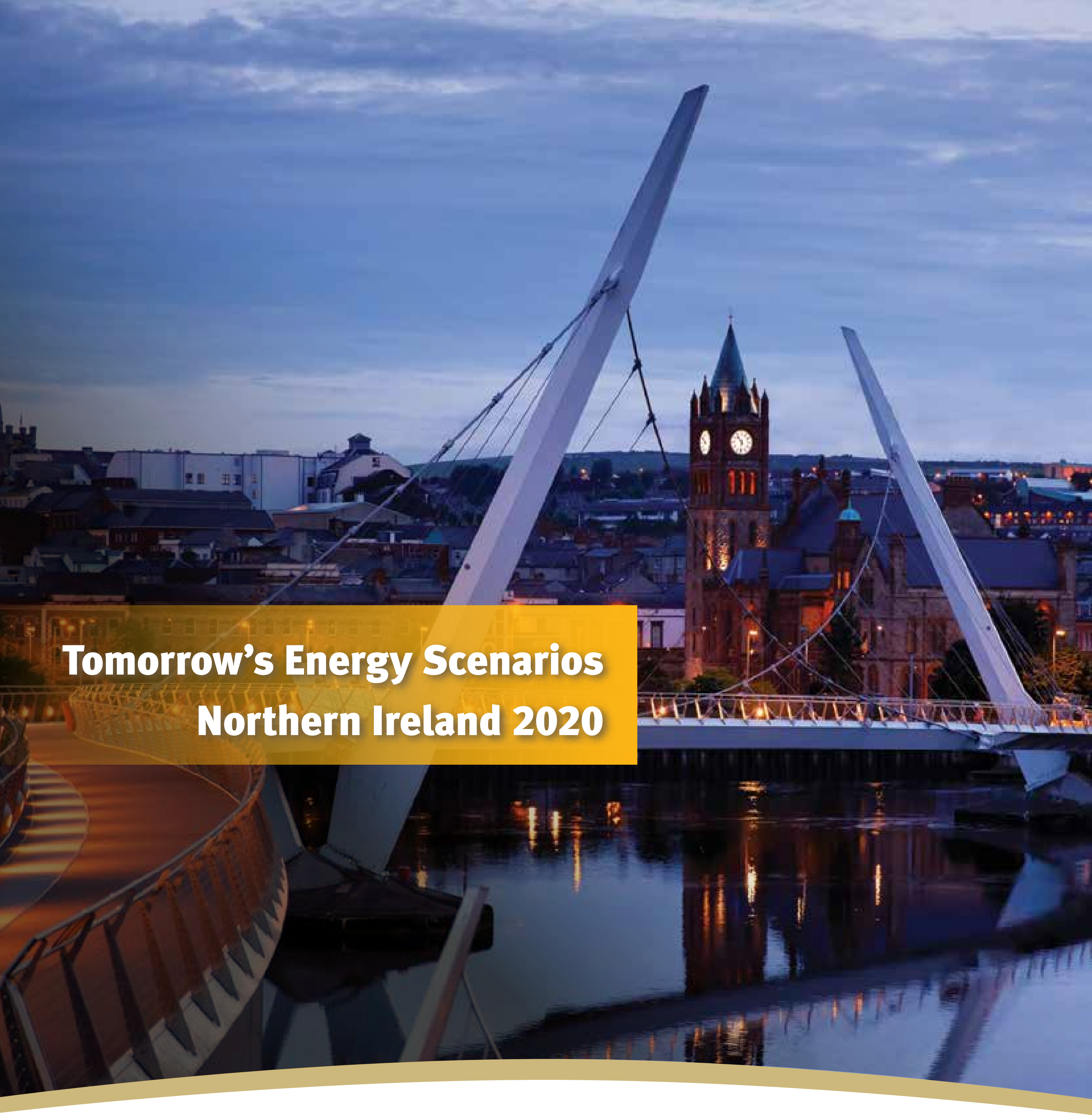

Tomorrow's Energy Scenarios Northern Ireland 2020

SONI

The current. The future.

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Foreword

Dealing with climate change is more important than ever.

The environment experienced something of a renaissance as a result of restrictions imposed on society as we dealt with the threat of COVID-19. Sadly, this respite was all too brief and at the cost of businesses, incomes and, tragically, beloved family members and friends.

It does not have to be this way.

We should take heart from the collective behavioural changes made to protect ourselves from coronavirus; the rapid governmental, societal and individual response proves that we are capable of swift action in the face of threat; we can do the same against the climate emergency.

SONI, as the Electricity Transmission System Operator for Northern Ireland is committed to transforming the power system as a direct response to climate crisis. In October 2019, we launched our new five-year strategy (2020-25) which recognises SONI's pivotal role in ensuring Northern Ireland has a clean energy system; able to facilitate challenging renewable targets; balancing decarbonisation with security of supply and costs to consumers.

SONI's 'Tomorrow's Energy Scenarios Northern Ireland 2020' (TESNI) is a key piece of research in support of this journey.

Within this important piece of work, we have consulted on three credible pathways for the transformation of the power system. We have engaged with government, policy makers, the electricity regulator, the energy industry, broader business, consumer representatives and the public to understand the challenges and opportunities the energy transition presents.

The research, analysis and consultation for TESNI 2020 was completed in advance of the COVID-19 pandemic and it will take time to understand the impact on the Northern Ireland economy. The world will keep changing, shaped by new technological advances, new policies and the condition of the economy, and that is why our TESNI work is updated on a bi-annual basis.

Future iterations of TESNI will be informed by updated demand forecasts which consider the longer-term impacts of the COVID-19 pandemic and other relevant factors. Given the time horizon of this work and its purpose to inform decision making, it is not thought to be affected by the short-to-medium term economic impacts of COVID-19, particularly given that two of our scenarios already reflect low growth demand in the early years.

TESNI 2020 shows that decarbonisation of the energy sector will result in a significant increase in electricity demand into the future, primarily as a result of the electrification of heating and transport.

The electricity generation portfolio will continue to decarbonise; large increases in renewable generation will be required to meet growing electricity demand and to replace coal and oil generators expected to exit over time.

Our Modest Progress Scenario sees low growth in electricity demand out to 2030. Our central scenario, Addressing Climate Change, also sees relatively low growth in demand out to 2025, beyond which electrification picks up pace. We believe these scenarios remain viable.

Our Accelerated Ambition scenario sets out a pathway to achieve Northern Ireland's commitments to the UK's 2050 net-zero emissions target by 2040; it anticipates the introduction of a more urgent and rapid effort to decarbonise the energy sector.

A critical factor in deciding on which scenario to follow is the pace of change; this is dependent on the Northern Ireland Executive's approach to addressing climate change as a key pillar to restarting, reviving and renewing the economy.

The Department for the Economy (DfE) has recently concluded a Call for Evidence with stakeholders to develop the future Energy Strategy for Northern Ireland. We are encouraged by the strong leadership from Minister Dodds MLA and her Departmental Officials in relation to this strategy.

SONI delivered a comprehensive response to the DfE's Call for Evidence. We are continuing to work with the Department to support their delivery of this critical strategy which will inform future energy targets and the approach to facilitating further growth in renewable generation.

TESNI 2020 reflects the feedback received from our consultation in autumn 2019. As a result, we have extended the horizon out to 2050 to provide a more extensive view of what is needed and the long-term impacts for each scenario.

We are very grateful for your engagement in the process which has helped us shape and update TESNI 2020, thank you.

Jo Aston
Managing Director
SONI Ltd.

Key Messages

The context of climate change is well understood and the question now is how fast society can respond to limit the damage, protecting our planet for current and future generations.

Northern Ireland can deliver its contribution to the UK's net-zero emissions target for 2050, based on emissions reductions calculated by the Committee on Climate Change. This will require strong policy and fast action across all sectors of the energy system to transition to low carbon and renewable energy.

This transformation of the Northern Ireland power system will have widespread consequences:

- There will be major changes in how electricity is generated, and in how it is bought and sold; and
- There will be major changes in how electricity is used, such as for transport and heat.

The electricity system will carry more power than ever before and most of that power will be from renewable sources. Coal and oil-based generation will be phased out in the next decade. While that happens, new technology will allow electricity users to generate and store power and return any surplus to the grid. Combined with real-time consumption information from electricity users, this creates opportunities for all.

Realising these opportunities will require a significant transformation of the electricity system. More importantly, these changes will need to be managed in a co-ordinated and cost-effective way.

SONI has a unique role to play in ensuring that we have a green power system ready for the radical transformation that is now required.

A strong energy policy which confronts the accelerating climate crisis, while delivering a low-carbon, cost-effective power system is essential. It should look out to 2050 with a clear roadmap and have ambitious measurable targets. A five year action plan framework is required including mid-term reviews. This framework means that priorities can be weighted, delivering co-ordinated cross-departmental policies, and aligning and tailoring directions of travel to deliver maximum benefit and progress.

The Strategic Energy Framework (SEF) target of 40% of electricity produced from renewable energy sources (RES-E) by 2020 and the use of a support mechanism (Renewable Obligation Certificates) led to a large increase in renewable generation capacity in the last decade. A new energy strategy, with ambitious RES-E targets and appropriate incentivisation mechanisms, is urgently required to continue to deliver renewable generation capacity.

Renewable generation capacity in Northern Ireland is dominated by onshore wind. As part of the energy transition, Northern Ireland will have to consider the most appropriate mix of technologies to deliver long term ambitions. Strategies for encouraging and developing a more diverse renewable energy supply should be explored, in particular the potential for utilising significant offshore energy resources.

A holistic and collaborative approach is essential for success with the interaction between power, heating and transport sectors underpinned by energy efficiency measures being optimised and supported by policy. For example, the uptake of electric vehicles should be in parallel with the development of renewable generation. In addition, supporting the development of low carbon heating solutions should be in tandem with improvements in the thermal efficiency of housing and reduction in reliance on oil fired heating.

The transition to electric vehicles and low carbon heating will increase the use of electricity as an energy source. As a result, peak electricity demand is expected to rise significantly. Manging the increase of peak demand through measures such as smart vehicle charging, demand side management and consumer action will be important to reduce the impact on the electricity transmission system.

Investment in the electricity grid and realisation of strategic infrastructure in a timely manner is crucial. This is an essential enabler to attracting and facilitating competitive low carbon generation technology to the Northern Ireland marketplace. Planning policies and processes need to deliver timely decisions to build investor confidence in grid capacity and realisation of their projects with appropriate investor returns. Planning, both strategic and local, needs to be more efficient, strategically aligned to deliver government policy; co-ordinated and involving of communities.

The second North South interconnector is required to ensure efficient operation of the Single Electricity Market (SEM) and allow long-term strategies to be achieved. Without the second interconnector in place, a fundamental grid constraint is limiting the efficiency of the wholesale energy market and, with the drive to increase the level of renewables on the system, could become a barrier to potential investors. The second North South Interconnector needs to be delivered so that energy targets for 2030 and 2050 can be achieved, in conjunction with security of supply and best value for consumers.

Educating and empowering consumers to make changes and to develop a different relationship with how they use and pay for electricity should be considered alongside a ‘just transition’ for vulnerable consumers.

Glossary of terms

Biogas
The gas produced from the anaerobic digestion of biodegradable material such as grass, animal slurry and domestic waste. It has similar qualities to natural gas but requires upgrading (CO_2 removal) before injection into the gas network.

Carbon dioxide equivalent (CO_2e)
The number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas.

Capacity adequacy [electricity system]
The ability to meet electricity demand at all times.

Capacity factor
A measure of energy production. It is calculated as a percentage, generally by dividing the total electricity produced during some period of time, for example a year, by the amount of electricity the technology would have produced if it ran at full output during that time.

Carbon capture and storage (CCS)
The process of capturing, transporting and storing the carbon dioxide produced from the combustion of fossil fuels, before it is released into the atmosphere.

Climate neutrality
Net-zero greenhouse gas emissions: when the total level of greenhouse gases emitted is offset by the greenhouse gases stored by sinks.

Coefficient of performance (COP)
The efficiency of a heating system: the ratio of energy output to energy input.

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 level of carbon dioxide emission reductions.

Decentralisation
The size and proximity of energy production in relation to the consumer. A higher level of decentralisation means that more energy will be produced by smaller scale units located close to consumers.

Decentralised generation
Generation connected to the distribution system.

