.
- Electricity generated through network gas falls from 2018 levels across all scenarios by 2050. While network gas generation remains at 7% of the total production in High Electrification, output has dropped dramticaly by around 38%.

Figure 4.36: Installed electricity capacity by source in 2018 and by scenario over time

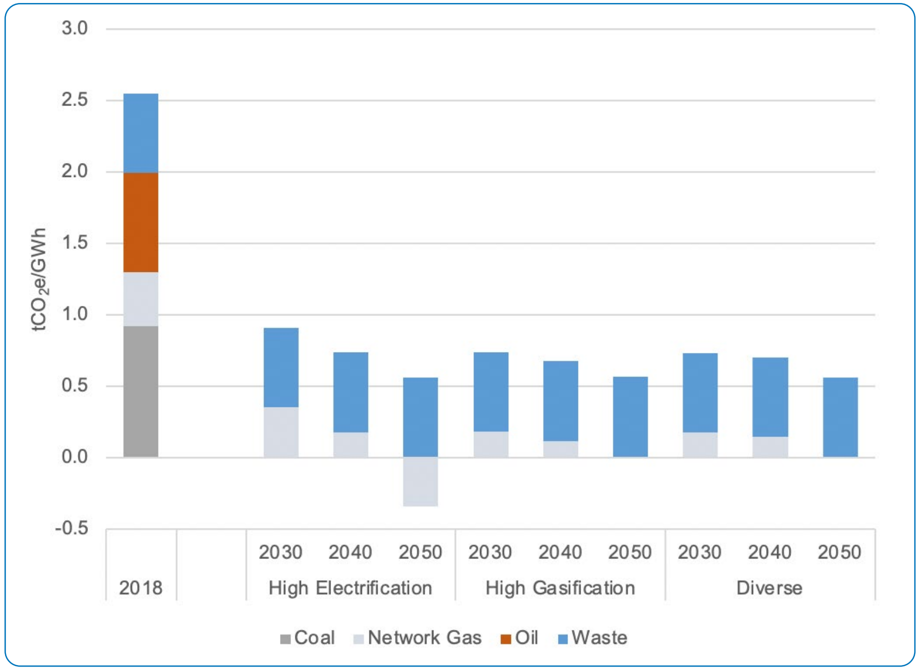


Across all scenarios electricity capacity is expected to grow over the coming decades. This is a result of the changing demand profiles we have discussed prior in this report. Electricity capacity requirements are driven by the level of electricity generation needed to meet energy demand, based on assumptions as detailed in the high level narratives.

The changing electricity capacity mix is also a reflection of the RES-E targets at various points in the transition to 2050. In order to ensure the targets are achieved the overall installed capacity must include high levels of renewables:

- By 2030, coal and oil capacity has been removed from NI electricity generation mix. In 2018, these carbon intense fuels made up a fifth (20%) NI total installed capacity.
- Installed electricity capacity under High Electrification almost doubles (95% increase) the 2018 baseline (4.7 GW) by 2050 (9.3 GW).
- High Gasification experiences a constant rate of growth, albeit at a smoother rate. Capacity is estimated to grow at around 35% by 2050.
- Initial rate of growth is slow in the Diverse scenario out to 2040. However by 2050, capacity has grown by 39% on the previous decade, which can be largely attributed to the growth in renewable capacity.

Figure 4.37: Carbon intensity of electricity production by fuel in 2018 and by scenario over time

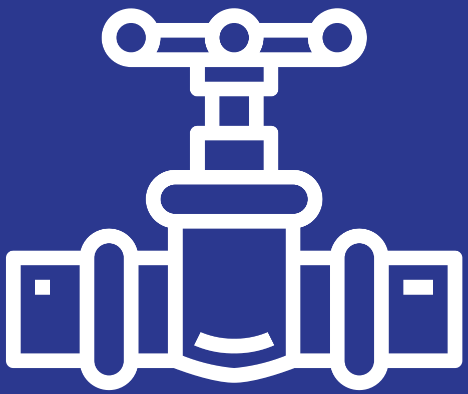


Carbon intensity of electricity production is the amount of carbon by weight (tCO_2) emitted per unit of energy produced (tCO_2/GWh).

Figure 4.37 illustrates how the carbon intensity of electricity production reduces over time across all scenarios:

- Carbon intensity reduces due to the complete removal of oil and coal in electricity production by 2050 across all scenarios.
- High Electrification is the only scenario with a negative carbon intensity, this is due to carbon capture being introduced for the network gas producing electricity, which is required in this scenario to achieve net zero carbon by 2050.
- Electricity produced through waste is the only remaining carbon emitter in 2050 across all scenarios.

NETWORK GAS



Network Gas Production

Network gas produces around 13 TWh of energy in 2018, through the treatment and regasification of natural gas. Throughout the future energy scenarios, the level of network gas production falls drastically by 2030. Continuing this downward trend to 2050.

This reduction in network gas production can be attributed to a decrease in the production of electricity meet through network gas, alongside a fall in demand:

- A drop in network gas is present in the production of electricity. In 2018, 45% of electricity generation was produced through network gas. Due to the growing volume of electricity produced through renewable resources, in line with RES-E targets, the need for network gas production is displaced, causing generation to fall as low as 4% of total electricity production in both High Gasification and Diverse.
- In 2018, almost a third (31%) of heat demand was meet through network gas. By 2050, demand drops across all scenarios, especially in High Electrification, with network gas demand at 2%.
- Network gas demand also drops in the Residence and Service sectors, throughout all scenarios.

By 2050, throughout the future energy scenarios, the network gas supply will have a changing composition. In order to create net zero energy system, the network gas supply must decarbonise, switching to a carbon neutral fuel of green gas.

Figure 4.38: Network gas production in 2018 and by scenario over time

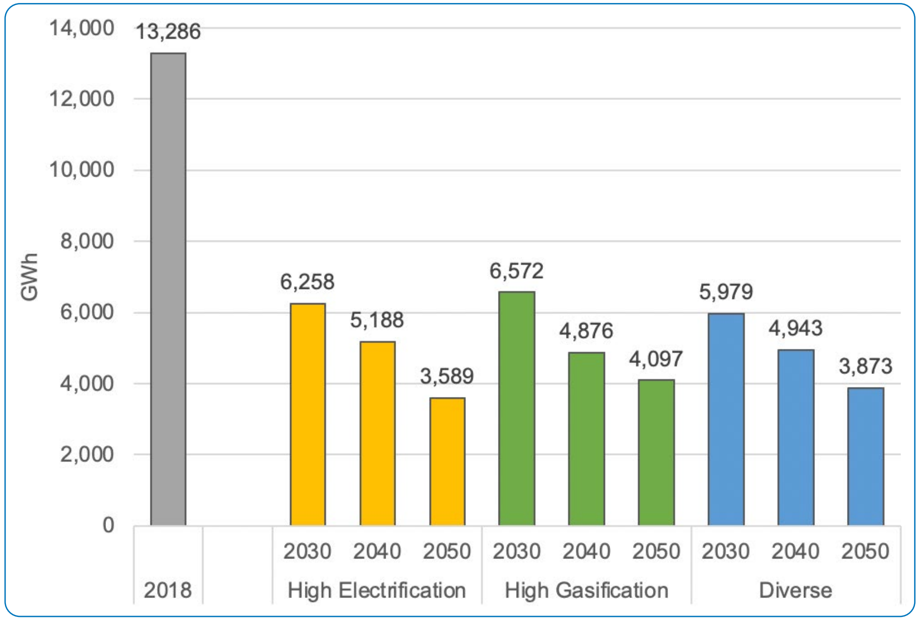


Figure 4.38 shows the network gas production which indicates:

- High Electrification presents the largest fall in network gas production by 2050, falling 73% below 2018 generation.
- While High Gasification has the highest level of network gas production in 2050, production still falls by 69%. This is due to a reduction in network gas demand throughout the Residence and Service sectors, coupled with a drop in gas generation used to produce electricity (-90%).
- Network gas experiences its sharpest initial drop in the Diverse scenario. Production falls by 55% in the first decade. During this period, Diverse experiences the sharpest drop in demand in the Service sector (-53%), partially due to the decrease in gas fired heating (-43%), while consumers switch to biofuel fired heaters.

Figure 4.39: Proportion of network gas production by fuel type in 2018 and by scenario over time

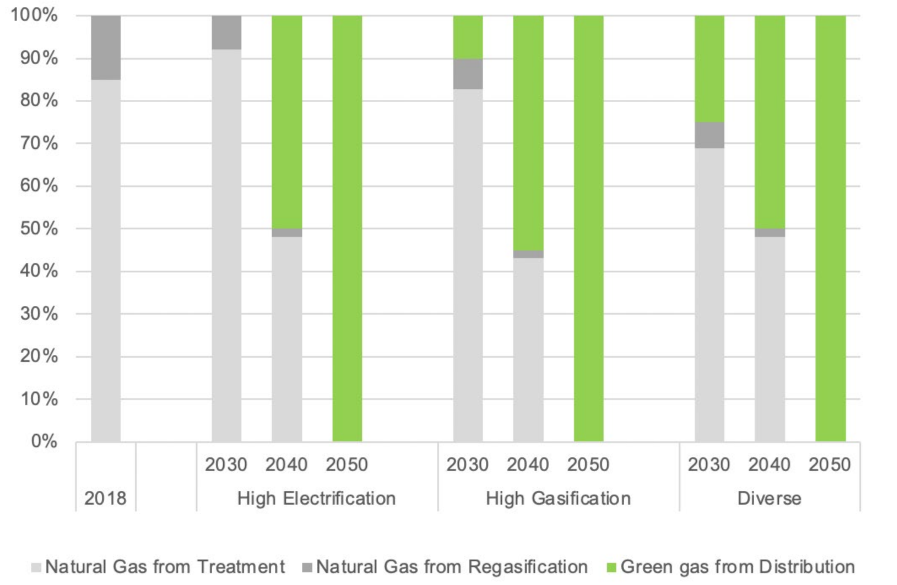


Figure 4.39 shows the proportion of network gas production by fuel type, which indicates:

- By 2050 network gas will be 100% green gas, across all scenarios.
- Green gas production is slow out the gate in High Electrification, as production only starts in 2040.
- High Gasification shows promising signs, as green gas enters the mix at a steady pace across the decades.
- Diverse has the largest proportion of green gas production across the scenarios in 2030 at 25%.

HYDROGEN

H_2

Hydrogen Production

While the production of hydrogen may not be a new process, as around 2,000 TWh of energy is produced globally every year[12]. The deployment and production of hydrogen in Northern Ireland is. The production of hydrogen is largely driven by local demand, which is prevalent across all scenarios. It is assumed all hydrogen demand will be meet by local production.

Two types of hydrogen production are assumed during the transition to 2050:

- Green hydrogen – this a carbon neutral fuel, produced via electrolysis using zero carbon electricity, e.g. electrolysis from solar.
- Blue hydrogen – this is a non-renewable fuel created via methane reforming using natural gas as an input. However when used in conjunction with CCUS is classified as renewable.