Demand side management (DSM)
The modification of normal demand patterns, usually through the use of incentives.

Demand side unit (DSU)
One or more individual demand sites, typically in the industrial or commercial sectors, that can be dispatched by the transmission system operator.

Digitalisation
The scale of the role played by digital technology and data.

Dispatch [unit commitment and economic dispatch]
A set of indicative operating points for generators, interconnectors, storage and demand side units required to meet electricity demand over a given time horizon.

Distribution grid [electricity]
The typically radial network of high, medium and low voltage (110 kV and below) circuits and other equipment used for supplying electricity to consumers.

Electrification
The substitution of electricity for other fuels, such as oil and gas, used to provide similar services, for example heating and transport.

European Network of Transmission System Operators for Electricity (ENTSO-E)
A group of 43 transmission system operators from 36 countries across Europe with the common goal of setting up the internal energy market and ensuring its optimal functioning, and of supporting the ambitious European energy and climate agenda.

European Union emissions trading system (EU ETS)
The European market for carbon trading. The ETS scheme allows participants to buy and sell carbon emission allowances under a reducing annual limit (cap). The EU ETS covers carbon emissions from the sectors of electricity and heat generation, energy intensive industry and commercial aviation.

Flexibility [electricity system]
The ability to respond to both expected and unexpected changes in demand and generation.

Final use energy
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.

Greenhouse Gas (GHG)
One of several gases, especially carbon dioxide, that prevent heat from earth escaping into space, causing the greenhouse effect.

Interconnector
A transmission line which crosses or spans a border between countries and which connects the transmission systems of the countries.

Marine generation
Generation from wave or tidal technologies.

Micro-generation
Micro-generation refers to generation that is less than 11 kW, usually for self-consumption purposes, connected to the low voltage distribution grid.

Need
A future deficiency identified on the grid that arises as a result of one or more drivers, such as additional generation or demand in certain locations. Our technical planning standards play a central role in identifying future needs.

Net load
Electricity demand minus generation from weather dependent renewables.

Northern Ireland Electricity Networks (NIE Networks)
The transmission and distribution network owner and distribution network operator.

Power Purchase Agreement (PPA)
A long-term electricity supply agreement between two parties, usually between a power producer and a customer (an electricity consumer or trader).

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.

RES-E
Electricity produced using renewable sources.

Repowering
Replacing a generation site's equipment with typically more efficient equipment, so that it can continue to produce electricity.

Reserve
Capacity available for assisting the balancing of deviations in generation and demand.

Self-consumption
Demand met by on-site generation, for example when the electricity demand of a dwelling is met by electricity produced from a solar photovoltaic panel on its roof.

Single Electricity Market (SEM)
The wholesale electricity market operating in Northern Ireland and Ireland.

Smart meter [electricity]
A meter that employs digital technology to transmit information, such as the electricity consumption of appliances, to relevant actors, for example the consumer and supplier.

System Operator for Northern Ireland (SONI)
The independent statutory electricity transmission system operator in Northern Ireland.

Technical planning standards
The set of standards, set out in the Transmission System Security and Planning Standards, that the transmission grid is designed to meet. Our technical planning standards are a licence obligation and are approved by the Utility Regulator (UREGNI).

Total electricity requirement
The total amount of electricity required by a country, usually defined in annual energy terms TWh/yr.

Transmission grid [electricity]
The typically meshed network of high voltage (400 kV, 275 kV, and 110 kV) circuits and other equipment used to transmit bulk electricity supplies around Ireland. The terms grid, network and system can be used interchangeably.

Transmission system operator [electricity]
The licensed entity that is responsible for transmitting electricity from generators.

1. Introduction

1. Introduction

SONI, as Transmission System Operator (TSO), plays a critical role in the economy of Northern Ireland. Through the provision of a secure electricity supply, SONI is responsible for ensuring that the lights stay on for homes and businesses across the region. Sustaining a reliable supply of electricity is not just important for existing consumers, it is also crucial for attracting investment[1]. To ensure a continued secure, reliable, economic and sustainable electricity supply, SONI must continue to identify the future needs of Northern Ireland's transmission grid and plan the investments needed to address these needs.

Northern Ireland's energy industry is in a period of change. Since the mid-1990s renewables have transformed the generation fleet, increasing their market share and in doing so have decreased our reliance on fossil fuels. Society has become more energy aware. New technologies have become available, improving how consumers meet their energy needs and, in some cases, enabling them to generate electricity themselves.

Growing evidence suggests that our energy use presents a threat to our climate through its contribution to global warming. In 2015, a number of countries, including the United Kingdom (UK), signed the Paris Agreement[2], committing to limit global warming to well below 2°C and to pursue efforts to limit it to 1.5°C. The UK's objective of reaching net-zero[3] greenhouse gas (GHG) emissions by 2050 demonstrates commitment to the Paris Agreement and is expected to be achieved through a range of policy measures.

1.1.SONI Strategy 2020-25

The decarbonisation of the energy system will be vital to ensuring Northern Ireland meets its contributions to the UK's target of net-zero emissions by 2050. In 2019, SONI launched its Strategy[4] for the period 2020-25. The primary goal of our strategy is to lead the electricity sector on sustainability and decarbonisation.

As the TSO for Northern Ireland, we are responsible for ensuring the transmission system will be able to accommodate the extra power required to decarbonise the energy system. This additional power will mostly be delivered from renewable generation. To support our primary goal, we therefore must operate, develop and enhance the Northern Ireland electricity grid and market, to ensure that both can accommodate an increasing amount of renewable generation.

The transformation of our energy system introduces many variables and uncertainties, particularly in the longer term. To allow us to deliver our primary strategic goal, we have developed a number of scenarios to reflect how the energy system may change into the future.

Through our strategy we are committed to working and engaging with stakeholders and partners to help deliver our primary goal. Extensive consultation and information sharing has enabled SONI to refine and deliver our scenarios.

1.2. What are Tomorrow's Energy Scenarios?

TESNI 2020 outlines a number of credible pathways for Northern Ireland's energy transition and considers the electricity system beyond the ten-year planning horizon. They are not forecasts of expected pathways; rather, they allow a range of future options and opportunities to be analysed. How the energy system ultimately develops could be a combination of some or all of the scenario pathways. Therefore, when making use of TESNI 2020, all of the scenarios should be considered as a single set.

1 Grant Thornton, Powering Northern Ireland, 2016
2 UN, Paris Agreement
3 UK Government, Climate Change Act 2008 (2050 Target Amendment) Order 2019
4 Full details of strategy at http://www.soni.ltd.uk/about/strategy-2025/

Our scenarios will be reviewed periodically to include new information. This allows the most up to date information to be included in the scenario building process, including demand forecasts, planned changes to the generation portfolio and updated governmental legislation.

Following the publication of this report, we will test the performance of the Northern Ireland electricity transmission grid for each of the scenarios. The results of this analysis will be published in the TESNI 2020 System Needs Assessment report.

1.3. How do we use the scenarios?

SONI is the licensed TSO in Northern Ireland responsible for a safe, secure and reliable electricity transmission system, now and in the future. To achieve this, we must continue to maintain and develop the electricity grid. The use of scenario planning allows a range of credible futures to be taken into account and thus manage the risk of uncertainty.

Figure 1.1 demonstrates how TESNI fits into our planning process, showing both publications that are informed by TESNI, and publications that provide input to TESNI.

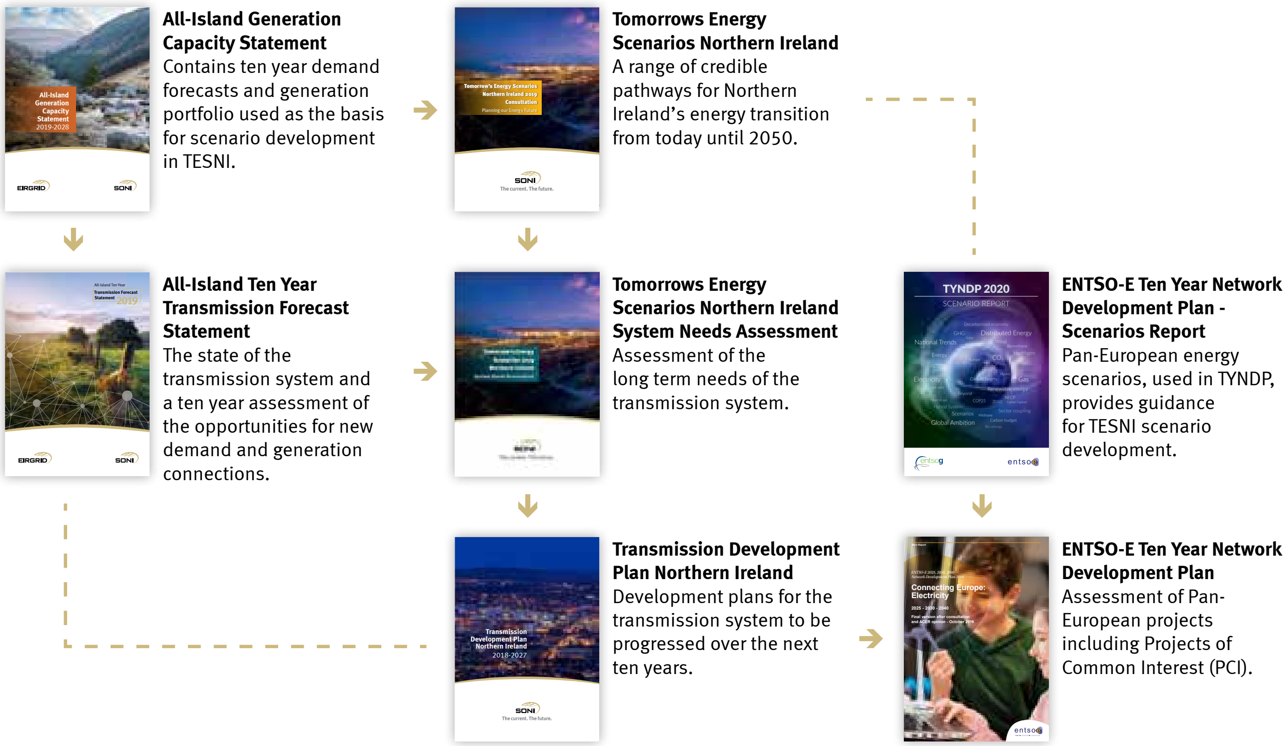


Figure 1.1: How TESNI is used in transmission network planning

Historically, SONI has assessed the need for new projects against one central scenario and, if required, a number of so-called 'sensitivities', to capture potential changes in the future. However, decarbonisation of the energy system introduces an increasing amount of uncertainties into longer term planning. With TESNI 2020, we have a robust set of scenarios with which to assess future needs. These scenarios have been subject to consultation and refined by stakeholder feedback. As such, they provide a strong foundation on which to assess the long-term performance of the transmission system.

1.3.1. The System Needs Assessment

The final scenarios presented in this report will form the foundation of the TESNI 2020 System Needs Assessment. We will perform power system studies assessing the performance of the transmission network for each scenario out to 2040. This will help identify future needs on the transmission system brought about by the changes in electricity generation, demand and storage.

1.3.2. The Northern Ireland grid development process

As the TSO licensee, we must develop an annual Transmission Development Plan Northern Ireland (TDPNI) which contains a reasonable number of future scenarios that reflect uncertainties and are consistent with scenarios used in other areas of work.

The TDPNI describes our grid development process which is made up of three parts, as shown in Figure 1.2. In Part 1, we identify optimum solutions required to address the future needs of the electricity transmission system and the areas of the grid affected. Future needs can be driven by changes to electricity demand, generation, storage and interconnection.

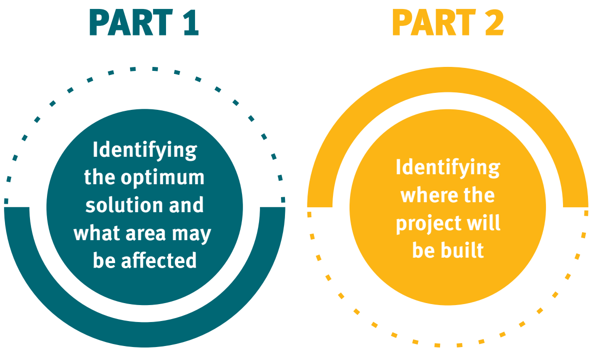


Figure 1.2: The grid development process in Northern Ireland

The Scenarios are used to test the transmission system against a set of performance standards. We use the results of these tests to identify grid development needs. Needs that may materialise within the ten-year timeframe are detailed in the TDPNI. TESNI therefore does not identify explicit network reinforcements; rather, it provides input into Part 1 of our grid development process.