Figure 4.40: Hydrogen production in 2018 and by scenario over time

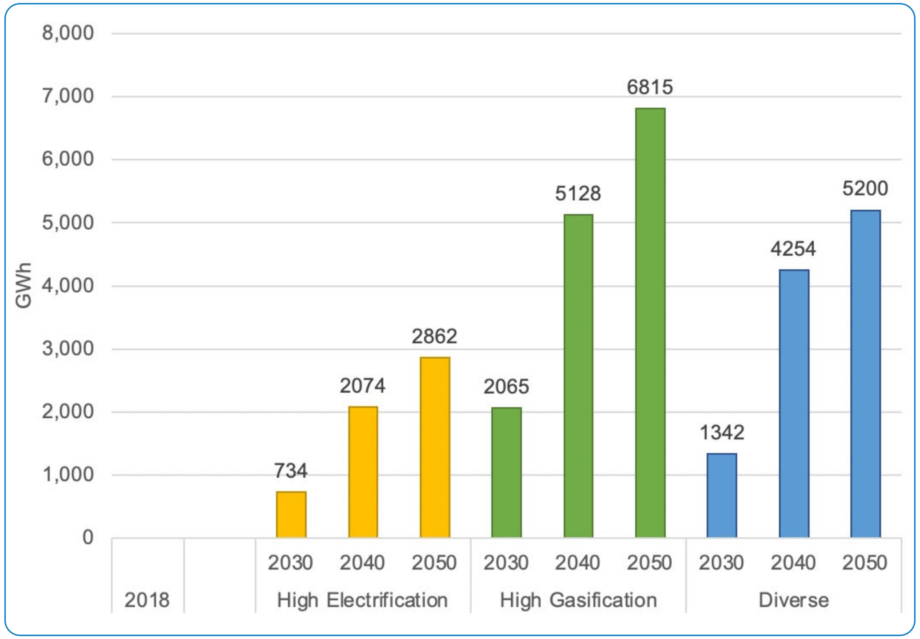


Figure 4.40 illustrates the level of hydrogen production:

- Hydrogen production is highest in High Gasification, with generation trebling 2030 (2,065 GWh) output by 2050 (6,815 GWh).
- Diverse production follows closely behind, albeit at a reduced volume. By 2050 (5,200 GWh), production grows by almost 4 times the rate seen in 2030 (1,342 GWh).
- In comparison to other scenarios, High Electrification has a much lower demand for hydrogen in 2050 (2,862 GWh), resulting in a moderate growth rate.

12 International Energy Agency/National Grid

Figure 4.41: Proportion of hydrogen production by method and by scenario over time

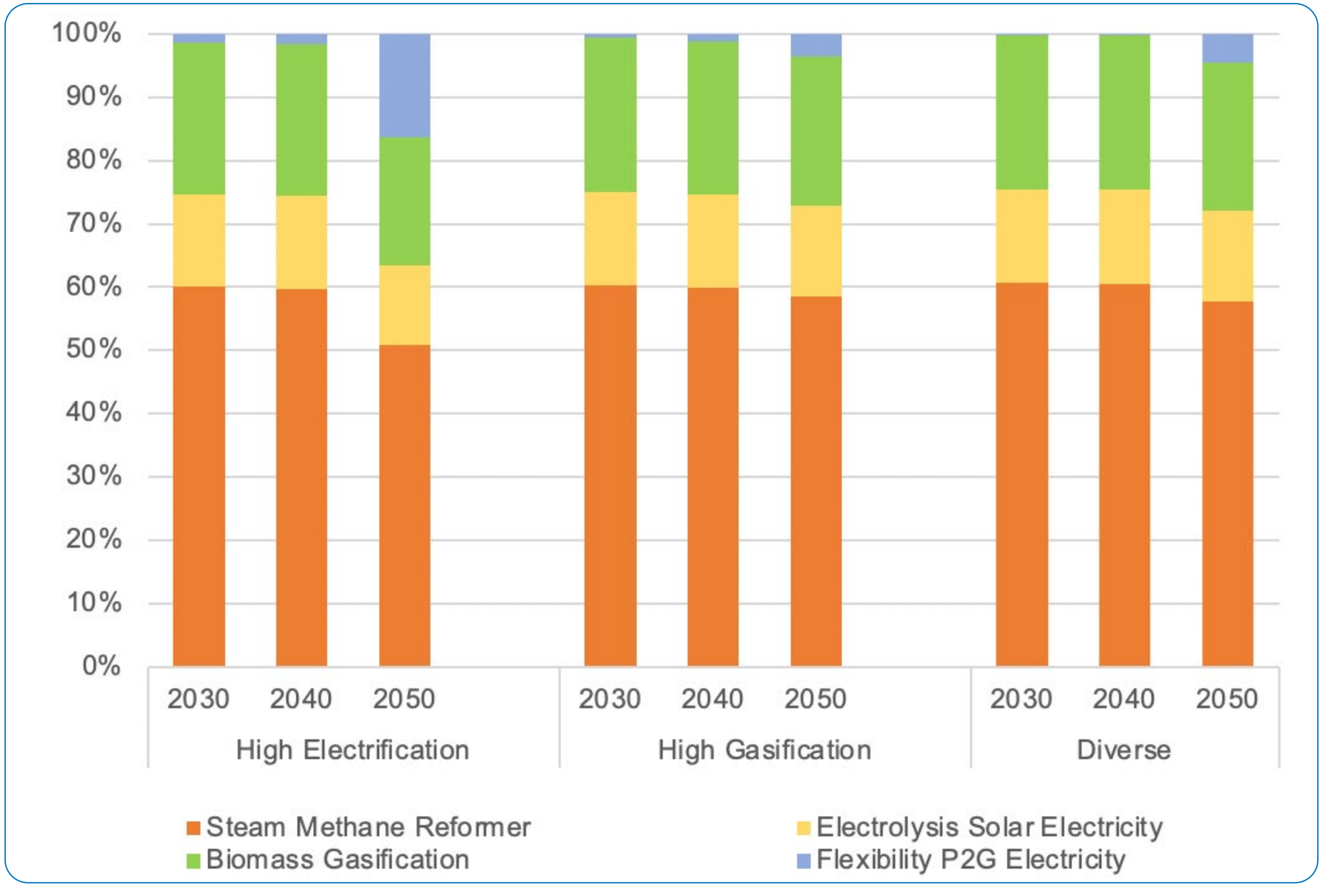
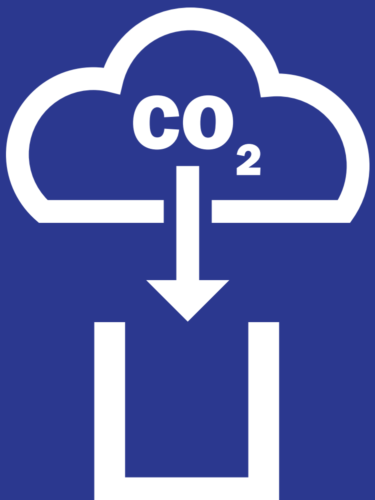


Figure 4.41 presents the proportion of hydrogen production by method:

- Throughout High Gasification and Diverse the generation mix stays consistent across 2030/2040, with steam methane reforming, biomass gasification and electrolysis from solar making up the bulk of the generation profile. By 2050, flexible power-to-gas (P2G) starts to make a significant contribution to the mix.
- While High Electrification has the smallest uptake in hydrogen production, the highest proportion (16%) of flexible P2G electricity hydrogen production by 2050 in this scenario.
- Hydrogen demand is meet locally throughout the scenarios, removing import requirements.

CARBON CAPTURE, UTILISATION AND STORAGE (CCUS)



Carbon Capture, Utilisation and Storage (CCUS)

Carbon Capture, Utilisation and Storage (CCUS) is a group of technologies to capture the CO_2 emitted from (e.g.) industrial processes and subsequently to store or 'recycle' these emissions. CCUS could play a key role in the transition to a net zero carbon energy system.

Figure 4.42: Carbon capture (MtCO_2) in energy production in 2018 and by scenario over time

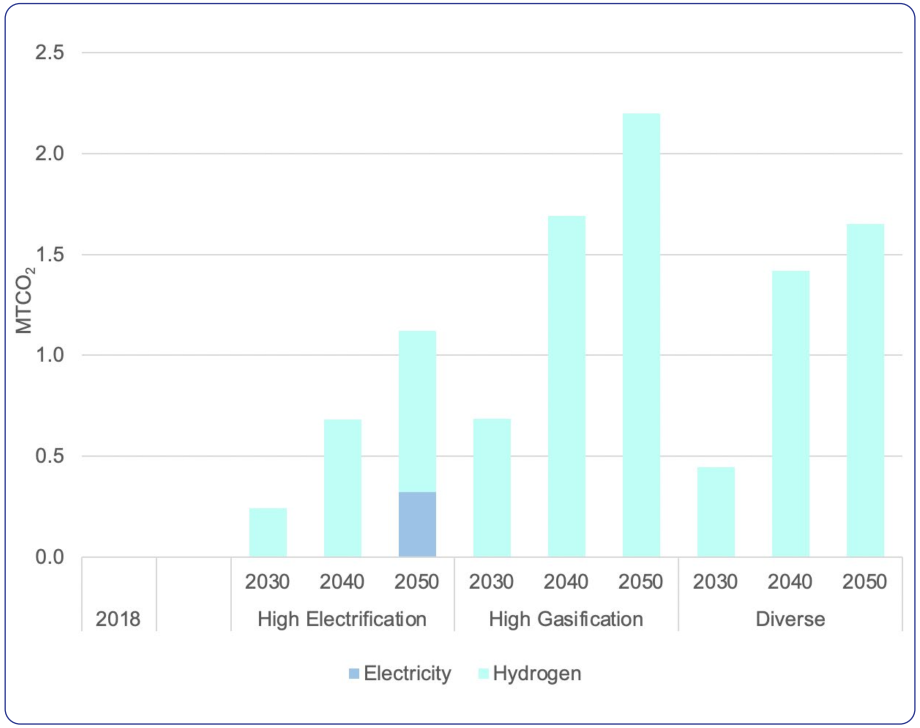
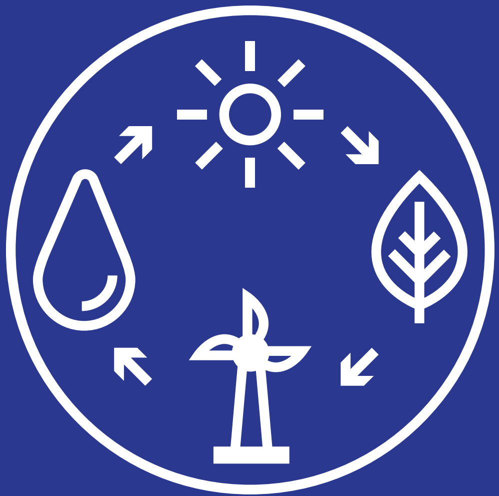


Figure 4.42 shows the amount of carbon capture required in each scenario to achieve net zero carbon in 2050:

- All hydrogen production is assumed to be carbon neutral. The production from both Steam Methane Reformers and Biomass Gasification are accompanied by Carbon Capture units in all scenarios and across time.
- High Electrification is the only scenario that has carbon capture on electricity production through gas Combined Cycle Gas Turbines (CCGT), this is required in this scenario to have net zero carbon emissions by 2050.

RENEWABLE ENERGY



Renewable Energy Source

In 2018, around 87% of the final energy consumed in NI came from fossil fuels. In order to transition to a net zero economy by 2050, a role reversal must take place between the use of renewables and fossil fuels.

The level of renewable energy used in the final energy consumption is commonly referred to as the overall Renewable Energy Source (RES).

The RES can be further examined across each of the three main modes of energy use:

- Renewable Energy Source use in Electricity (RES-E);
- Renewable Energy Source use in Heating and Cooling (RES-H); and
- Renewable Energy Source use in Transport (RES-T).

Figure 4.43: Final energy supply by fuel type in 2018 and by scenario over time[13]

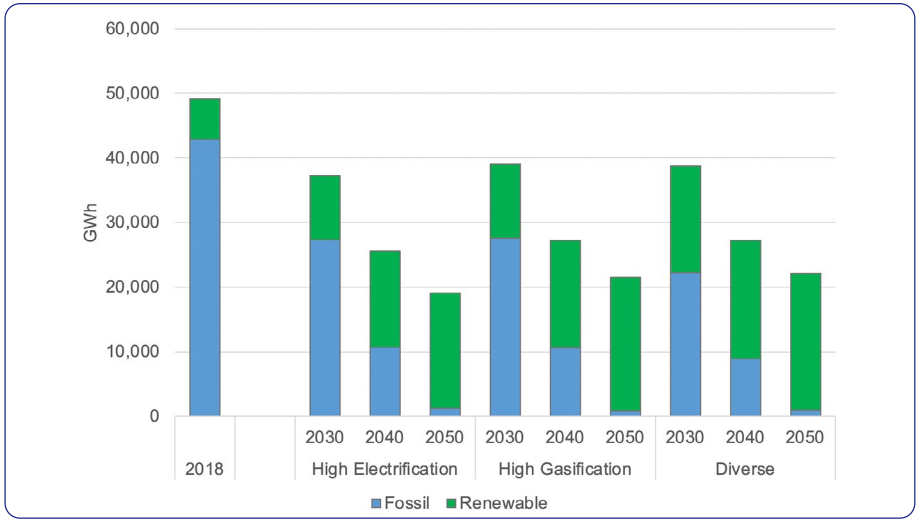


Figure 4.43 illustrates the composition of NI final energy fuel supply, in terms of fossil or renewable energy:

- Throughout all scenarios the volume of energy produced by renewable resources grows over the next three decades, becoming the leading type of fuel by 2040.
- The introduction of various renewable technologies causes a consistent fall in fossil fuel use, allowing for a cleaner, low carbon energy supply.