1.3.3. Inputs to TESNI

The scenarios in TESNI are informed by the annual Generation Capacity Statement (GCS), which provides a range of growth forecasts for the Total Electricity Requirement (TER) over the ten-year period from the date of publication. The GCS ultimately provides an assessment of the adequacy of the supply and demand balance on the island of Ireland for ten years, taking the growth forecasts into account. These forecasts form the underlying growth assumptions used in the scenario building process.

ENTSO-E produces a biannual Ten Year Network Development Plan[5] (TYNDP). The TYNDP is built around a number of scenarios, which provide guidance on the energy transition at a European level, and is therefore an important reference for TESNI. Network reinforcements identified from our grid development process which are of European significance can be submitted and assessed in the TYNDP. Infrastructure projects of pan European significance may ultimately be deemed Projects of Common Interest[6] (PCIs).

5 TYNDP 2018 available at https://tyndp.entsoe.eu/tyndp2018/
6 Information on PCIs at https://ec.europa.eu/energy/topics/infrastructure/projects-common-interest_en

2. The Scenarios

2. The Scenarios

TESNI 2020 comprises three scenarios which provide 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 contribution is based on recommendations from the Committee on Climate Change (CCC).

Our three scenarios for TESNI 2020 are:

Modest Progress

Addressing Climate Change

Accelerated Ambition

The three scenarios are the result of considerable analysis. In autumn 2019, we presented a draft set of scenarios which were subject to a consultation[7]. Stakeholder feedback is vital to the development of the scenarios and TESNI 2020 is informed by responses received. In particular, significant changes include:

- More ambitious targets for electricity produced from renewable energy sources (RES-E) for 2030;
- Changes to the uptake in the electrification of heat and transport; and
- Showing scenario development out to 2050 and how the scenarios meet the UK Net-Zero requirements.

The most notable change is the dropping of the 'Least Effort' scenario from the consultation, which has been replaced with a new **Accelerated Ambition** scenario.

SONI has coordinated closely with Northern Ireland Electricity Networks (NIE Networks) in developing aspects of the scenarios. A joint working group set up in 2019 ensured an aligned position from both SONI and NIE Networks was determined for the uptake of low carbon technologies, including electric heat and transport and micro-generation.

Building and finalising the scenarios is a comprehensive process involving data gathering, stakeholder engagement and dispatch modelling and analysis. This document details the first set of scenarios produced by SONI. As we enhance and refine our scenario building process for future TESNI, we expect stakeholder input to provide an increasingly important role in developing our scenarios.

7 Information at http://www.soni.ltd.uk/media/documents/TES-NI-2019-Consultation.pdf

2.1. Modest Progress

- 60% of electricity from renewables by 2030
- Little economic growth over the next decade
- A ban on new petrol and diesel cars by 2040
- Adoption of Future Homes Standard to new homes from 2025 and existing properties from 2035
- Achieves the core emissions reduction contribution for NI set out by the CCC for 2050

In **Modest Progress**, the low carbon transition continues at a similar pace to the last decade.

Renewable generation capacity grows at a steady pace. Policies and support favour existing technologies, so new capacity is delivered by onshore wind and solar generation.

The transition to electric heat is initially slow as a result of high costs and lower economic growth. The Future Homes Standard proposes new builds must be future-proofed with low carbon heating from 2025. The transition to electric heating is generally limited to new buildings until 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.

With less favourable economic conditions, the public is less accepting of the higher cost solutions required to achieve net zero emissions targets by 2050. Instead, **Modest Progress** ultimately delivers Northern Ireland's contribution to the prior UK target of an 80% reduction in emissions by 2050.

2.2. Addressing Climate Change

- 70% of electricity from renewables by 2030
- Modest economic growth over the next decade
- A ban on new petrol and diesel cars by 2035
- Adoption of Future Homes Standard to new homes from 2025 and existing properties from 2030
- Achieves UK net zero emissions reduction contribution for NI set out by the CCC by 2050

In **Addressing Climate Change**, Northern Ireland meets its net zero targets for 2050 through a combination of high electrification and a significant increase in renewable generation capacity.

To aid the low carbon transition, a 70% RES-E target for 2030 is met. Onshore wind continues to play a significant role in renewable generation; however, new policies enable other technologies such as 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.

Decarbonisation of heat and transport is vital to minimise emissions, and a government ban on new petrol and diesel cars by 2035, in combination with price parity between electric vehicles and petrol and diesel cars being achieved by 2025, sees a rapid uptake in electric vehicles from 2030.

The deployment of electric heat lags the uptake of electric vehicles, with a similar trajectory to that in **Modest Progress**. Beyond 2030, this transitions to a faster uptake driven by anticipated government restrictions on fossil fuelled boilers.

2.3. Accelerated Ambition

- 80% of electricity from renewables by 2030
- Modest economic growth over the next decade, increasing towards the end of the period
- A ban on new petrol and diesel cars by 2032
- Adoption of Future Homes Standard to new homes and existing properties from 2025
- Achieves UK net zero emissions reduction contribution for NI set out by the CCC by 2040

Accelerated Ambition anticipates a requirement to meet decarbonisation targets earlier than 2050. In this scenario, a very ambitious target of 80% RES-E by 2030 is met primarily through continued development of onshore wind and a large increase in solar generation. This includes a significant uptake by consumers through the use of rooftop PV, due to favourable economic conditions.

Strong government support for offshore development sees both wind and marine technology in place by 2030, and this continues to develop in subsequent years.

Decarbonisation of heat and transport is vital to minimise emissions. In **Accelerated Ambition** the government brings forward a ban on new petrol and diesel cars to 2032. As in **Addressing Climate Change**, price parity between electric vehicles and petrol and diesel cars is achieved by 2025. These factors, along with improved economic conditions, drive a significant uptake in electric vehicles from 2025.

Electrification of heating happens earlier and faster than in the other scenarios, as proposed requirements for new builds in the Future Homes Standard are also adopted for existing buildings from 2025, with policy and financial support from the government.

2.4. Relationship to EirGrid scenarios

Due to differing political, economic, social and technology drivers in Northern Ireland and Ireland, two sets of scenarios are required - one set for each jurisdiction. However, our scenarios share a close relationship with EirGrid's Tomorrows Energy Scenarios 2019[8].

The alignment indicated in Figure 2.1 has been used in the dispatch modelling analysis in this report. It will also be used in the creation of dispatches to be used in the forthcoming TESNI 2020 System Needs Assessment.

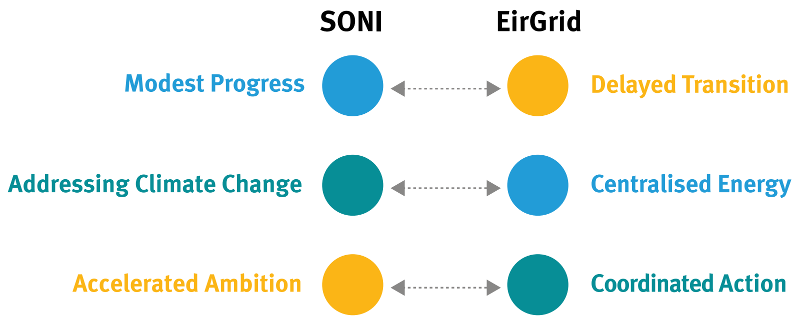


Figure 2.1: Relationship between SONI's and EirGrid's scenarios

Whilst there is no precise alignment between SONI's scenarios and EirGrid's scenarios, we are confident the alignment is appropriate for assessment of all-island market generation dispatches in the planning of the Northern Ireland transmission network. The 2030 RES-E targets in **Modest Progress** and **Addressing Climate Change** match those in the aligned EirGrid scenarios. Whilst **Accelerated Ambition** sees 80% RES-E by 2030, in contrast to the 70% target in Coordinated Action, the high electrification and net-zero power system ambition in EirGrid's scenario matches the ambitions of **Accelerated Ambition**.

8 EirGrid, http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-TES-2019-Report.pdf

3. Scenario framework

3. Scenario framework

Our scenarios are constructed around a framework which considers two main drivers, decarbonisation and decentralisation.

3.1. Decarbonisation

Northern Ireland does not currently have any legally binding emissions reduction targets; however, it will have to contribute to the UK's aim to achieve net-zero emissions by 2050. In the absence of defined targets for Northern Ireland, we make use of the recommendations from the CCC to set decarbonisation targets for our scenarios.

Decarbonisation refers to the level of carbon abatement. A higher level of decarbonisation results in lower carbon dioxide (CO_2) emissions released into the atmosphere. The Climate Change Act of 2008 legally bound the UK to reduce all GHG emissions by at least 80% from 1990 levels by 2050. In 2019, this legally binding target was revised to net zero emissions in the UK by 2050.

A 2019 report[9] by the CCC sets out how emissions can be reduced across the UK to meet both the previous 80% target (referred to in their report as the 'core scenario') and the net zero target (their 'further ambition' scenario). The report sets out Northern Ireland's expected contributions to these reductions, and the proposals within this document help shape our scenarios.

Figure 3.1 shows Northern Ireland's GHG emissions[10] from 1990 to 2017, expressed as a percentage of the 1990 figure. It also shows the range of decarbonisation considered in our scenarios out to 2050. The range is shaped by applying the targets discussed above. While emissions continued to rise through the 1990s, since 2000 there has been a steady trend of a reduction in emissions. This reduction is explained by many factors, including:

- The Moyle interconnector coming into operation in 2001;
- The closure of some oil-fired generation;
- A sharp reduction in energy demand following the recession of 2008;
- A displacement of fossil fuel generation resulting from a large increase in renewable generation capacity in response to a target of 40% RES-E by 2020; and
- A general reduction in electricity demand through energy efficiency improvements.

By 2017, GHG emissions in Northern Ireland were almost 18% below 1990 levels. Currently, the energy sector is responsible for two thirds of Northern Ireland's GHG emissions. Decarbonisation of the energy system is therefore critical to mitigate the impact of climate change.

9 CCC Net Zero: The UK's contribution to stopping global warming, May 2019
10 Data from https://www.daera-ni.gov.uk/articles/northern-ireland-greenhouse-gas-inventory

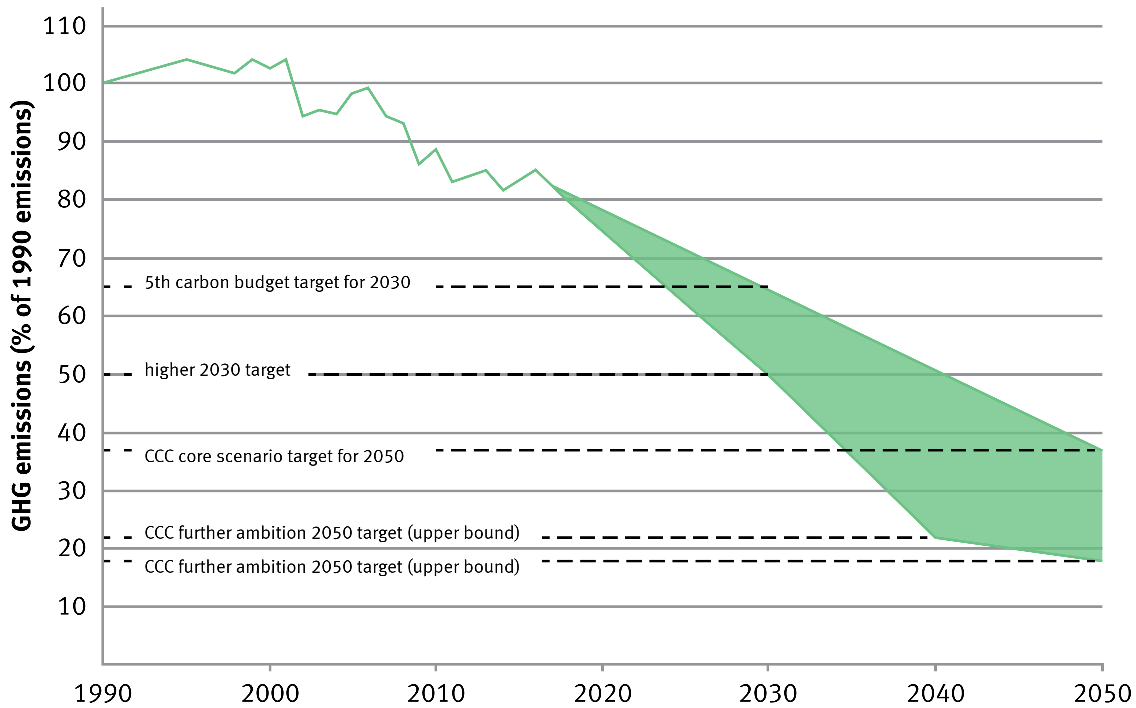


Figure 3.1: Emissions reductions (historical and targeted) for Northern Ireland

To meet its decarbonisation ambitions, the UK has set a number of carbon budgets[11] which provide a legal limit on the amount of GHG emissions over a five-year period. Five such carbon budgets have been drawn up; the fifth[12] covers the period from 2028 to 2032 and sets a limit of 1,725 $MtCO_2e$. Northern Ireland's contribution to the fifth carbon budget requires a 35% reduction in GHG emissions against 1990 levels by 2030. In light of the UK's decision to achieve net-zero emissions by 2050, this figure will likely be revised higher. In Figure 3.1, we assume this could be up to a 50% reduction. Varying GHG emissions reductions targets by 2030 will set Northern Ireland on different decarbonisation pathways towards 2050. Our scenarios are built within the range shown in Figure 3.1, informed by the indicated assumptions. Further reductions in emissions can be achieved through various measures, including:

- Continued integration of renewable generation, including exploiting Northern Ireland's offshore resources;
- A transition to lower-intensity carbon generation sources and ultimately to the phasing out of fossil fuel-based generation;
- Transitioning from fossil fuel-based transport to transport powered by electricity;
- Reducing heat demand in buildings through energy efficiency improvements;
- Replacing fossil fuel-based heating with electrified heat sources; and
- The use of technologies such as carbon capture and storage and power to gas in the longer term.

These measures, and others, range from proven, mature technologies to innovative solutions that demonstrate significant potential. Newer technologies will likely be initially expensive, and require clear policy support and financial incentives to be researched and developed before becoming commercially viable. The level of economic growth in the scenarios will help inform which technologies are considered as feasible options to decarbonise the energy sector.

11 UK Government, guidance on carbon budgets
12 CCC, The fifth carbon budget

3.1.1. Decarbonising power

The Strategic Energy Framework (SEF)[13] 2010-2020 set a target of 40% of electricity consumption in Northern Ireland to be met from renewable generation by 2020. Figure 3.2 shows the installed capacities for renewable generation since 2000. Looking from 2010 onwards, it highlights how clear policies and incentives enabled the growth of renewable generation capacity. This significant investment in renewable generation enabled Northern Ireland to achieve the 40% target in 2019.

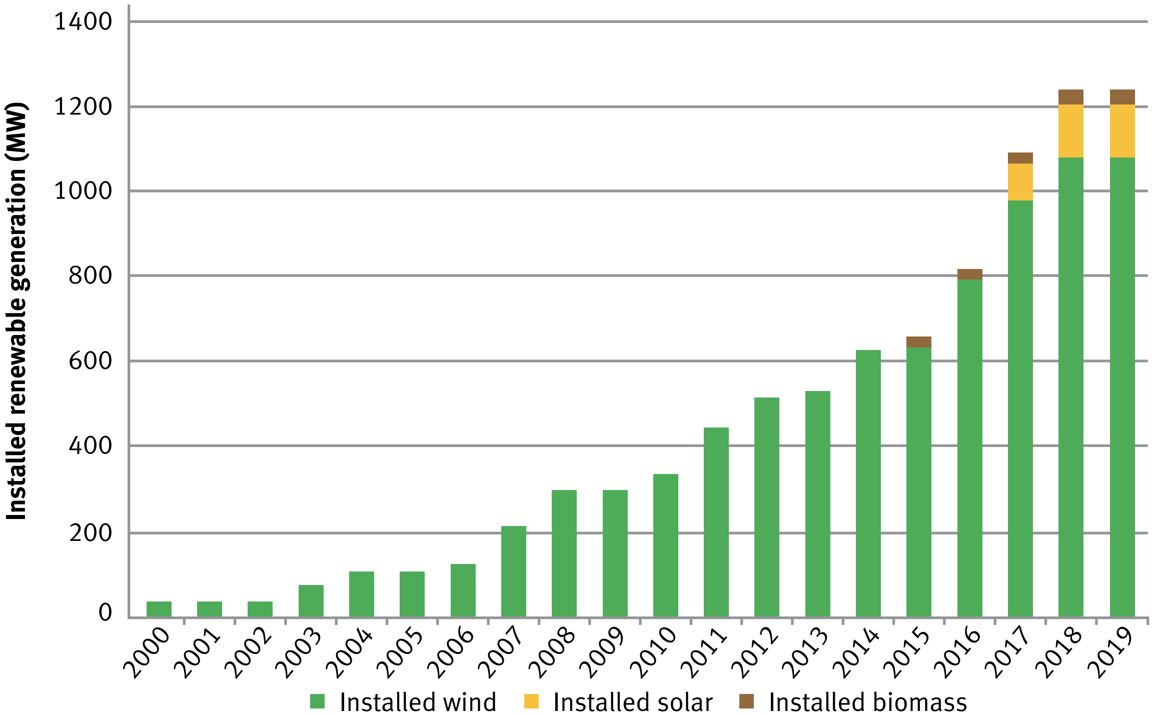


Figure 3.2: Annual installed renewable generation capacity 2000-2019

Figure 3.2 also shows that growth in renewable capacity stabilised in 2018. Reasons include the closure of the Northern Ireland Renewables Obligations Certificate (ROCs) scheme to new wind generation in June 2016, and transmission network congestion. To aid continued decarbonisation of the energy sector, new policies and support mechanisms will be required. Relieving congested areas of the transmission network, and delivery of the planned North South Interconnector, will be vital.

The DfE is presently gathering evidence on an energy strategy[14] for Northern Ireland; requirements from this process will inform future iterations of TESNI. New technologies may have to be introduced and integrated to ensure future targets are met; for example, Northern Ireland has considerable offshore energy resources[15] that to date have not been realised.

Transmission network reinforcement will also be required to accommodate significant amounts of new renewable generation. However, development of new generation near stronger areas of the network, and other technologies such as energy storage and power to gas will influence and reduce the amount of network development required.

13 DETI, Strategic Energy Framework
14 Department for the Economy, Energy Strategy – Call for Evidence
15 DETI, Offshore Renewable Energy Strategic Action Plan 2012-2020

3.1.2. Decarbonising transport

Due to its small geographical size, Northern Ireland has great potential for the uptake of electric vehicles, particularly given present day concerns over vehicle range (referred to as 'range anxiety'). Significant investment is required in charging infrastructure to ensure this potential can be realised.

The CCC recommends a number of measures in its 'Reducing Emissions in Northern Ireland' report, including:

- Reducing the emissions intensity of conventional fossil fuelled powered vehicles;
- A 60% market share of electric vehicles by 2030, helped by the removal of financial barriers; and
- Encouraging the use of public transport and transitioning the public sector fleet to electric and other low emission vehicles.

The UK government had a target[16] of banning the sale of all new fossil fuel powered vehicles by 2040. In February 2020, during the preparation of this report, this date was brought forward to 2035. A consultation[17] is presently being held into bringing that date forward further still to 2032. Our scenarios consider a range of dates where such a ban is bought in to place.

The UK Road to Zero[18] sees a long-term ambition of almost all cars and vans by 2050 being zero emission. Two of our scenarios, **Addressing Climate Change** and **Accelerated Ambition**, reflect that ambition achieved in Northern Ireland.

3.1.3. Decarbonising heating

The decarbonisation of heat is likely to be a significant challenge in Northern Ireland where over 67%[19] of households are heated via an oil boiler. The gas network is much less developed than in Great Britain, and so a much lower percentage of households are heated using gas in Northern Ireland compared to the rest of the UK.

The CCC estimates[20] that Northern Ireland requires a 14% reduction in heat demand from 2016 to 2030, and that 25% of heat energy is supplied by low carbon technologies by 2030, to ensure that the country is on track to meet emissions reduction targets.

The UK government recently consulted on updating sections of the Building Regulations, referred to as The Future Homes Standard[21]. Proposed changes to Part L of the Building Regulations would require new buildings to be future-proofed with low carbon heating and world leading levels of energy efficiency. The Future Homes Standard would require a 75-80% reduction in CO_2 emissions from the average household compared to 2013 levels. Similar requirements are not currently proposed for existing buildings.

The Future Homes Standard consultation considered England and Wales only; we assume changes to regulation resulting from the consultation would be adopted in Northern Ireland.

Our scenarios consider varying uptakes in low carbon technologies and energy efficiency improvements to aid the decarbonisation of heating in Northern Ireland.

16 UK Government- UK plan for tackling roadside nitrogen dioxide concentrations
17 UK Government- Consulting on ending the sale of new petrol, diesel and hybrid cars and vans
18 UK Government- The Road to Zero
19 Northern Ireland Housing Statistics 2018-19
20 CCC, Reducing Emissions in Northern Ireland
21 The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings

3.2. Decentralisation

Decentralisation refers to the size and proximity of energy production in relation to the consumer. A higher level of decentralisation means that more energy will be produced by smaller scale units positioned close to consumers. As a result of government incentives and support, there has been a notable adoption of small scale and micro generation across Northern Ireland over the last decade. This has reduced the demand of electricity required to be supplied from the transmission system.

In general, we would consider generation connected to the transmission system as centralised, and generation connected to the distribution system and micro generation as decentralised. In Northern Ireland, large scale renewable generation tends to be connected to the distribution system. However, a clustering policy introduced in the last decade has allowed groups of generators to be collected at distribution level but connected via a single point into the transmission network. Generation connected in such a manner would therefore also be considered as centralised generation.

Figure 3.3 shows how centralised generation (transmission connected and cluster connected) and decentralised generation (distribution connected and micro generation) develops across the three scenarios. Today, there is approximately 0.97 GW of decentralised generation connected in Northern Ireland; by 2050, this figure grows to between 1.7 GW in **Modest Progress** and 2.6 GW in **Accelerated Ambition**.

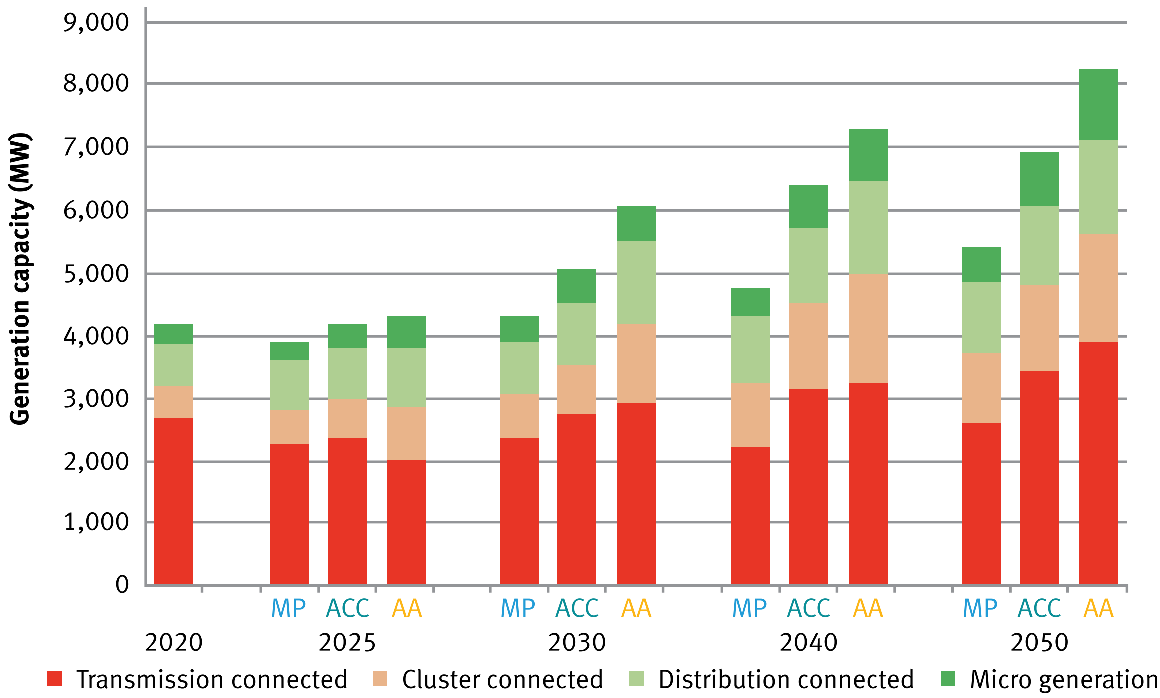


Figure 3.3: Centralised and decentralised generation

The electrification of transport is also a factor. In the case of electric vehicles, both the uptake and the charging regime can influence the decentralisation of vehicle charging options. In our scenarios, we consider a range of charging regimes that influence the time of day vehicles will be charging, and therefore influence the shape of the daily demand profile.

3.3. Scenario design

Table 3.1 presents a summary of the key design characteristics for the three scenarios.

Table 3.1: Scenario design characteristic matrix

	Modest Progress	Addressing Climate Change	Accelerated Ambition
Decarbonisation	**Medium**	**High**	**High**
RES-E by 2030	60%	70%	80%
Coal generation phase out	2024	2024	2024
Oil generation phase out	2040	2040	2035
Carbon capture and storage	No	Before 2050	2040
Electrification of heat	Low	Medium	High
Electrification of transport	Medium	High	High
Energy efficiency gains	Medium	High	High
GHG reduction by 2030	›35%	›45%	›50%
GHG reduction by 2050	›63%	›78%	›78% [2040]
Decentralisation	**Low**	**Medium**	**High**
Distribution connected generation	Low	Medium	High
Self-consumption	Low	Medium	High
EV charging	Simple	Smart	Smarter

4. Energy demand

4. Energy demand

Energy underpins our everyday life. Primary energy usage is ultimately the cost for driving the economy. Primary energy is the sum of all energy sources used, and covers the final use of energy as well as the transformation and distribution of energy, and losses[22]. Final use energy is the energy required by the end user. In this section, we set out how primary energy usage and sources change over time out to 2050 in our scenarios.

When assessing energy, it is important to take a holistic view of the energy system. GHG emissions are related to primary energy usage. To determine the decarbonisation pathways in our scenarios, we have to assess how energy usage will change across the whole energy sector, and how those changes will impact the demand for energy from electricity. In our assessments, we consider the energy usage in the following sectors: transport, residential, industry, and tertiary. The tertiary sector comprises commercial activities such as retail, office and services.

Figure 4.1 shows the primary energy usage in the four sectors, as recorded in 2016. Energy from electricity meets a portion of the energy demand in three of the sectors. The primary energy use in the generation of electricity in 2016 is also shown in Figure 4.1.

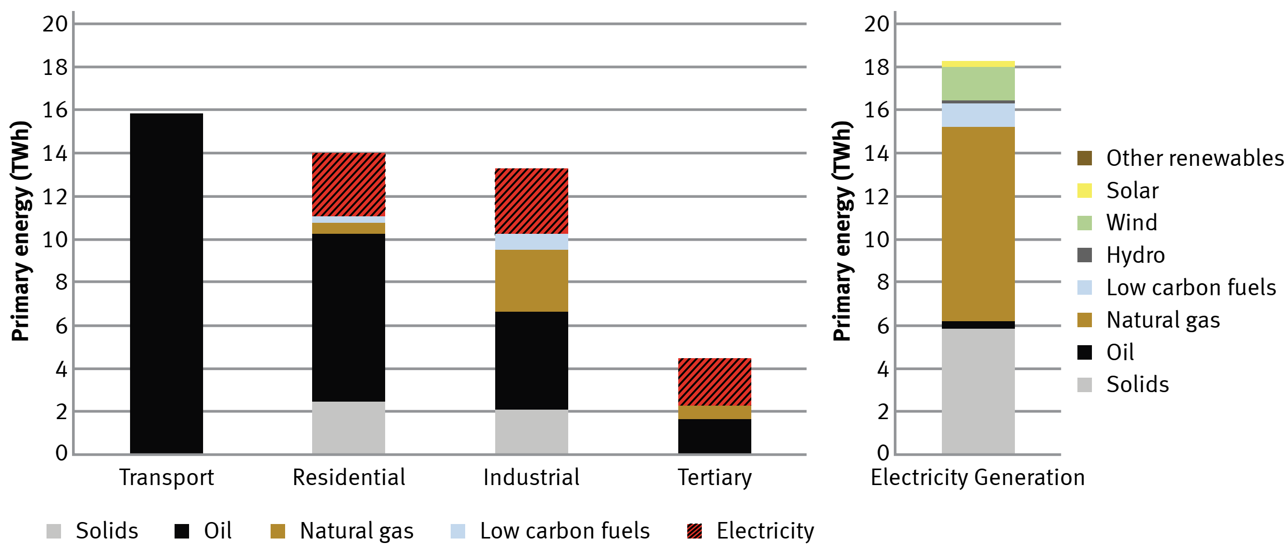


Figure 4.1: Primary energy sources in Northern Ireland in 2016[23]

Figure 4.1 highlights the scale of the energy transition required in Northern Ireland. Fossil fuels supply the vast majority of energy in the country- in 2016, they comprised 92% of all primary energy usage.

To meet Northern Ireland's contribution to UK decarbonisation targets, our scenarios see energy usage in all sectors, and in particular the transport and residential sectors, increasingly switch to electricity. At the same time, the proportion of electricity generated from renewable sources increases. Electricity is an efficient energy carrier, and when generated from renewable sources, a clean energy source.

22 Losses describe the difference between the amount of energy entering a system and the amount of energy leaving it. For example, on the transmission grid, some energy provided by generators is lost, typically as heat and noise, as it travels across the grid to where it is needed.
23 In this figure, and others in this section, low carbon fuels include the following: biomass burned for heating and biomethane, biogas and green gas.

4.1. Energy efficiency

Energy efficiency simply describes the amount of energy required to meet a demand. Improving energy efficiency is a significant method to help reduce the primary energy usage. Increased energy efficiency is achieved through the implementation of energy saving measures, which include:

- Switching from low efficiency fossil fuelled transport to more efficient forms of transport, including electric vehicles;
- Changing from less efficient fossil fuelled heating to more efficient heat pump technologies;
- Improvements to insulation and glazing in the built environment to reduce the demand for heating; and
- Consumer action, through measures such as increased use of public transport, more active travel such as by foot or by bicycle and changes to heating patterns.

Energy efficiency also plays a role in reducing the final use energy. A common example is the replacement of halogen light bulbs with energy saving light bulbs such as Light Emitting Diodes (LED), which have a lower use of electrical energy.

The EU has a collective target of 32.5%[24] reduction of final use energy by 2030 compared to 2005 levels. Achieving this will require improvements in energy efficiency across all sectors of final use energy. The annual energy efficiency gains for the residential, commercial, transport and industrial sectors in each of the scenarios is set out in Table 4.1.

Table 4.1: Annual energy efficiency improvements in the scenarios

	Modest Progress	Addressing Climate Change	Accelerated Ambition
Residential			
Electrical appliances (%)	1.0	1.0	1.0
Thermal (%)	0.8	1.0	1.0
Commercial			
Electrical appliances (%)	1.0	1.5	1.5
Thermal (%)	0.5	0.8	0.8
Transport			
Electric Vehicles (%)	0.9	1.6	1.6
Industrial			
Aggregated efficiencies (%)	1.0	1.0	1.0

24 European Union, Clean energy for all Europeans package

Modest Progress

- A ban on new petrol and diesel cars by 2040
- Adoption of Future Home Standards to existing properties from 2035

Modest Progress sees the total primary energy fall by 33% between 2020 and 2050. Fossil fuel use reduces over time, but still makes up approximately 43% of the supply by 2050. A slower initial transition to electric heat and transport sees oil remain a significant energy source to 2040.

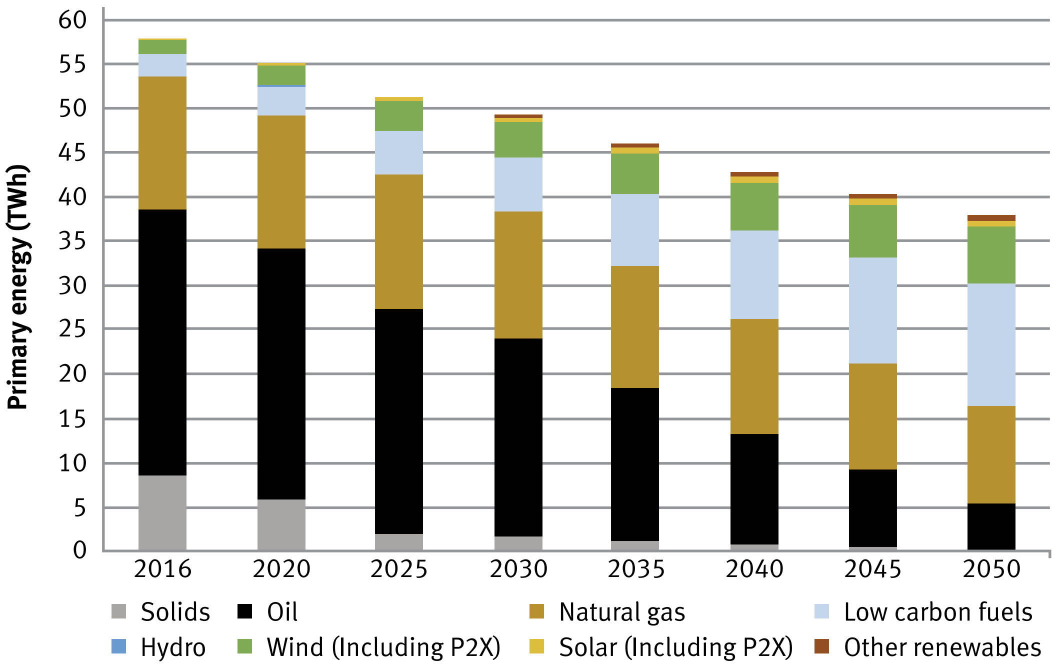


Figure 4.2: Primary energy sources in Modest Progress

The slow uptake in electrified heat and transport can be observed in the final use energy in Figure 4.3. Final use energy for transport sees significant reductions from 2030, as the transition to electric vehicles picks up pace. Electrification of heating is largely restricted to new builds initially, and so a significant reduction in residential energy usage is not observed until 2035 and beyond.

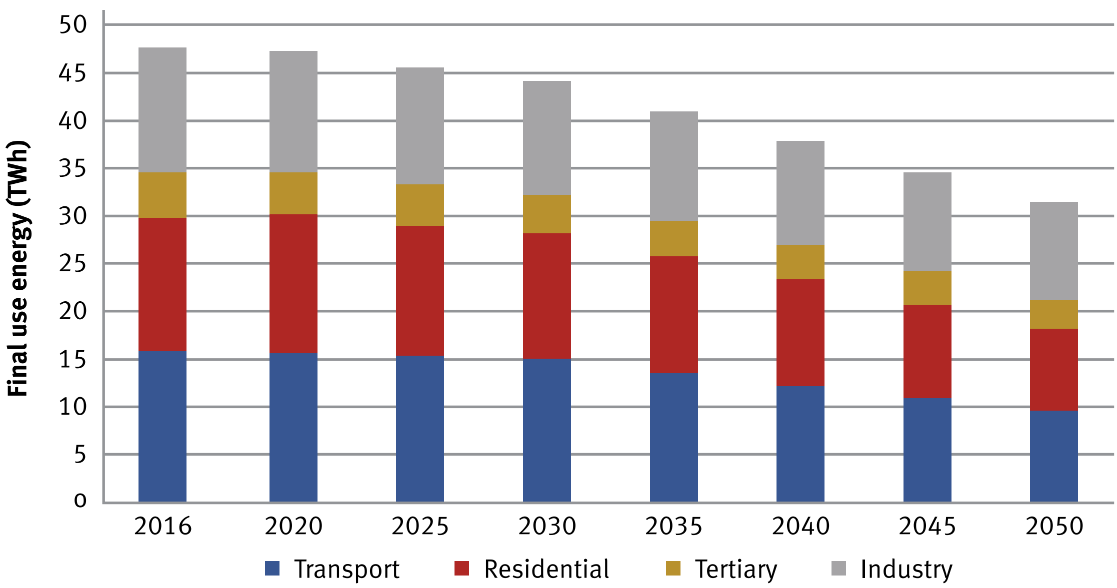


Figure 4.3: Final use energy in Modest Progress

Addressing Climate Change

- A ban on new petrol and diesel cars by 2035
- Adoption of Future Home Standards to existing properties from 2030

In **Addressing Climate Change** only 15% of primary energy is sourced from fossil fuels by 2050. With higher year on year efficiency gains, and a faster switch to electric alternatives for heating and transport, the total primary energy falls by 48% by 2050 compared to today.