13 Please note that in determining renewable or fossil energy the emissions associated with imported electricity decreases over time from 351g/kWh in 2018 and 2030 to a 50% reduction in 2040 and 100% reduction by 2050. Hydrogen production is accompanied with carbon capture and therefore regarded as renewable in this analysis.

Figure 4.44: Proportion of renewable energy source (RES) in 2018 and by scenario over time

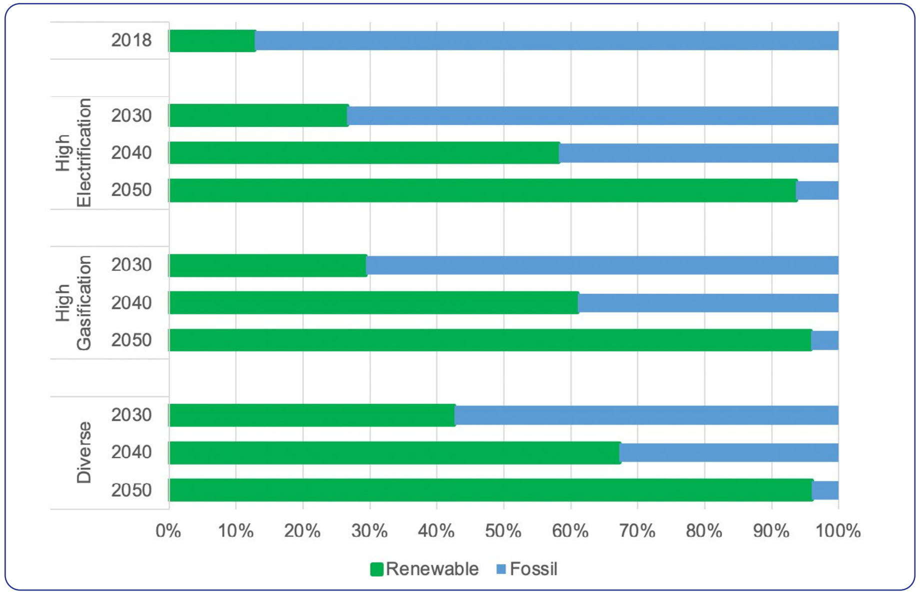


Figure 4.44 shows the percentage of renewable energy source up to 2050:

- Fossil fuel supply is still evident in 2050, this is due to small amounts of oil still used in heat and transport.
- A small amount of fossil fuels remain in the production of electricity and heat, due to the use of waste incinerators. Given the emission profile, within the NI ETM, half of the generation is classed as a fossil fuel with carbon emissions. The other half is regarded as having zero emissions and therefore classed as renewable.
- The process of steam methane reforming and biomass gasification will be accompanied by carbon capture to offset their emissions, allowing hydrogen to be produced in a renewable manner.
- Diverse has the highest RES by 2050, at 96%, which is largest reduction on 2018 levels (-83%).

RENEWABLE - ELECTRICITY

Renewable Energy Source – Electricity

Future RES-E levels across the scenarios are calculated as a percentage of electricity produced by local renewable sources divided by total electricity consumption in NI. This is similar to the current methodology[14] used to calculate the proportion of generation classed as renewable in NI[15].

By 2050, each scenario creates an economy in which 100% of electricity consumed by the NI consumer comes from renewably generated electricity. Given the different pathways to net zero, each narrative has a different stepping stone, as illustrated below:

Figure 4.45 – Proportion of renewable electricity in 2018 and by scenario over time

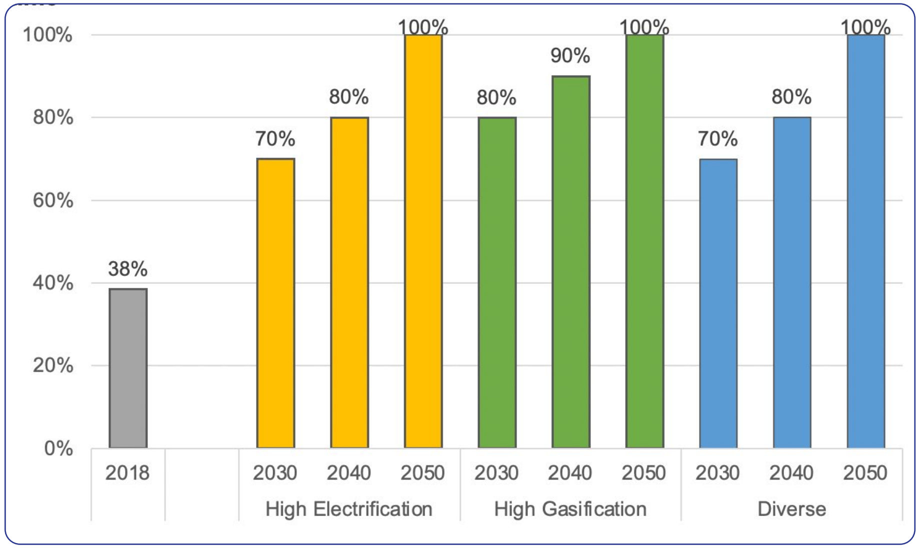


Figure 4.45 illustrates the percentage of electricity generated through renewables divided by total electricity consumption in NI over time:

- By 2030, both High Electrification and Diverse scenario assume renewable electricity generation will make up 70% of electricity consumed in NI, increasing to 80% by 2040.
- High Gasification moves at an accelerated pace, reaching 80% by 2030, before pushing to 90% by 2040. This is largely due to the reduced electrification rate, compared to other scenarios.
- Each of the scenarios reach their RES-E targets during the transition to a fully decarbonised power sector as referenced in the high level narratives.

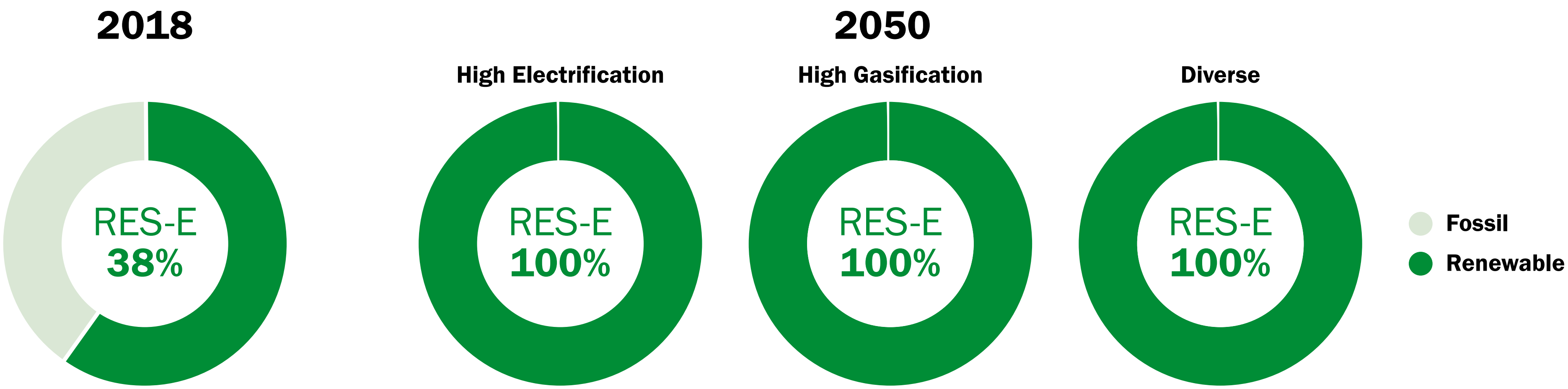
14 It should be noted by the reader that the RES-E levels determined in this analysis are similar with the current methodology used to monitor the Departmental target. However, they are not directly comparable due to the various conditions included in the current methodology. Further details on the methodology for the Departmental target can be found in the official publication under "Background notes.

15 Electricity Consumption and Renewable Generation Statistics | Department for the Economy (economy-ni.gov.uk)

Figure 4.46; Proportion of renewable fuels used for electricity in 2018 and by scenario in 2050

Electricity production comes from different sources of generation. Each scenario includes indigenous generation through renewable technologies:

- In 2018, around 62% of the electricity generated in NI came from non-renewable fuels, including coal, oil and waste.
- By 2050, due to the growing amount of electricity produced in a carbon neutral manner through the use of renewables each scenario has a similar composition, with 100% of electricity consumed in NI coming from renewable resources.



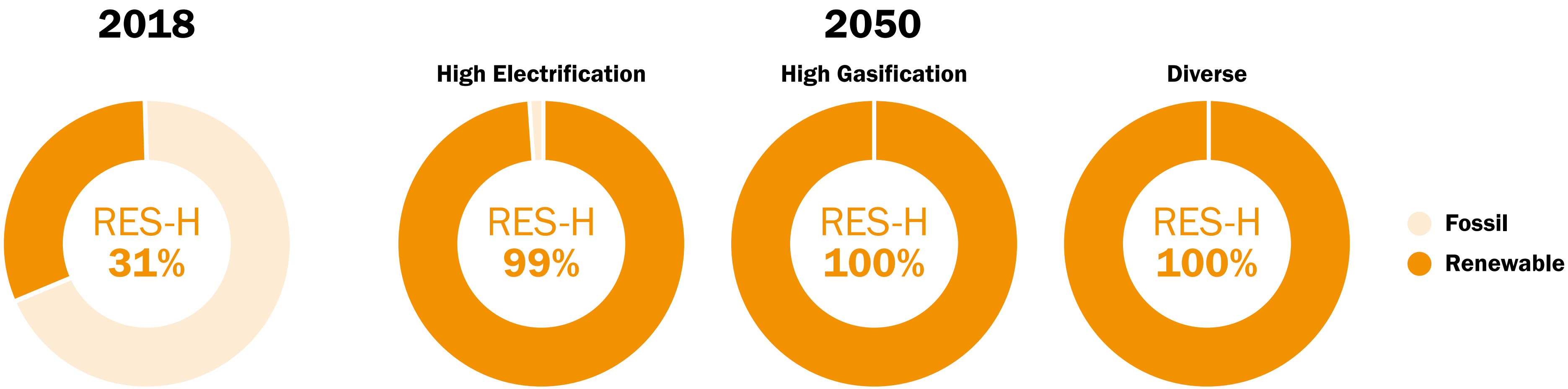
RENEWABLE - HEAT

Renewable Energy Source – Heat

By 2050, across all scenarios the volume of renewable resources used in the production of heat will be between 99-100%. This is a large reduction on the proportion of fossil fuels used in 2018 for heat (69%):

- In 2018, the high percentage (69%) of fossil fuels used in heat was achieved through a collective of coal, oil, natural gas and waste.
- By 2050, these fuels are largely removed from the energy system and replaced by energy that is produced in a renewable manner, such as hydrogen, electricity, biofuels etc.
- As gas, in 2050, is now produced in a carbon neutral manner through the introduction of green gas, it now contributes to the RES-H target.
- The High Electricity scenario falls slightly short of 100% RES-H due to the small remains of oil, equalling 1%. The remaining oil demand is due to space heating appliances, within the Residences and Services sectors.