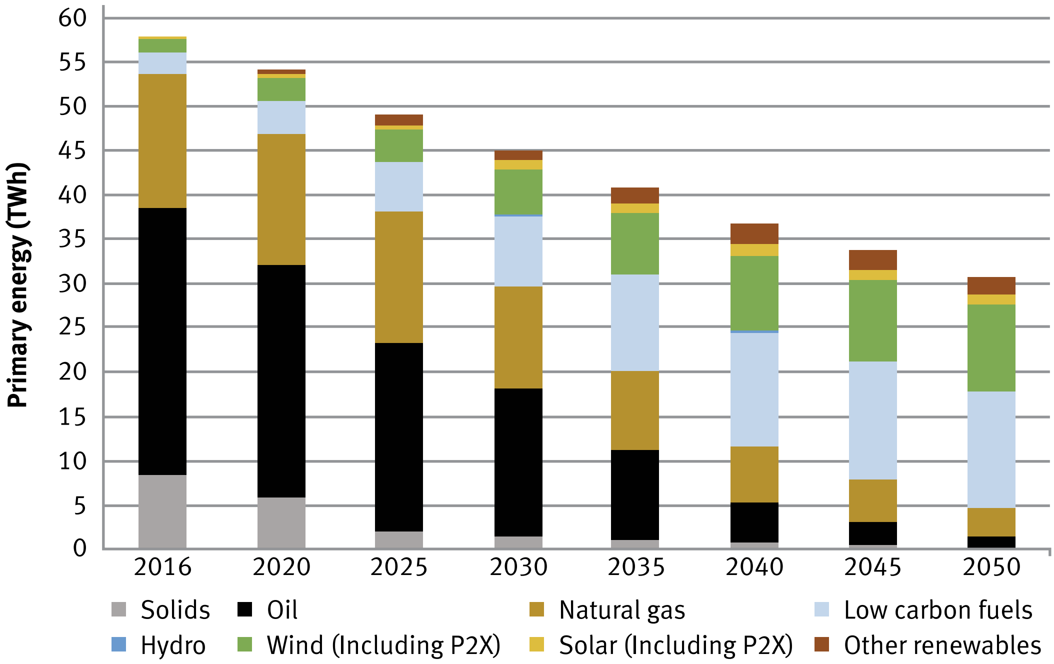


Figure 4.4: Primary energy sources in Addressing Climate Change

The earlier and faster transition to electric vehicles can be observed in the final use energy in Figure 4.5. Energy used for transport sees more significant reductions beyond 2030, as the transition to electric vehicles picks up pace. The greater uptake in heat pumps can be observed with residential demand reducing from 2035.

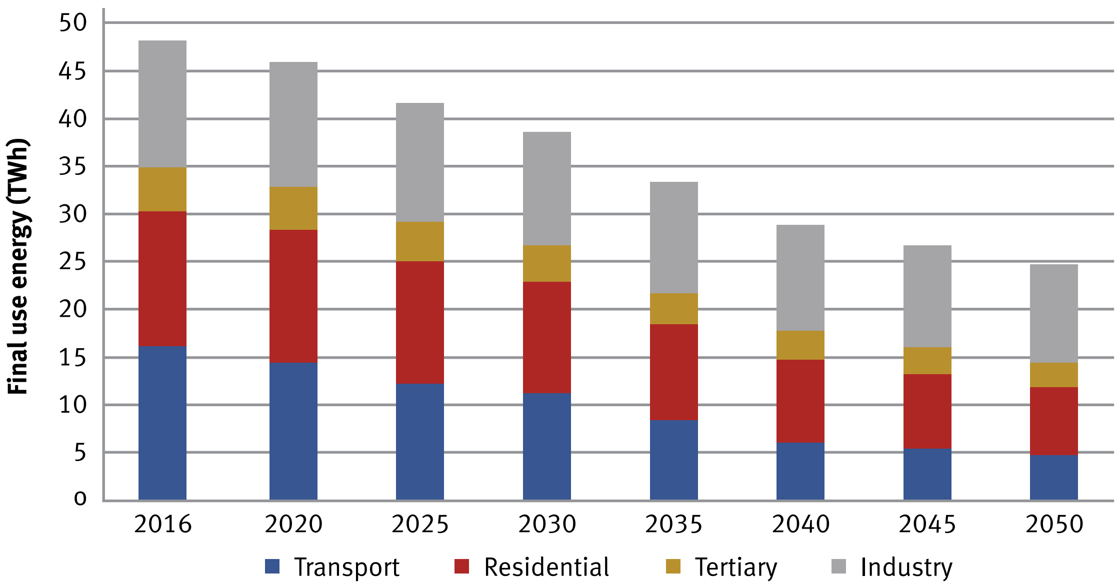


Figure 4.5: Final use energy in Addressing Climate Change

Accelerated Ambition

- A ban on new petrol and diesel cars by 2032
- Adoption of Future Home Standards to existing properties from 2025

By 2050, **Accelerated Ambition** sees a 49% reduction in primary energy usage. This is a similar reduction to that in **Addressing Climate Change** which is to be expected as both scenarios ultimately meet the CCC's contribution from Northern Ireland to the UK's 2050 Net Zero emissions target. In **Accelerated Ambition**, however, almost the entirety of energy in 2050 is supplied from either renewable or low carbon sources.

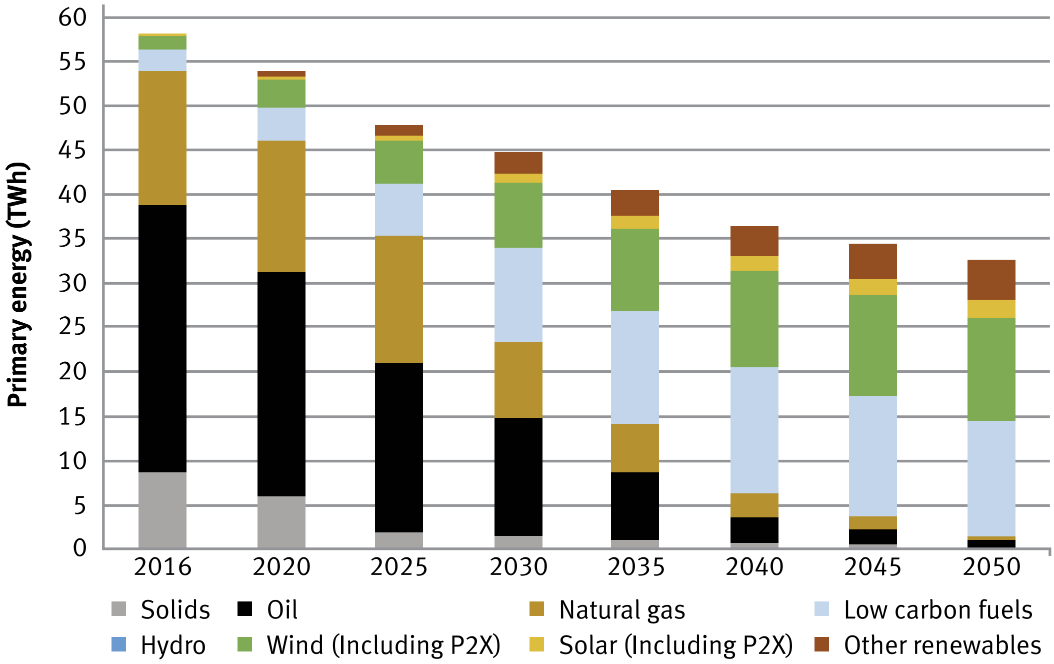


Figure 4.6: Primary energy sources in Accelerated Ambition

Final use energy is similar to that in **Addressing Climate Change**; however, Figure 4.7 shows a faster reduction in residential demand, due to a faster uptake in heat pumps.

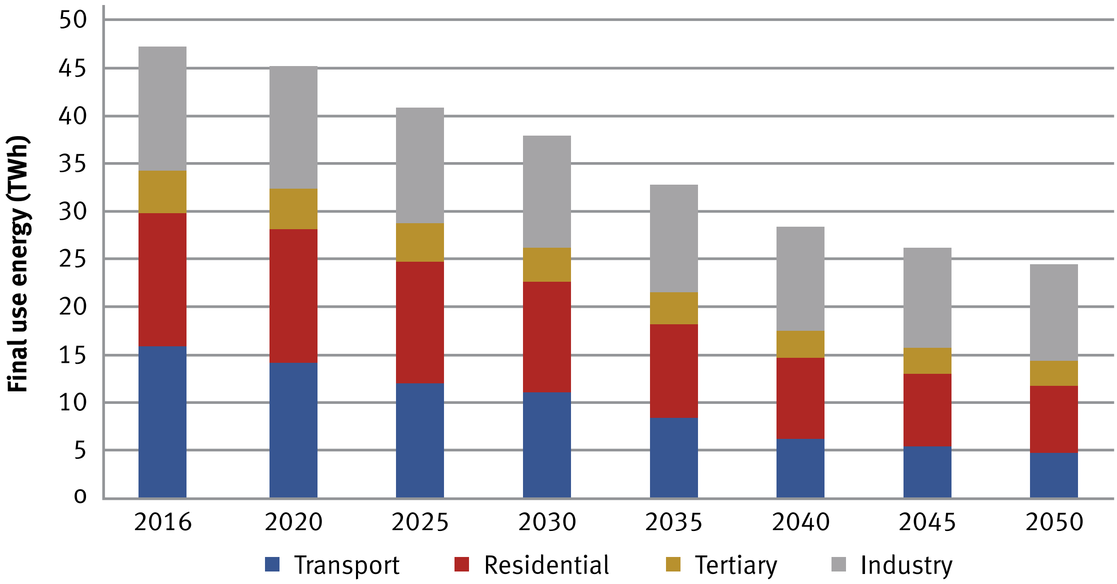


Figure 4.7: Final use energy in Accelerated Ambition

5. Electricity demand

5. Electricity demand

Section 4 described how the primary energy sources change out to 2050 in our scenarios. To aid with the transition from fossil fuel sources, an increasing proportion of the energy demand will be met with electricity. This section sets out our assumptions on how areas of demand, traditionally met from fossil fuel sources, will be supplied by electricity.

5.1. New electrical demand

5.1.1. Residential

Residential and tertiary (commercial businesses) electricity demand can be broken down into two components: (i) lighting and power, and (ii) any heating and cooling that have been electrified. Historically, heating/cooling has an energy demand five-fold higher[25] than lighting and power. Electric space heating comes in the form of direct electric, air-source heat pump, ground-source heat pump and hybrid heat pumps. We focus on air source heat pumps as a low carbon solution that can help decarbonise Northern Ireland's heating demand, particularly oil dependent households.

Requirements to meet the EC's Nearly Zero Energy Building[26] (NZEB) regulation drive legislation on new housing builds. This is achieved with measures including: triple glazing on all windows; the use of heat pumps; and new insulation standards for walls, floors and roofs.

The proposed Future Homes Standard updates the Building Regulations for new builds from 2025, including requiring the use of low carbon heating. Presently, the Future Homes Standard will apply to new builds in England and Wales only. In our scenarios, we assume the requirements will be adopted in Northern Ireland and implemented from 2025. We also assume similar standards will ultimately be required of existing buildings with the date such a policy is implemented differing in the scenarios.

Following feedback from the 2019 consultation, the trajectory of installed heat pumps in our scenarios was slowed out to 2030. The trajectories in our final scenarios were developed through close coordination with NIE Networks.

The Future Homes Standard will apply to new builds in the UK from 2025, and for both **Modest Progress** and **Addressing Climate Change**, we assume the installation of heat pumps over the next decade is largely restricted to new builds.

Beyond 2030, however, we assume the implementation of new policies such as The Future Homes Standard will also be applied to existing buildings. As a result the pace of uptake of electric heating increases, particularly in **Addressing Climate Change**.

In **Accelerated Ambition**, we assume a significant transition to low-carbon heating happens much earlier. This is driven by the assumption that efficiency standards for new builds will also be adopted by 2025 for existing buildings.

Figure 5.1 shows the installed number of residential air source heat pumps assumed in Northern Ireland for the three scenarios.

25 European Commission, Energy Demand for Heating and Cooling in European Countries, 2012
26 European Commission- The Energy Performance of Buildings Directive

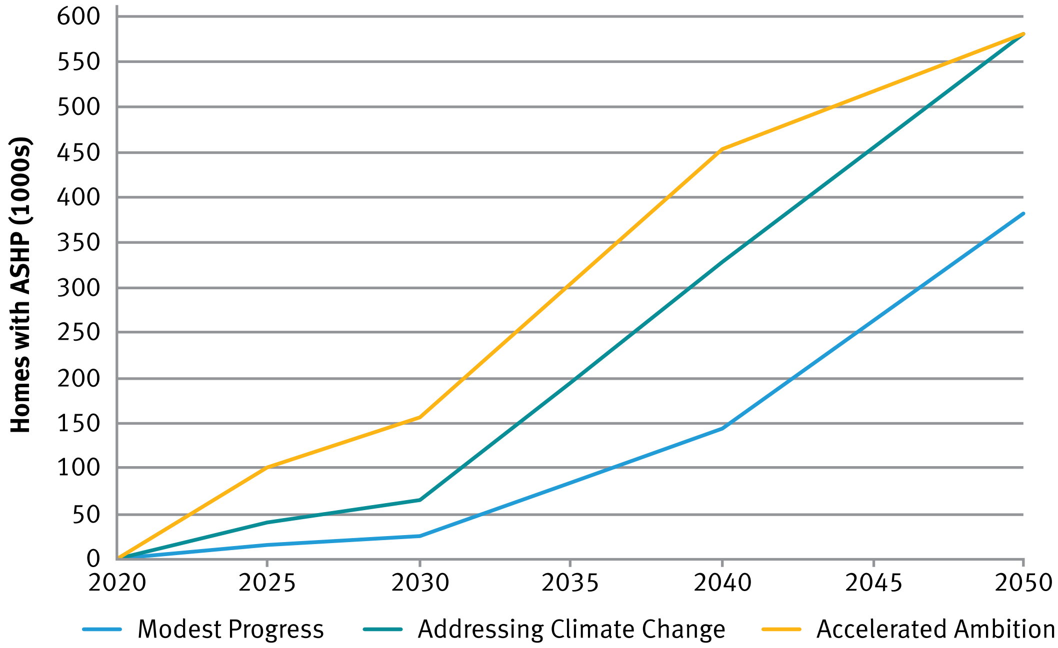


Figure 5.1: Residential air source heat pumps

The energy demand from a heat pump is a function of the average heat demand from a dwelling and the efficiency of the heat pump. This is known as the coefficient of performance (COP) of the heat pump. The air source heat pump COP assumptions used in our scenarios are shown in Table 5.1. The assumptions are fixed across all three scenarios.

Table 5.1: Air source heat pump coefficient of performance

	2020	2025	2030	2040
Coefficient of Performance	2.31	2.43	2.54	2.77

Locational information on heat pump installations is provided in Table A.6 in **Appendix A**.

5.1.2. Transport

Fossil fuels dominate the transport sector, fuelling the hugely successful internal combustion engine (ICE). Over recent decades, manufacturers have made significant improvements to the efficiency of these engines. In spite of this, they remain a long way off the efficiencies achievable through the electrification of vehicles. With its greater efficiency, an electric vehicle (EV) requires less primary energy than an ICE vehicle. Being powered by electricity also means that electric vehicles can be powered by renewable energy, rather than fossil fuels.

In comparison to electric vehicles, an ICE vehicle has a much greater range of travel before refuelling is required. In recent years, manufacturers have improved the battery range in electric vehicles; this is expected to increase further, as research and design efforts will likely escalate as a result of government bans on petrol and diesel engines forcing manufacturers to use alternative technologies.

The electricity demand from transport is a function of which modes of transport are electrified (motorcycles, cars, vans, buses, freight, and rail), the distance and type (urban, rural and motorway) of travel by citizens, and the efficiency of electric transport mode.

We focus on EV uptake in passenger transport (cars and vans). We will continue to monitor the potential electrification of buses, rail and freight.

The efficiency of EVs is assumed to improve over time, leading to a higher distance travelled per unit of electricity input, known as specific consumption. Table 5.2 shows our EV consumption assumptions.

Table 5.2: EV specific consumption (kWh/100 km)

	2020	2025	2030	2035	2040
Modest Progress	19.13	18.28	17.47	16.70	15.96
Addressing Climate Change	18.99	17.52	16.16	14.91	13.75
Accelerated Ambition	18.99	17.52	16.16	14.91	13.75

We assume a variation of EV uptake across scenarios to represent the range of possible rates of EV adoption, as shown in Figure 5.2.

In **Addressing Climate Change**, higher levels of uptake are promoted by falling EV costs and the UK government's plan to ban the sale of new fossil fuelled cars by 2035. **Accelerated Ambition** sees a faster rate of adoption, reflecting the possible move to bring forward the ban on new fossil fuelled cars to 2032 currently being consulted on by the government.

As the number of electric vehicles grows, they will have an increasing impact on the electricity grid and on electricity markets. The scale of this impact will depend on a wide range of factors such as the number and types of electric vehicle, vehicle usage, types and locations of vehicle chargers and the charging patterns of vehicle owners. 'Smart' vehicle charger technology has the potential to minimise the potential impact of electric vehicle demand on the electricity transmission system, and on electricity markets. In effect, smarter charging technology can allow some demand at peak time to be transferred to a time of lower demand. Such impacts are observed in the daily peak demand profiles presented in **Section 5.3**.

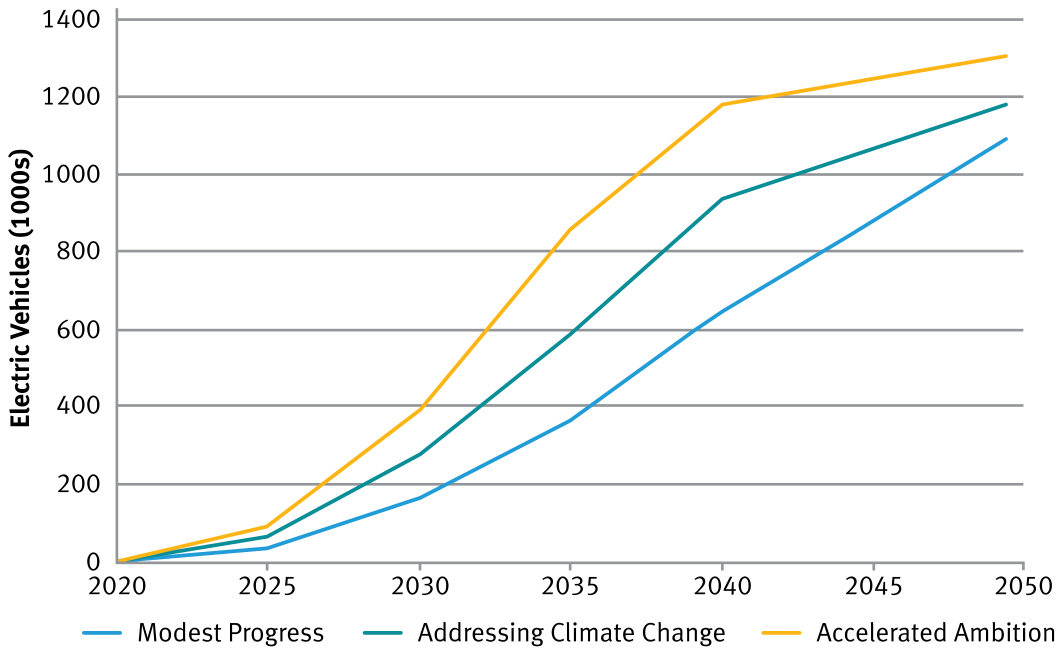


Figure 5.2: Number of electric vehicles

It is assumed that vehicle charger technology will evolve over time from simple chargers and patterns that are readily available today to smart chargers with features such as programmable charge start times. Further beyond, smarter charging technology could optimise vehicle charging in line with dynamic electricity price signals and system services for active network management.

The evolution from simple charging is already apparent today, with some models of electric vehicle offering the option to program the charge time. The TESNI 2020 framework for electric vehicle chargers is shown in Table 5.3. The most dominant type of charging regime is listed per vehicle type for each scenario and study year.

Table 5.3: Electric vehicle charger framework

	2025			2030			2040		
EV Type	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Car and van	Simple	Smart	Smart	Simple	Smart	Smarter	Smarter		
Public bus	Simple			Simple	Smart	Smart	Smart		
Freight	Simple			Smart			Smart		

The level of sophistication of vehicle chargers is expected to evolve from simple, to smart and to smarter. Using the simple profile as a baseline, the smart profile is developed by estimating changes to charging behaviours incentivised by time-of-use tariffs and facilitated by chargers that allow users to program charging to occur at predefined times such as overnight, when electricity prices are lower. Whilst there is a steady shift toward cost reflective charging patterns, some vehicle users still avail of day time charging; a proportion of the workforce provide essential services, and would likely remain price insensitive.

Smarter charging is an evolution of the smart charging profile. Algorithmic charger technologies leverage recorded vehicle usage patterns along with smart meter data and dynamic price signals to optimise charging of individual vehicles. This technology will play an important role in maximising the diversity of electric vehicle charging thereby reducing the impact on system peak demand. Weekday and weekend charging profiles for various types of electric vehicles are shown in Figure 5.3.

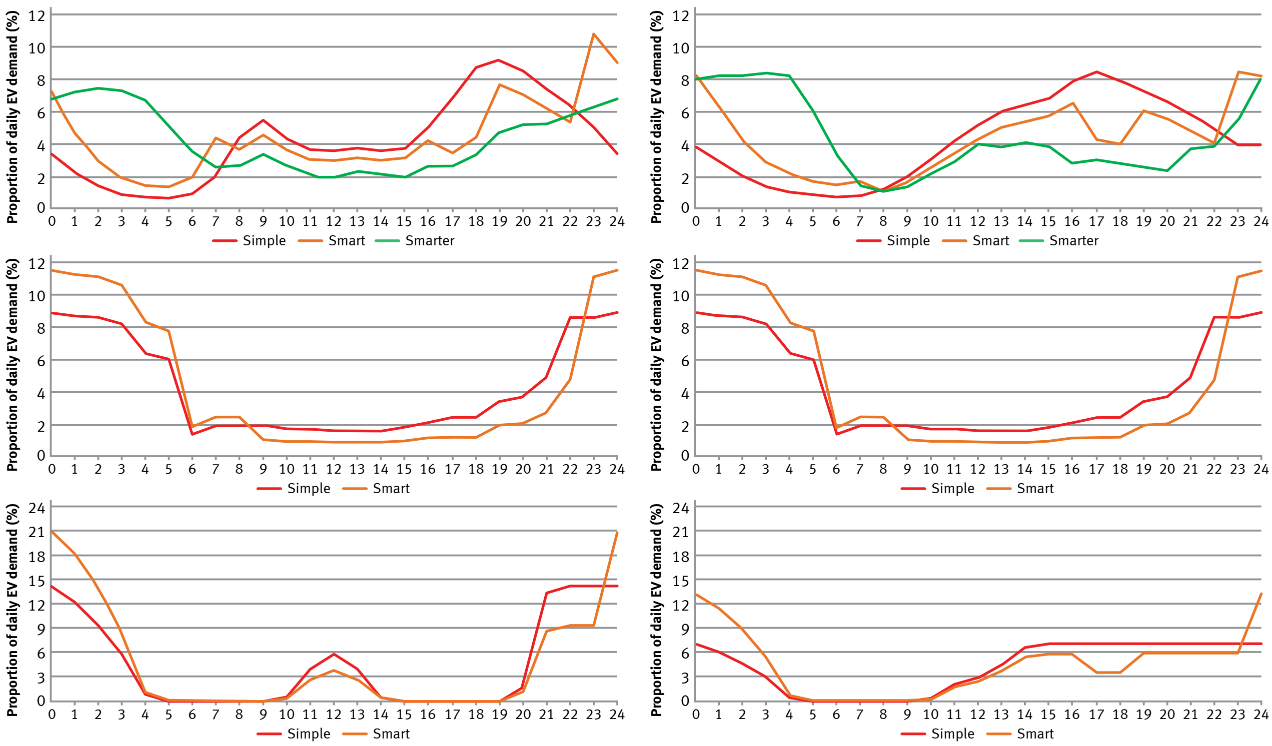


Figure 5.3: Weekday (L) and weekend (R) charging profiles for various electric vehicles - cars and vans (top), buses (middle) and freight (bottom)

Locational information on electric vehicles is provided in Table A.7 in **Appendix A**.