Figure 4.47; Proportion of renewable fuels used for heat in 2018 and by scenario



RENEWABLE - TRANSPORT

Renewable Energy Source – Transport

By 2050, the volume of renewable fuels used to supply the transport sector has grown immensely compared to 2018 figures. In 2018, around 97% of fuels used to power the transport sector in NI were derived from oil & derivatives through the use of diesel and petrol vehicles:

- Figure 4.49 highlights the changing picture in the transport sector by 2050, with the overwhelming use of renewable fuels across all scenarios.
- The residual of non-renewable fuels in 2050 is from the use of oil (petrol/diesel) in transport. The renewable production of electricity, hydrogen and biofuels has enabled the transport sector to significantly boost its proportion of renewable resources.

Figure 4.48: Proportion of renewable fuels used in transport in 2018 and by scenario in 2050

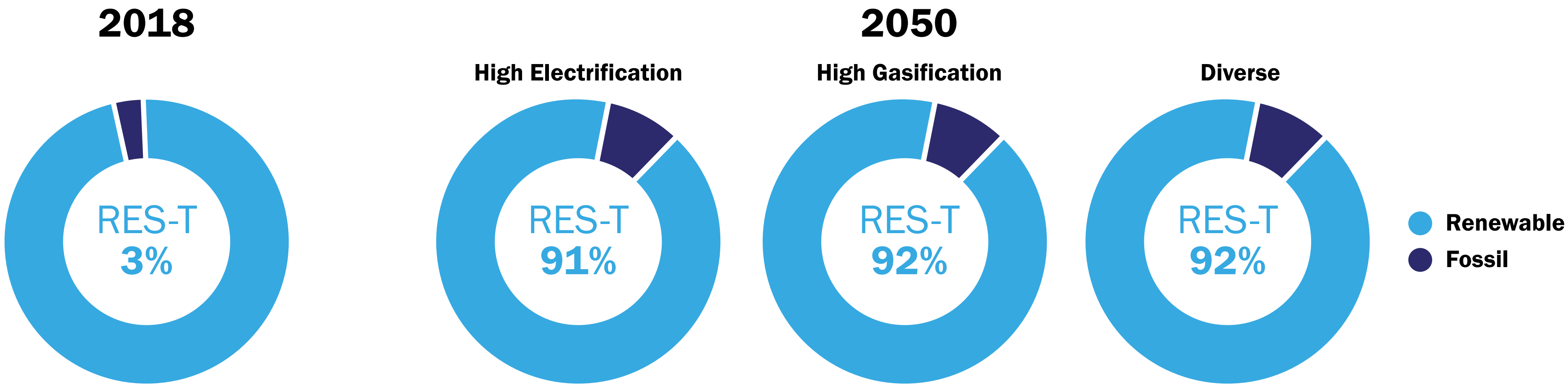
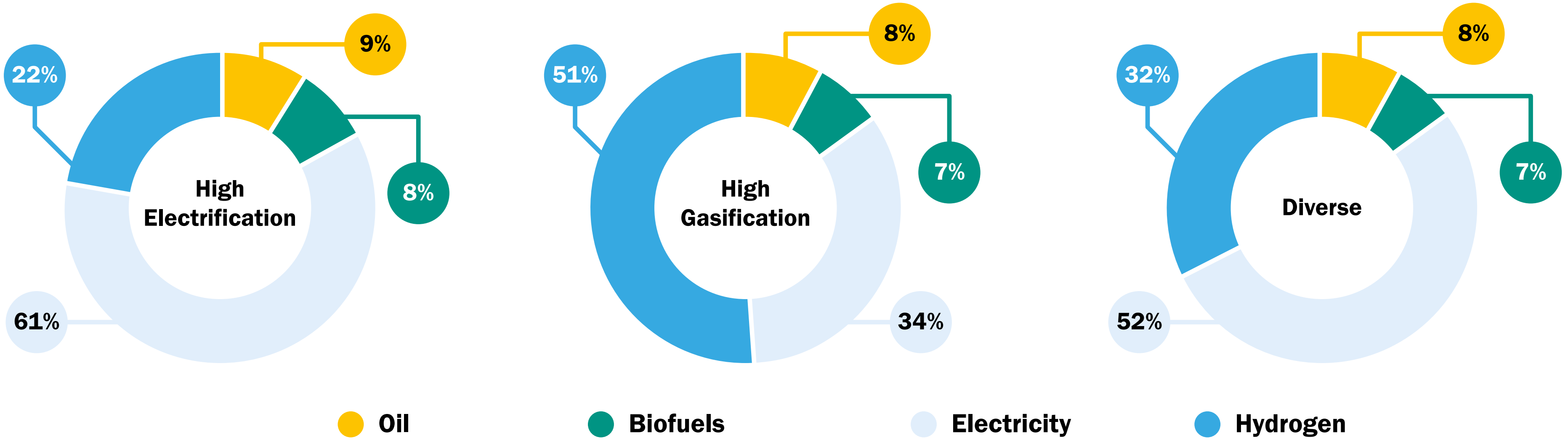


Figure 4.49 illustrates the fuel composition used in the supply of fuel for transport in 2050:

- Within each scenario the share of vehicles powered by fossil fuels, through the use of oil (petrol/diesel), has fallen to around 8-9%.
- High levels of electric powered vehicles in High Electrification has created a transport sector mainly dependent on electricity (61%). The ability to fully decarbonise electricity supply by 2050, will largely impact the proportion of renewable energy used in transport.
- A similar picture is present in High Gasification, however the majority role is hydrogen (51%). This is a result of the increased demand for hydrogen powered vehicles, which is produced locally through low carbon methods. Within this scenario the percentage of hydrogen energy demand for trucks (80%) and cars (25%) the highest proportion of demand in transport of any scenario in 2050.

Figure 4.49 Fuels used in transport by scenario in 2050



BENCHMARKING

SECTION 5
BENCHMARKING

Existing future energy scenarios for Northern Ireland

“There have been a limited number of future energy scenarios in 2050 for Northern Ireland. In this benchmarking section, there are two existing scenarios reports we examine against the NI ETM produced Future Energy Decarbonisation Scenarios:

1. Climate Change Committee’s sixth carbon budget
2. System Operator for Northern Ireland’s Tomorrow’s Energy Scenarios

As part of a quality process for scenario building we have compared the three net zero Future Energy Decarbonisation Scenarios However, it is acknowledged there are different assumptions, purposes for the other studies and indeed the unit of energy being measured. For example, the NI ETM calculates the energy in Lower Heating Value (LHV) while CCC analysis is in Higher Heating Value (HHV) making them not directly comparable.

Therefore in this benchmarking section we have focused the analysis on the proportions of primary or final energy demand by fuel and sector. It includes the data for the base year (2018) for reference as the starting position.

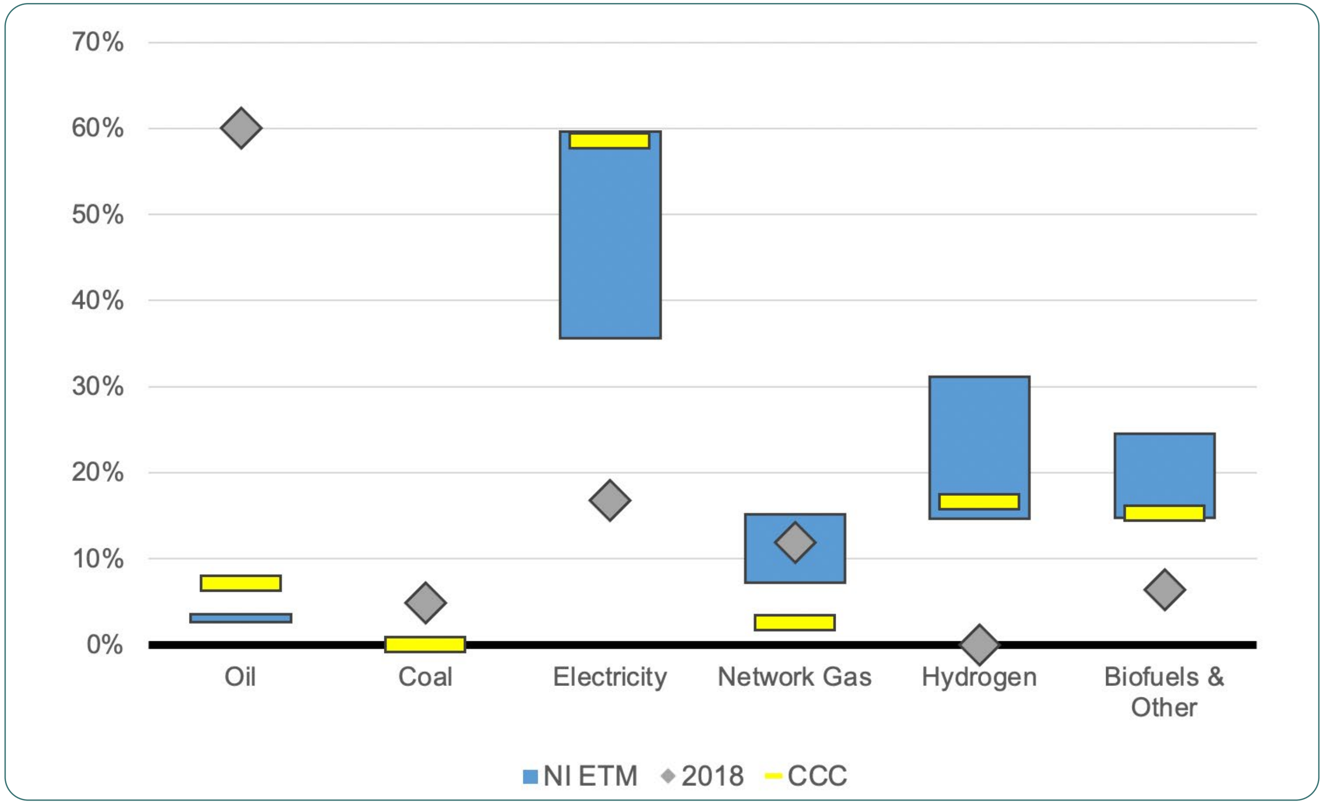
A summary of existing scenarios are detailed in this section. In Annex C there are further details of the assumptions for both external reports set out against the same main themes for the Future Energy Decarbonisation Scenarios high level narratives as presented in section 3, Table 3.1.

Committee for Climate Change Sixth Carbon Budget

In December 2020, Climate Change Committee (CCC) released their recommendations for the sixth carbon budget for the period 2033-37 for the UK. As part of the comprehensive analysis of different pathways to reach Net Zero they provided further advice on the appropriate trajectory for emissions in Northern Ireland between now and 2050. CCC recommended that **any climate legislation for Northern Ireland must include a target to reduce all GHGs by at least 82% by 2050** in line with the UK Net Zero goal to ensure that these emissions. While for CO_2 emissions it should be set to net zero by 2050. A balanced net zero pathway for Northern Ireland to achieve these goals is illustrated in the 2020 CCC report.

Benchmarking

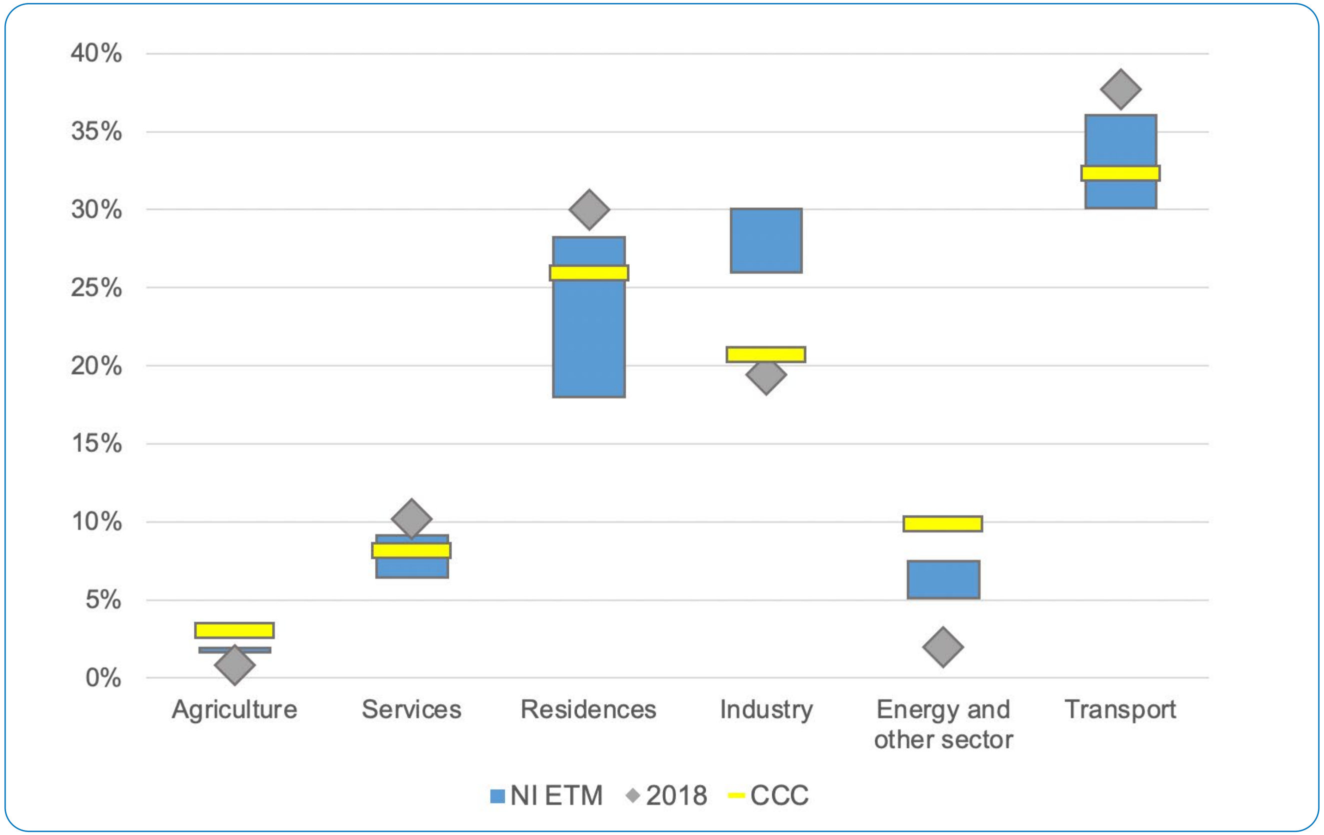
Figure 5.1 Comparison of proportion of final energy demand by fuel against Climate Change Committee Balance Net Zero pathway for Northern Ireland



Figures 5.1 illustrates the range (maximum and minimum values) of the proportions, for each fuel, across the net zero Future Energy Decarbonisation Scenarios in 2050 (blue rectangle) against the position in 2018 (grey diamond) and the CCC balanced net zero pathway for NI has assumed (yellow line). Some key observations:

- For most fuels the CCC suggested position in 2050 is within the range of net zero Future Energy Decarbonisation Scenarios. For network gas, the CCC have suggested a lower proportion of final energy demand (3%) and a slightly higher use of oil (7%).
- The movement from the 2018 data point indicates a large drop in the proportion of final energy demand for oil. Coal is no longer being consumed which is consistent across the CCC and Future Energy Decarbonisation Scenarios in 2050.
- Electricity and Hydrogen both have assumed large increases in proportion of final demand relative to the position in 2018.

Figure 5.2 Comparison of proportion of final energy demand by sector against Climate Change Committee Balance Net Zero pathway for Northern Ireland



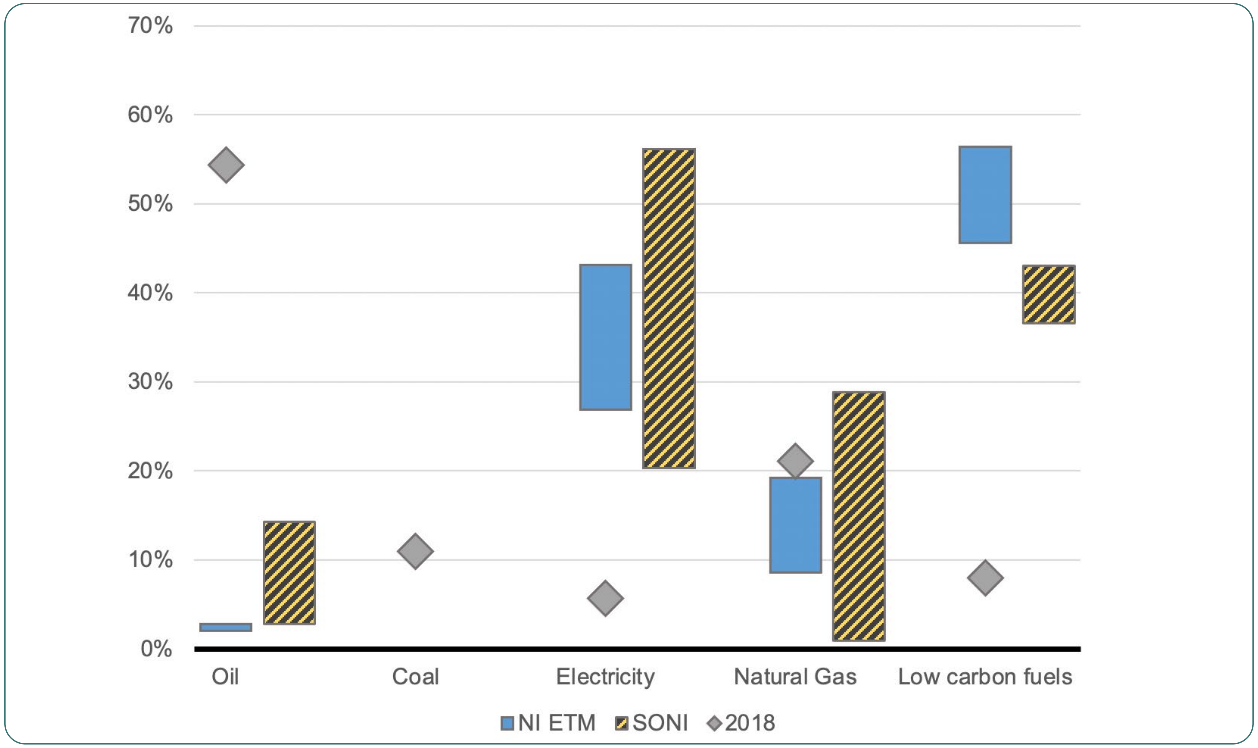
Figures 5.2 illustrates the range (maximum and minimum values) of the proportions, within each sector, across the net zero Future Energy Decarbonisation Scenarios in 2050 (blue rectangle) against the position in 2018 (grey diamond) and the CCC balanced net zero pathway has assumed (yellow line). Some key observations:

- For most sectors the CCC balanced net zero pathway in 2050 is within the range of net zero future energy decarbonisation scenarios. For Industry, CCC have suggested a lower proportion of final energy demand (21%).
- The CCC and Future Energy Decarbonisation Scenarios suggest that the proportions for final energy demands across Services, Residential and Transport are all lower than the 2018 position (yellow line lower than grey diamond).
- In contrast, there are increases across Agriculture and the Energy and other sector, with the CCC and Future Energy Decarbonisation Scenarios suggesting a bigger share of the final energy demands in these sectors by 2050.

System Operator for Northern Ireland Tomorrow's Energy Scenarios

System Operator for Northern Ireland (SONI) is the Electricity Transmission System Operator for Northern Ireland. SONI published the Tomorrow's Energy Scenarios Northern Ireland (TESNI 2020), which comprises of three scenarios providing a range of credible outcomes for the electricity grid in Northern Ireland. The scenarios ultimately set out pathways to deliver Northern Ireland's contribution towards an overall UK net-zero emissions target for 2050. This NI contribution is based on recommendations from the Committee on Climate Change (CCC) in 2019, which outlines a target of 80% reduction in emissions by 2050. Two of the three scenarios (Modest Progress and Addressing Climate Change) meet the target by 2050, while the third (Accelerated Ambition) by 2040.

Figure 5.3[16] Comparison of proportions of primary energy demand by fuel against Tomorrow's Energy Scenarios

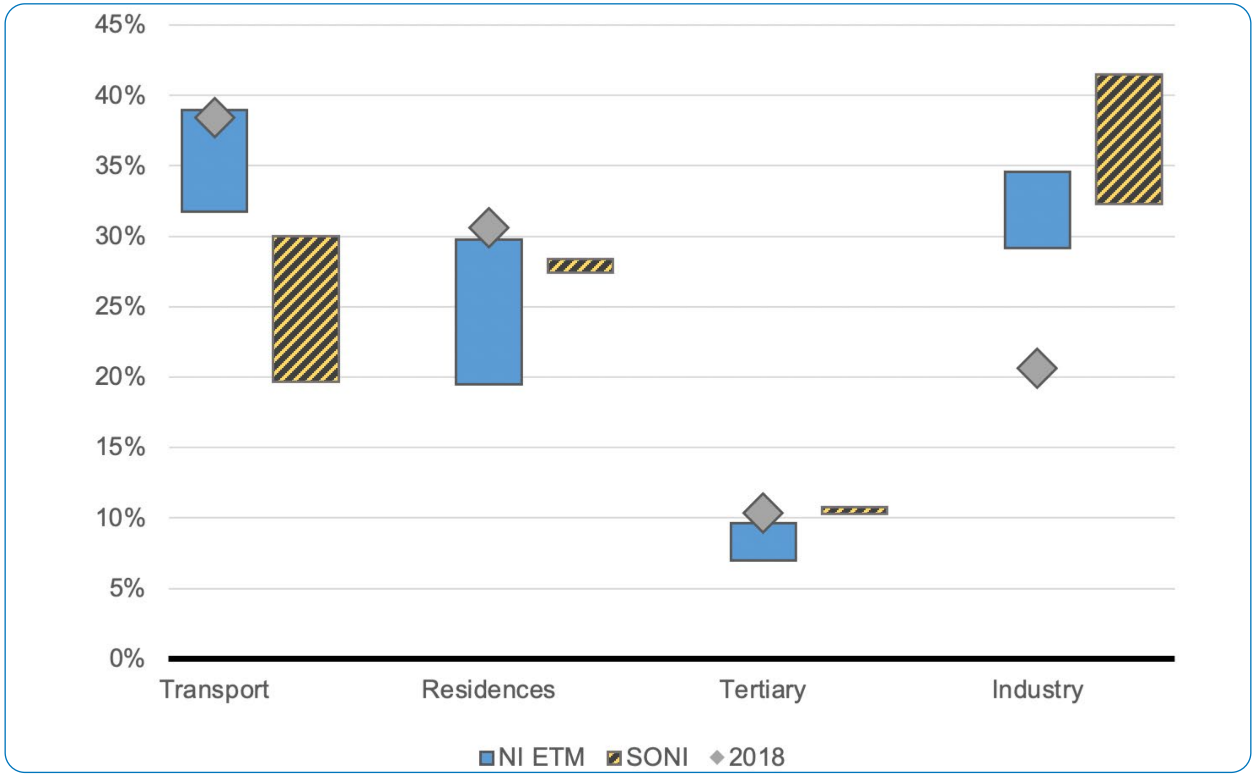


Figures 5.3 illustrates the range (maximum and minimum values) of the proportions, within each fuel, for both the net zero future energy decarbonisation scenarios in 2050 (blue rectangle) and the three TESNI position in 2050 has assumed (yellow/black diagonal striped rectangle). The position in 2018 (grey diamond) is also included. Some key observations:

- For most fuels the TESNI suggested positions in 2050 are broadly similar to the range for the net zero Future Energy Decarbonisation Scenarios, with the blue and the yellow/black diagonal striped rectangles overlapping.
- Proportions of oil in TESNI are assumed to be higher than in the net zero Future Energy Decarbonisation Scenarios.
- Across both 2050 set of scenarios, electricity and low carbon fuels are set to rise above 2018 levels.

16 In line with TESNI assumptions, low carbon fuels identity in the future energy decarbonisation scenarios include the fuels green gas and biofuels & others.

Figure 5.4[17] Comparison of proportions of final energy demand by sector against Tomorrow's Energy Scenarios



Figures 5.4 illustrates the range (maximum and minimum values) of the proportions, within each sector, for both the net zero Future Energy Decarbonisation Scenarios in 2050 (blue rectangle) and the three TESNI position in 2050 has assumed (yellow/black diagonal striped rectangle). The position in 2018 (grey diamond) is also included. Some key observations:

- For most sectors the TESNI suggested positions in 2050 are broadly similar to the range for the net zero Future Energy Decarbonisation Scenarios, with the blue and the yellow/black diagonal striped rectangles overlapping.
- The largest deviation in assumed positions in 2050 is in the Transport sector. TESNI suggests that the proportion of final energy demands across Transport is lower (20-30%) than the net zero Future Energy Decarbonisation Scenarios (32-39%) (blue higher than yellow/black diagonal striped rectangle).
- Within both 2050 set of scenarios the proportion of final demand for Industry is assumed to be higher than the 2018 position (blue and yellow/black diagonal striped rectangles higher than grey diamond).

17 In line with TESNI assumptions, Industry represents a combination of final energy demand from Industry and Agriculture in the future energy decarbonisation scenarios. This comparison does not take account final energy demand from Energy and other sector.

CONTINUING THE DISCUSSION

FUTURE ENERGY DECARBONISATION SCENARIOS - NEXT STEPS

The development of these illustrative scenarios is intended as a starting point for future discussions around how the energy system of the future might change.

The Energy Strategy Options Consultation outlines "intelligence" as one of the key delivery priorities for a new strategy and we are keen to engage with stakeholders as we both develop future modelling resources and the wider intelligence programme.

Email us with your views on this future energy decarbonisation scenario report and/or suggestions around the contents of a future energy intelligence work programme at: energystrategy@economy-ni.gov.uk and one of our team will get in touch.

Write to us at:
Energy intelligence Branch
Department for the Economy
Netherleigh
Massey Avenue
Belfast
BT4 2JP

ANNEXES

INCLUDED IN THE ANNEXES ARE:

Annex A – Glossary of terms

Annex B – Acronyms

Annex C – Comparison of high level narratives across Climate Change Committee Balanced net zero Pathway for Northern Ireland and the Tomorrows Energy Scenarios for Northern Ireland

Annex D – Definition of sectors in ETM using International Standard Industrial Classification of All Economic Activities

Annex E – Data used in the Future Energy Decarbonisation Scenarios

Annex F – Proxies used within NI ETM to reflect Future Energy decarbonisation Scenarios

Annex G – Links to Future Energy Decarbonisation Scenarios built in the Northern Ireland Energy Transition Model

Annex A – Glossary of terms

- **Agriculture sector -** The agriculture sector is primarily focused on energy used for heating with agriculture. The NI ETM does not include aspects associated with variations in land use as it is an energy related model.
- **Air Source Heat Pump (ASHP) -** Heat pump which absorbs heat from the outside air. This heat can then be used to produce hot water or space heating.
- **Ambient heat production -** Ambient heat which is available for free from environmental sources like the sun for heating water, building materials, or air. The production of ambient heat is from heat pump technology.
- **Bioenergy with Carbon Capture and Storage (BECCS) -** The coupling of bioenergy with carbon capture and storage to capture the CO_2 produced during combustion. This process delivers negative emissions.
- **Biofuels -** Solid (wood, biomass) and liquid (Hydrogenated Vegetable Oil (HVO), Bio- Liquefied Petroleum Gas (Bio-LPG) and biofuel blend in transport) biofuels.
- **Biogas -** A naturally occurring gas produced from the anaerobic digestion of biodegradable material such as grass, animal slurry and domestic waste. It has similar characteristics to natural gas but requires upgrading, through CO_2 removal, before injection into the gas network.
- **Bio-Liquefied Petroleum Gas (Bio-LPG) -** the same chemical composition of LPG. It is produced from renewable sources, including biological oil and fats, and the fermentation of glucose by microorganisms
- **Biomass -** Plant or animal material used for energy production, heat production or in various industrial processes as a raw material.
- **Biomass Gasification -** A process that generates hydrogen from biomass. When combined with CCUS technology this can produce hydrogen while also delivering negative emissions.
- **Biomethane -** Biogas that has been further processed to make it suitable for injection into gas transmission or distribution networks.
- **Blue Hydrogen -** Hydrogen created via methane reforming using natural gas as an input, plus CCUS.
- **Capacity -** The power output of an electricity generation technology usually measured in Watts (or kW, MW or GW)
- **Carbon Capture, Usage and Storage (CCUS) -** is a group of technologies to capture the CO_2 emitted from (e.g.) industrial processes and subsequently to store or 'recycle' these emissions.
- **Carbon Dioxide (CO_2) emissions -** The main greenhouse gas. The vast majority of CO_2 emissions come from the burning of fossil fuels.
- **Carbon Intensity -** A way of examining how CO_2 is emitted in different processes. Usually expressed as the amount of CO_2 emitted per km travelled, per unit of heat created or per kWh of electricity produced.
- **Carbon Neutral -** When applied to bioenergy, indicates that the carbon dioxide given off from combustion is offset by carbon dioxide absorbed during the plant matter's lifetime.
- **Climate Change -** Greenhouse gases released from activities which trap more energy and increasing the temperature. This is known as climate change or global warming.
- **Coal -** Coal and derivatives.
- **Coefficient of performance (COP) -** The efficiency of a heating system: the ratio of energy output to energy input.
- **Combined Cycle Gas Turbines (CCGT) -** A power station that uses the combustion of natural gas or liquid fuel to drive a gas turbine generator to produce electricity. The exhaust gas from this process is used to produce steam in a heat recovery boiler. This steam then drives a steam turbine generator to generate more electricity.

- **Combined Heat and Power (CHP) -** An energy efficient technology that generates electricity and captures the heat that would otherwise be wasted to provide useful thermal energy.
- **Decarbonisation -** The process of removing carbon emissions (e.g. generated by burning fossil fuels) from our economic and social activities.
- **District Heating -** A community based heating solution, which uses a single central hub to heat water, which is then pumped around a number of different homes and buildings.
- **Electric Vehicle (EV) -** A vehicle driven by an electric motor. It can either be driven solely off a battery, as part of a hybrid system, or have a generator that can recharge the battery but does not drive the wheels. We only consider EVs that can be plugged in to charge in this report.
- **Electrification -** The substitution of electricity for other fuels, such as oil and gas, used to provide similar services, for example heating and transport.
- **Electrification rate -** the electrification rate represents the amount of electricity demanded as a proportion of final demand.
- **Electricity -** Renewable and fossil fuel generated electricity.
- **Electricity Production (Generation) -** The amount of output from an electricity production (generation) technology measured in Watts (or kWh, MWh or GWh)
- **Electrolysis -** Electrolysis is the process of using electricity to split water into hydrogen and oxygen.
- **Energy-related -** defined as Greenhouse Gas emissions assigned to the following sectors: Business; Energy Supply; Industrial Process; Public; Residential and Transport
- **Final energy demand -** The total energy consumed by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that used by the energy sector itself. It is also referred to as total final consumption.
- **Gasification rate -** the gasification rate represents the amount of gas (including natural gas, green gas and hydrogen) demanded as proportion of final demand.
- **Gigawatt (GW) -** 1,000,000,000 watts, a unit of power.
- **Gigawatt Hour (GWh) -** 1,000,000,000 watt hours, a unit of energy.
- **Green Gas -** In our scenarios, this is used to cover both biomethane and bioSNG (i.e. biomethane which is created by larger, more industrial processes).
- **Greenhouse Gas (GHG) -** A gas in the atmosphere that absorbs and emits radiation within the thermal infrared range. One of several gases, especially carbon dioxide, that prevent heat from earth escaping into space, causing the greenhouse effect.
- **Green Hydrogen -** Hydrogen produced via electrolysis using zero carbon electricity.
- **Grid Curtailment -** This is when the output from a generation unit connected to the electricity system is reduced due to operational balancing.
- **Ground Source Heat Pump (GSHP) -** Heat pump which absorbs heat from the ground. This heat can then be used to produce hot water or space heating.
- **Halogen Bulbs -** High luminosity incandescent light bulbs, sale banned within the EU in September 2018.
- **Heat demand -** is the demand for space and water heating and cooling across all sectors and is correlated directly with the level of insulation and energy demand growth or decline.
- **Heat Pump -** A device that transfers heat energy from a lower temperature source to a higher temperature destination. Can include ground source or air source varieties.
- **Heavy Goods Vehicle (HGVs) -** A truck weighing over 3.5 tonnes.
- **Hybrid Heat Pump -** An integrated heating system using an electric heat pump alongside a traditional installation such as a gas or hydrogen boiler.

- **Hydrogen -** Locally produced and imported hydrogen
- **Hydrogen Boiler -** Home heating technology which burns hydrogen (rather than natural gas) for space heating and hot water.
- **Hydrogen Combined Cycle Turbine (Hydrogen CCGT) -** Combined cycle turbine that burns hydrogen (rather than natural gas) to generate electricity.
- **Industry sector -** Industry sector includes all energy used for industrial processes across industry in Northern Ireland. It is predominately concerned with the energy consumed within the manufacturing and construction sector.
- **Installed electricity capacity -** Installed electricity Capacity - The amount of installed power which can produce an output of electricity usually measured in Watts (or kW, MW or GW).
- **Interconnector -** Transmission assets that connect the GB market to Europe and allow suppliers to trade electricity or gas between markets. A transmission line which crosses or spans a border between countries and which connects the transmission systems of the countries.
- **Internal Combustion Engine (ICE) -** Traditional engine used in transport sector which is powered by fossil fuels such as petrol or diesel.
- **Kilowatt Hour (kWh) -** 1,000 watt hours, a unit of energy.
- **Light-emitting Diode (LED) -** Electric light with higher efficiency and longer lifetime than conventional bulbs.
- **Light Goods Vehicle (LGVs) -** a commercial carrier vehicle with a gross vehicle weight of no more than 3.5 tonnes.
- **Liquefied Natural Gas (LNG) -** Formed by chilling natural gas to -161˚C to condense as a liquid. Its volume reduces 600 times from the gaseous form.
- **Liquefied Petroleum Gas (LPG) -** A mix of propane and butane, used for heating homes in off gas grid areas as well as a number of other uses.
- **Low carbon fuels -** are alternative fuels and cleaner fossil fuels, such as green gas and biofuels.
- **Mega Tonnes of CO_2 Equivalent ($MtCO_2e$) -** The equivalent of 1,000,000 tonnes of carbon dioxide, standard unit for measuring national and international greenhouse gas emissions.
- **Mega Tonnes of CO_2 ($MtCO_2$) -** 1,000,000 tonnes of carbon dioxide.
- **Megawatt (MW) -** 1,000,000 watts, a unit of power.
- **Megawatt Hour (MWh) -** 1,000,000 watt hours, a unit of energy.
- **Methane Reformation -** A method for producing hydrogen, ammonia, or other useful products from hydrocarbon fuels such as natural gas. In addition to Steam Methane Reforming (SMR), this could include Autothermal reforming (ATR) which uses a pure stream of oxygen to drive the reaction and increase the hydrogen production and CO_2 capture.
- **Natural Gas -** A mixture of gases, primarily methane, suitable for transport through gas transmission and distribution networks.
- **Natural Gas Regasification;** liquefied natural gas (LNG) is natural gas that has been temporarily converted into a liquid. Regasification is a process of converting LNG at −162 °C back to natural gas at atmospheric temperature.
- **Natural Gas Treatment;** a process of treating raw natural gas to meet pipeline and liquefaction specifications.
- **Negative Emissions (carbon) -** When more carbon is removed from the atmosphere and stored by a process than is emitted into the atmosphere, this is termed negative emissions. For example with BECCS, carbon is removed from the atmosphere by the growth of the biomass as well as then being captured by CCUS.
- **Network gas -** Natural gas and green gas.
- **Net Zero -** When the total amount of greenhouse gases emitted in a year reaches zero, after all emissions and all carbon sequestration has been accounted for. This is the current UK target for 2050.
- **Net zero carbon emissions -** When the total amount of carbon dioxide emitted in a year reaches zero, after all emissions and all carbon sequestration has been accounted for.

- **Oil -** Oil and derivatives including transport fuels such as petrol and diesel
- **Other fuels -** District heating and solar thermal.
- **Other RE -** this means other renewable energy sources used in electricity production which includes combine heat and power, hydropower and wood pellets.
- **Other sector -** this sector includes energy used in the production of energy.
- **Power to gas (P2G) -** The process of using electricity to produce hydrogen via electrolysis, or, in a consecutive step, using the hydrogen together with carbon dioxide to produce methane via methanisation.
- **Primary Energy Demand -** Total input energy that is required to meet end consumer demand including conversion and transportation losses.
- **Primary energy supply -** energy production plus energy imports, minus energy exports
- **Renewable energy source -** energy that is derived from renewable resources, which are naturally replenished on a human timescale, including carbon neutral sources like sunlight, wind, rain, tides, waves, and geothermal heat.
- **Renewable energy source use in electricity (RES-E) -** Electricity produced using renewable sources.
- **Renewable energy source use in heating and cooling (RES-H) -** Renewable energy share in heating and cooling
- **Renewable energy source use in transport (RES-T) -** renewable energy share in transport
- **Residences sector -** The residences sector covers all energy consumed within domestic households. This includes heating, hot water, ventilation, household appliances, cooking and lighting.
- **Sankey diagram -** This type of diagram visually represents the NI energy balances in showing how, where and how much energy is used, based.
- **Services sector -** The service sector covers both commercial and public sectors, such as, Wholesale and retail trade; Accommodation and food service activities, Public administration, Education, Human health and social work activities and Arts, entertainment and recreation. It is identified through the classifications as defined International Standard Industrial Classification (ISIC) of All Economic Activities.
- **Societal Change -** The extent of future change to the behaviour and lifestyle of energy consumers across domestic, industrial and commercial sectors.
- **Steam Methane Reforming -** a process in which high-temperature steam (700°C–1,000°C) is used to produce hydrogen from a methane source, such as natural gas.
- **Terawatt Hour (TWh) -** 1,000,000,000,000 watt hours, a unit of energy.
- **Tertiary sector** - sector of the economy, generally known as the service sector.
- **Thermal Storage -** A store of heat, for example in a hot water tank or phase change material that allows heat to be stored and then released when it is needed.
- **Total electricity requirement -** The total amount of electricity required by a country, usually defined in annual energy terms TWh/yr.
- **Transformation sector -** This is where energy commodities are used in their original form and go through a transformation to generate electricity and/or heat.
- **Waste Incinerators;** a process that involves the combustion of organic substances contained in waste materials. Industrial plants for waste incineration are commonly referred to as waste-to-energy facilities.

Annex B – Acronyms

BAU - Business as Usual

Bio-LPG - Bio- Liquefied Petroleum Gas

CCC - Climate Change Committee

CCGT - Combined cycle gas turbine

CHP - Combined heat and power

CO_2 - Carbon dioxide

D - Diverse

ETM - Energy Transition Model

EV - Electric Vehicles

FEDS - Future Energy Decarbonisation Scenarios

GHG - Greenhouse gas

HE - High Electrification

HG - High Gasification

HVO - Hydrogenated Vegetable Oil

IPCC - Intergovernmental Panel on Climate Change

$MtCO_2e$ - Million tonne of carbon dioxide and equivalents

NAEI - National Atmospheric Emissions Inventory

NI - Northern Ireland

NISRA - Northern Ireland Statistics & Research Agency

PV - Photovoltaic

R&D - Research and development

RE - Renewable energy

RES - Renewable energy source

RES-E - Renewable energy source use in electricity

RES-H - Renewable energy source use in heating and cooling

RES-T - Renewable energy source use in transport

SONI - System Operator for Northern Ireland

UK - United Kingdom

Annex C – Comparison of high level narratives across Climate Change Committee Balanced net zero Pathway for Northern Ireland and the Tomorrows Energy Scenarios for Northern Ireland

This table sets out some of the main narratives describing the scenarios across the main energy themes and future energy scenario reports. Included are the Climate Change Committee (CCC) balanced Net Zero pathway for NI and the Tomorrows Energy Scenarios for NI by SONI [Modest Progress; Addressing Climate Change and Accelerated Ambition]. They are set out against the same main themes the Future Energy Decarbonisation Scenarios high level narratives were presented in section 3, Table 3.1.

Theme	CCC Balanced Net Zero for NI	TES - Modest Progress	TES – Addressing Climate Change	TES – Accelerated Ambition
Consumer	51% fall in edible food waste by 2030 and 61% by 2050. 33% reduction in all waste by 2037 68% recycling by 2030.	Low levels of self-consumption.	Medium levels of self-consumption.	High levels of self-consumption.
Energy efficiency	Moderate energy efficiency uptake (12% heat demand reduction) in homes. 27% in non-residential buildings. Loft and wall insulation for all fuel poor. Fast commercial uptake. Moderate-paced public uptake.	Medium energy efficiency gains. Adoption of Future Homes Standard to new homes from 2025 and existing properties from 2035.	High energy efficiency gains. Adoption of Future Homes Standard to new homes from 2025 and existing properties from 2030.	High energy efficiency gains. Adoption of Future Homes Standard to new homes and existing properties from 2025.
Heat	Moderate levels of behaviour change (homes). 25% of eligible households' pre-heat, 3% reduction in space heat demand from smarter heating management and use, low-flow shower heads. Hybrid hydrogen scenario in homes, with 14% of homes using hydrogen for heat. Limited use of biofuels in homes. Heat networks fully electrified. Non-residential buildings heat and catering demands mainly electrified with some hydrogen.	Low electrification of heat. The transition to electric heat is initially slow as a result of high costs and lower economic growth. The transition to electric heating is generally limited to new buildings until 2040. Low uptake in heat pumps (146,800).	Medium electrification of heat. Initial lag in the deployment of electric heat. Beyond 2030, this transitions to a faster uptake driven by anticipated government restrictions on fossil fuelled boilers. Medium uptake in heat pumps (329,000).	High electrification of heat. Electrification of heating happens earlier and faster than in the other scenarios. High uptake in Heat pumps, estimated around half million by 2050.

Theme	CCC Balanced Net Zero for NI	TES - Modest Progress	TES – Addressing Climate Change	TES – Accelerated Ambition
Power	Renewable generation & capacity - 80% of total. Dispatchable generation & capacity includes Dispatchable low-carbon generation includes gas CCS, BECCS and hydrogen - 10% of total.	60% of electricity from renewables by 2030. Low levels of decentralisation - with less favourable economic conditions, the public is less accepting of the higher cost solutions. required to achieve net zero emissions targets by 2050. Additional capacity is delivered by onshore wind and solar generation.	70% of electricity from renewables by 2030. Medium levels of decentralisation. Onshore wind continues to play a significant role in renewable generation. Offshore wind to develop and form part of the generation portfolio. Solar generation sees moderate growth until 2040, after which a faster increase is driven both by large scale connections and consumer action, through the deployment of rooftop PV.	80% of electricity from renewables by 2030. High levels of decentralisation. High levels of onshore wind and a large increase in solar generation. Significant uptake by consumers through the use of rooftop PV, due to favourable economic conditions. Offshore wind and marine technology in place by 2030, and this continues to develop in subsequent years.
Transport	Moderate behavioural change, with gradual reduction up to 17% of total car miles by 2050. 80% of HGVs adopt efficiency measures; up to 200km/year of rail electrification and diesel efficiency improving by 2050 to 0.5kgCO_2/kWh (from current levels of 0.8kgCO_2/kWh). 2032 phase-out date for fossil fuel cars and vans; no clear technology choice for HGVs, so most cost-effective technology mix is deployed. Aviation Demand growth to 2050 (vs. 2018) = 25% Efficiency improvements (%/year) = 1.4% Biofuel share in 2050 = 17% Synthetic jet fuel share in 2050 = 8%	Medium electrification of transport. A ban on new petrol and diesel cars by 2040. The transition to electric vehicles is slow, with a significant uptake in electric vehicles only occurring. after a ban on new petrol and diesel cars in 2040. 625,100 EV's by 2050. Simple EV charging. Annual efficiency improvement of 0.9%.	High electrification of transport. A ban on new petrol and diesel cars by 2035. Price parity between electric vehicles and petrol and diesel cars being achieved by 2025, sees a rapid uptake in electric vehicles from 2030. 939,900 EV's by 2050. Smart EV charging. Annual energy efficiency improvement of 1.6%.	High electrification of transport. A ban on new petrol and diesel cars by 2032. Price parity between electric vehicles and petrol and diesel cars being achieved by 2025. Significant uptake in electric vehicles 1.1 million EV's by 2050. Smarter EV charging. Annual energy efficiency improvement of 1.6%.

Theme	CCC Balanced Net Zero for NI	TES - Modest Progress	TES – Addressing Climate Change	TES – Accelerated Ambition
Industry	High level driven by mix of behaviour and innovation. Balance of electrification and (mostly) blue hydrogen. Most businesses follow incentives.	Industrial energy demand is expected to fall – due to 1% energy efficiency improvements. With lower economic growth conditions it is expected that industry is less willing to switch to newer technologies and so the rate of electrification remains relatively constant across the scenario.	Industrial energy demand is expected to fall - due to 1% energy efficiency improvements. Increase in the proportion of industrial demand becoming electrified. Due to improving energy efficiency and a drive to alternative fuels and technologies, such as heat pumps.	Industrial energy demand is expected to fall - due to 1% energy efficiency improvements. Increase in the proportion of industrial demand becoming electrified. Due to improving energy efficiency and a drive to alternative fuels and technologies, such as heat pumps.
Agriculture	<u>Behaviour change and demand reduction</u> 20% cut in meat and dairy by 2030, rising to 35% by 2050 for meat only. All replaced with plant-based; and Medium level: 50% cut in food waste by 2030, 60% by 2050. <u>Agricultural machinery</u> Mix of electrification, hydrogen and later phase-out of biofuels.			
Macro		Little economic growth over the next decade.	Modest economic growth over the next decade.	Modest economic growth over the next decade, increasing towards the end of the period.

Theme	CCC Balanced Net Zero for NI	TES - Modest Progress	TES – Addressing Climate Change	TES – Accelerated Ambition
Additional Consideration	Bio-energy carbon capture storage (BECCS) for UK ($MtCO_2$/yr in 2050) Power = 19 Energy from waste = 7 M&C = 3 Hydrogen = 14 Biofuels = 8 Biomethane = 0.6 DACCS = 5 Wood in construction = 0.4 CCS Demand not until 2040 across fuel supply, waste and industry (M&C)	Non deployment of carbon capture. Coal generation phased out by 2024. Oil generation phased out by 2040.	Existing CCGT is decommissioned and replaced with a new CCGT fitted with carbon capture and storage technology by 2045. Coal generation phased out by 2024. Oil generation phased out by 2040.	One existing CCGTs is decommissioned and replaced with a new CCGT fitted with carbon capture and storage technology by 2040. Coal generation phased out by 2024. Oil generation phased out by 2035.

Annex D - Definition of sectors in ETM using International Standard Industrial Classification of All Economic Activities

Section	Description	ETM sector
A	Agriculture, forestry and fishing	Agriculture
D	Electricity, gas, steam and air conditioning supply	Energy
B	Mining and quarrying	Industry
C	Manufacturing	Industry
E	Water supply; sewerage, waste management and remediation activities	Industry
F	Construction	Industry
J	Information and communication	Industry
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	Services
H	Transportation and storage	Services
I	Accommodation and food service activities	Services
K	Financial and insurance activities	Services
L	Real estate activities	Services
M	Professional, scientific and technical activities	Services
N	Administrative and support service activities	Services
O	Public administration and defence; compulsory social security	Services
P	Education	Services
Q	Human health and social work activities	Services
R	Arts, entertainment and recreation	Services
S	Other service activities	Services
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	Services
U	Activities of extraterritorial organizations and bodies	Services

Source International Standard Industrial Classification of All Economic Activities, Revision 4

Data behind the ETM

The base year for the NI ETM is 2018. This year was selected as the most recent year comprehensive data for energy consumption and emissions was available for NI.

The ETM has specific data requirements to form a base year to work from, providing a high level energy balance for NI. This data provides a high level overview of energy flows from primary energy supply down to final energy use. Primarily the energy balance data for NI has been sourced from national or official statistical data readily available through statutory agencies. However, to build the energy model more detailed information about area regional characteristics was required. For example, how energy demand is split over various sub-sectors and/or applications within a sector, down to what technologies are used.

An extensive consultation exercise was undertaken to engage with appropriate stakeholders, including central & local government, industry representatives and academics, to ensure the data was as robust and reliable as possible and was incorporated into the ETM for NI. Further details on the sources of all data items utilised to build the base year for 2018 are available at https://refman.energytransitionmodel.com/publications/2140

Projections

Where projections have been employed, the values within the scenarios have been based on the Government's projections for population and number of households. Trying to estimate out to 2050 contains a range of uncertainties. Our assumptions are generally conservative.

Population. We use the latest population projection from the Northern Ireland Statistics & Research Agency (NISRA). Under this projection, the UK's population is expected to grow by 4% from 1.89 million in 2018 to reach 1.96 million in 2030, reaching 1.99 million in 2040 and 2 million in 2050.

Number of properties. For **domestic dwellings**, we use the latest household projection from NISRA. To convert into number of domestic dwellings we use the historical relationship (average over a five year period) between the dwelling stock and number of households. Household projections end in 2041, therefore estimates of household projections for 2042 to 2050 will need to be created. Population projections are published to 2050 and could be used to create household projections to 2050. The proposed solution is to use the relationship between household projections and population projections from NISRA. It is assumed the existing trend in the declining ratio (population increasing faster than household projections) between these two projections will continue across the remaining nine years to 2050.

This results in an estimated increase in the number of domestic dwellings of 11.7% from the 2018 position by 2050. This is consistent across all scenarios.

	2018	2030	2040	2050
No. of Domestic Dwellings	790,328	847,374	876,747	882,908

Source for 2018 - Department of Finance, NI - NI valuation list, 2018

The Energy Transition Model (ETM) also has input for the proportion of the **domestic dwelling stock split by house type**. The approach taken it sot calculate the percentage point change each year from 2008 to 2020 using the historical Department of Finance housing stock data. For each house type individually, establish the average percentage change over this period. Finally adjust the 2018 house type percentages by the annual average change, project this within each house type and continue out to 2050. This is consistent across all scenarios.

Housing Type	Percentage splits			
	2018	2030	2040	2050
Apartment	10.7%	11.9%	12.9%	13.9%
Detached	35.6%	35.5%	35.5%	35.4%
Semi-Detached	25.0%	25.7%	26.3%	26.9%
Mid terrace	17.6%	16.5%	15.6%	14.6%
Corner terrace	11.0%	10.3%	9.8%	9.2%

For **non-domestic units**, there is limited information available and there are fluctuations in the historical POINTER data. This is further complicated when considering the unknown impact that the COVID-19 pandemic will have on the workplace and the growth/decline of non-domestic units.

For the future energy decarbonisation scenario the assumption employed across all scenarios is no percentage change for non-domestic units from the current 2018 position. Over time, any new units displace old for a net zero change.

Economic activity. Another projection utilised in the ETM with uncertainty is the future performance of the economy, which is connected with the level of economic activity that could cause emissions. This uncertainty is greater than usual, relating to how the NI economy will recover after the COVID-19 pandemic and the impact of Brexit.

There is no NI economic forecasting out to 2050 available. However, from a UK perspective the Climate Change Committee (CCC) have assumed that there is no lasting impact on GDP, an assumption at the optimistic end of the latest scenarios from the Office for Budget Responsibility (OBR). Resulting from this we have assumed a moderated economic growth with no to limited impact on the associated sliders in the ETM.

Heat Demand Reduction. The estimates for heat demand reduction across domestic, split by housing type, and nondomestic properties are derived from the Research into the Future of Energy Efficiency Policy in Northern Ireland. There are number of scenarios assessed in this report examining the range of energy efficiency measures that could take place across domestic and non-domestic settings out to 2050. Within the future energy decarbonisation scenarios, we have assumed the business as usual energy efficiency scenario for our business as usual energy scenario and the high intervention scenario for the other three future scenarios. For High Electrification scenario we have assumed a faster transition to the full heat demand reduction estimated in the research paper.

This provides the heat demand reduction for the domestic and non-domestic properties. For non-domestic the estimates for heat demand reduction and used in the future energy scenarios as detailed in this table.

Scenario	2030	2040	2050
BAU	1%	2%	3%
HE/HG/Diverse	23%	44%	48%

However, for domestic the ETM requires the estimates by each house type within the domestic sector. In order to extrapolate this for each housing type, we assessed the average SAP rating for each house type within the National Energy Efficiency Data Framework (NEED). This contains Energy Performance Certificate (EPC) analysis and provides an indication of the levels of efficiency already in place within each housing type. The limitation with the NEED is it only contains properties in England and Wales so the assumption is the same profile exists in Northern Ireland.

The methodology is to base the percentage of heat demand reduction for the domestic sectors, against the average of the mean SAP rating in NEED. The percentage for each housing type is then adjusted dependent on the average SAP rating in NEED by house type. For example, as apartments had a higher average SAP rating, they had less opportunity to reduce heat demand therefore had a smaller percentage assumed in the scenarios. The following percentages were calculated and assumed the percentage of heat demand reduction across the scenarios. Note corner houses are end terrace and are treated the same as semi-detached in terms of heat demand reduction percentages.

Business As Usual

House Type	2030	2040	2050
Terraced houses	5.0%	10.3%	15.6%
Apartments	4.4%	9.1%	13.7%
Detached houses	5.3%	10.9%	16.5%
Semi-detached houses	5.1%	10.5%	15.9%
Corner houses	5.1%	10.5%	15.9%

High Electrification

House Type	2030	2040	2050
Terraced houses	45.6%	65.5%	68.6%
Apartments	41.3%	57.8%	60.3%
Detached houses	47.6%	69.1%	72.5%
Semi-detached houses	46.3%	64.8%	70.0%
Corner houses	46.3%	64.8%	70.0%

High Gasification and Diverse

House Type	2030	2040	2050
Terraced houses	35.6%	63.5%	68.6%
Apartments	31.3%	55.8%	60.3%
Detached houses	37.6%	67.1%	72.5%
Semi-detached houses	36.3%	66.8%	70.0%
Corner houses	36.3%	66.8%	70.0%

Limitations of the energy data for Northern Ireland

There are over 300 separate data items required for the base year including an energy balance for NI It is important to note that due to the detailed nature of the data requirements on the ETM and that some of this data is not available at NI level. For example, there is no NI data for the technology and carrier application (how different energy types are used e.g. appliances, lighting, heating etc.). In this instances an alternatives has been incorporated utilising data from the Energy Consumption UK. The assumption is patterns of use is the same across the UK.

Data on energy use within the industry is not available within each sector. As a result any changes to energy use within industry is at this high level and not specific to each sector. In addition, there are a number of hourly profiles for electricity demand which are not available for NI. To ensure the ETM has sufficient data to produce scenarios, default profiles are utilised. This has the impact of affecting the hourly curves for electricity demand over the year and reduces the risk of a security of supply issue being identified within the future energy scenarios.

Limitations of the Energy Transition Model

The ETM, as with any other model, encompasses a certain level of limitations. The ETM has not been developed is not bespoke for NI, therefore some elements of the future energy scenarios cannot be reflected within the ETM. On occasions a proxy has been used to represent, as closely as possible, the changes to the NI energy system which was intended to be portrayed. Any proxies selected have been dependent on the level of associated emissions of intended change for the energy sector.

Technology efficiencies, across power stations, space heating and transport, are set to a default value within the model. These values do differ (higher) from real technologies adopted by users or companies in NI. This has the effect of reducing demand for specific technologies to deliver the energy required for certain applications.

In addition to this, there are a number of technologies, which are represented by the NI ETM model, but their future potential and benefits are not correctly quantified in the model. Among these are technologies representing flexibility services, such as energy storage and demand-side response. It should be stated that this limitation representing flexibility requirements is typical to any energy system models and well researched and highlighted by other studies. However, as flexibility may well play a crucial role in the future energy decarbonisation it is recognised as a limitation.

Annex F - Proxies used within NI ETM to reflect Future Energy Decarbonisation Scenarios

The ETM, as with any other model, encompasses a certain level of limitations. The ETM has not been developed as a bespoke model for NI, therefore some elements of the Future Energy Decarbonisation Scenarios cannot be reflected within the ETM. On certain occasions a proxy has been used to represent, as closely as possible, the changes to the NI energy system which is intended to be portrayed. Any proxies selected have been dependent on the level of associated emissions of intended change for the energy sector. Details on proxies actioned in the scenarios are presented here.

1. **Requirement** – Scenario includes Hydrogen trains
   ETM issue – No slider in the ETM for hydrogen power trains
   ETM workaround solution - Incorporate the desired proportion of trains powered by hydrogen into the setting for hydrogen busses as the proxy

2. **Requirement** – Scenario includes use of Bio fuels, such as Hydrogenated Vegetable Oil (HVO), or Bio- Liquefied Petroleum Gas (Bio-LPG) in heating in any sector.
   ETM issue – no slider in the ETM for this fuel source for space heating
   ETM workaround solution – Establish the emissions level for the bio fuel relative to kerosene. For example, HVO has 98.4% less CO_2 emissions compared to kerosene. Allocate 98.4% of the assumed energy demand for heat in the relative sector into the Wood pellet stove slider. Next include 1.6% of demand into the oil slider. The wood pellet stove is regarded as biomass and no emissions which counts towards CO_2 monitoring levels as per NAEI methodology. Keeping a sufficient level of demand in oil ensures the relevant emissions are included in the scenario and analysis. The same process was employed for bio-LPG on the basis of a 75.7% reduction in CO_2 emissions.

3. **Requirement** – Change the gas mix for certain percentages:
   ETM issue – Can change the gas mix to cover natural, LNG and green gas. Unable to incorporate hydrogen into the gas mix options.
   ETM workaround solution – Decide the percentage of gas boilers in a specific sector. Set chosen value for the percentage of hydrogen technology and the remainder against a network gas technology. If adding green gas into the network gas, set the appropriate level of green gas going into the network.

4. **Requirement** – Use of hydrogen in home heating
   ETM issue – No specific hydrogen heaters in domestic options
   ETM workaround solution – Select the Hybrid heat pump for hydrogen and change the proportion to the assumed demand position of all demand for space heating. Next adjust the Coefficient of Performance (COP) in Flexibility then Net loads and then Demand response for threshold COP. Force the COP to the maximum to create a position when no electricity is utilized and ensure 100% hydrogen use.

5. **Requirement** – Include walking in passenger transport
   ETM issue – mode of transport options does not include walking
   ETM workaround solution - Decrease the number of passenger kilometers

Annex G - Links to Future Energy Decarbonisation Scenarios built in the Northern Ireland Energy Transition Model

The table below includes the links to the Future Energy Decarbonisation Scenarios created in the Northern Ireland Energy Transition Model.

Scenario	Future Year		
Business As Usual	2030	2040	2050
High Electrification	2030	2040	2050
High Gasification	2030	2040	2050
Diverse	2030	2040	2050