5.1.3. Industry

Final use energy demand in Northern Ireland's industrial sector is made up from various sub-sectors such as: agri-food production; quarrying and mining; manufacture of glass and building materials; agriculture; forestry and fisheries; wood and wood products; paper, pulp and print; transport equipment; textile and leather; and construction, among others. The extent of industrial demand electrification, i.e. the share electricity use in the final use industrial demand, is shown in Figure 5.4 for each scenario.

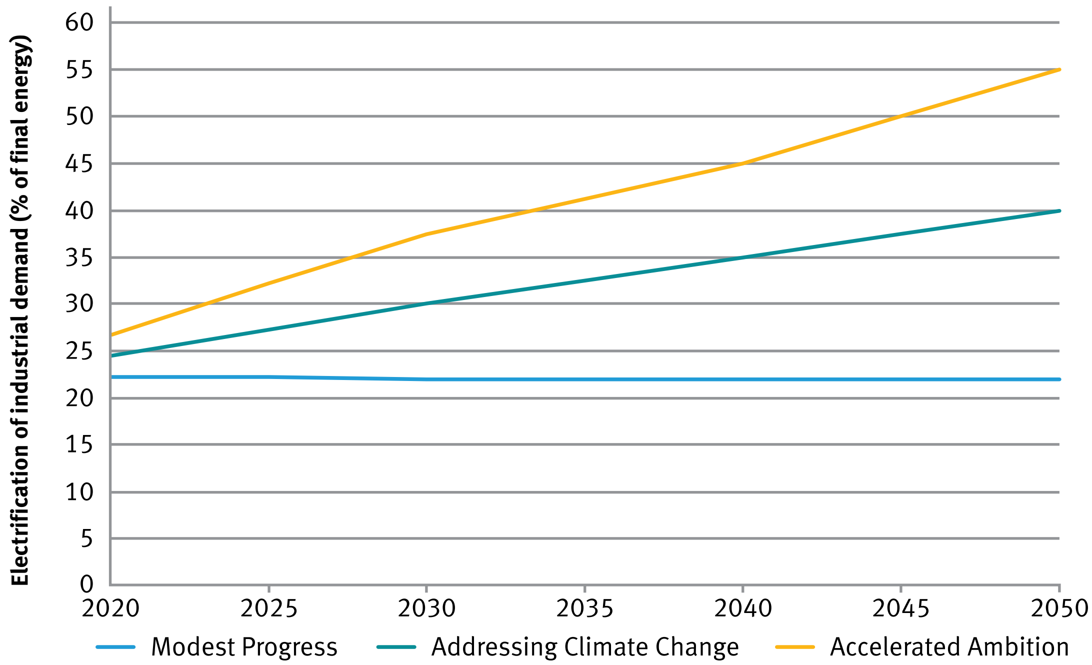


Figure 5.4: Electrification of industrial demand in the scenarios

Industrial energy demand is expected to reduce in the scenarios, as indicated in **Section 4**. In both **Addressing Climate Change** and **Accelerated Ambition**, we see an increase in the proportion of industrial demand becoming electrified, thanks to improved energy efficiency and a drive to alternative fuels and technologies, such as heat pumps. In **Modest Progress**, 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.

5.2. Total Electricity Requirement

The Total Electricity Requirement (TER) is the sum from electricity demand for the residential, tertiary and industrial sectors, including energy that is produced by micro-generators operated and owned by home and business owners. TER also includes power sector distribution and transmission system losses that are calculated to be approximately 10% of final use demand. Micro-generators can contribute to power system losses when they export surplus energy.

Figure 5.5 illustrates how the TER is built up from the various demand components. Growth in TER from 2025 is primarily driven by the electrification of heat and transport. **Modest Progress** sees no TER growth out to 2030, with limited development of heat pump usage the main driver.

Addressing Climate Change and **Accelerated Ambition** both see increasing levels of electrification of heat and transport beyond 2025, with government policies and incentives expected to drive this shift.

The 2025 and 2030 TER in **Modest Progress**, **Addressing Climate Change** and **Accelerated Ambition** is reflective of the expected growth in TER set out in the Generation Capacity Statement (GCS) for the low, median and high growth scenarios respectively. However, in **Accelerated Ambition**, the 2030 TER increases beyond the trajectory in the GCS thanks to a faster transition to low-carbon heating sources.

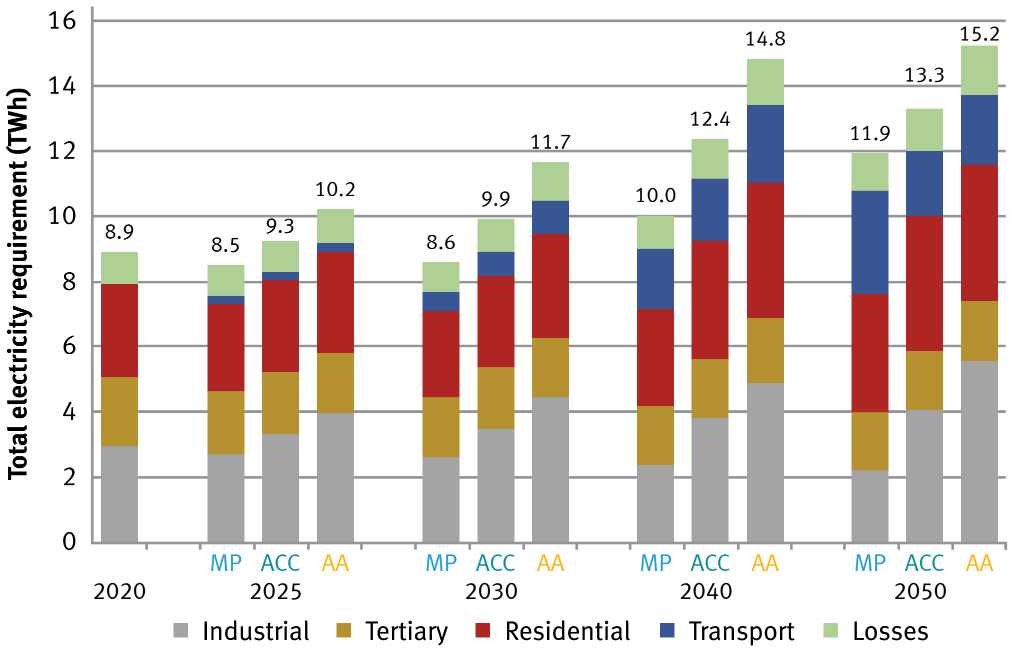


Figure 5.5: Total electricity requirement in the scenarios

5.3. Peak electricity demand

The electrification of heat and transport set out in **Section 5.1** significantly impacts the peak demand from electricity, as demonstrated in Figure 5.6.

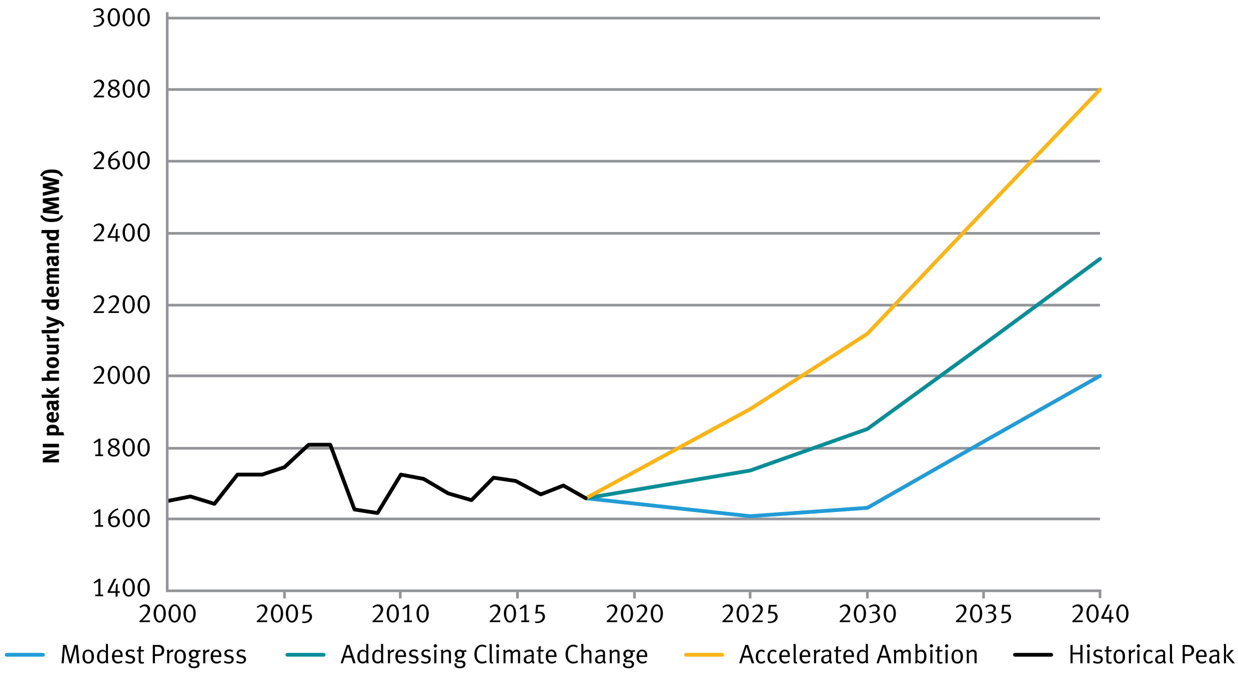


Figure 5.6: Hourly peak demand in the scenarios

The peak demand[27] in Northern Ireland typically occurs on a weeknight in winter at 5pm. Figure 5.6 shows that since 2000, the peak demand has been between 1600 MW and 1800 MW. The peak demand varies depending on temperature, with a period of colder weather generally resulting in a higher peak demand. As shown in Figure 5.6, the peak demand was also severely impacted by the recession in 2007/08.

Energy efficiency improvements have also impacted the peak demand, with a general downward trend since the mid-2000s. Continued reduction as a result of further efficiency improvements will be reversed as heat and transport becomes electrified. **Accelerated Ambition** sees the peak demand in 2040 increase by 70% from today's figure. In **Modest Progress**, the impact of energy efficiency improvements sees the peak demand figure fall out to 2025, before the electrification of heat and transport begins to have a noticeable impact.

In addition to the peak demand figure, electrifying heat and transport will also impact the daily demand profile, as demonstrated with the winter and summer daily demand profiles in 2030 for the three scenarios. Scenarios with large uptakes in electric vehicles will ultimately require smart management of vehicle charging to mitigate the impacts of the increased demand on the electricity network.

27 Our peak demand growth will take into account the impact of consumer action on electric vehicle charging. This varies across the scenarios. NIE Network's peak demand forecast will typically consider the maximum impact on demand before any such action, and will generally be higher than our forecasts.

Modest Progress

In **Modest Progress**, the biggest impact on the change in the winter peak day demand profile is the use of electric vehicles. With lower economic growth, underlying base demand growth is mitigated with moderate improvements in energy efficiency. As a result, there is a reduction in base demand by 2030 compared to today. There is also little impact on the demand profile from electric heating, due to the low uptake of heat pumps in this scenario by 2030.

Electric vehicle charging makes up the largest component of the increase in peak day demand. With limited smart charging in use, the majority of the charging occurs from when drivers arrive home from work, the result being a higher peak demand over a longer period of a few hours.

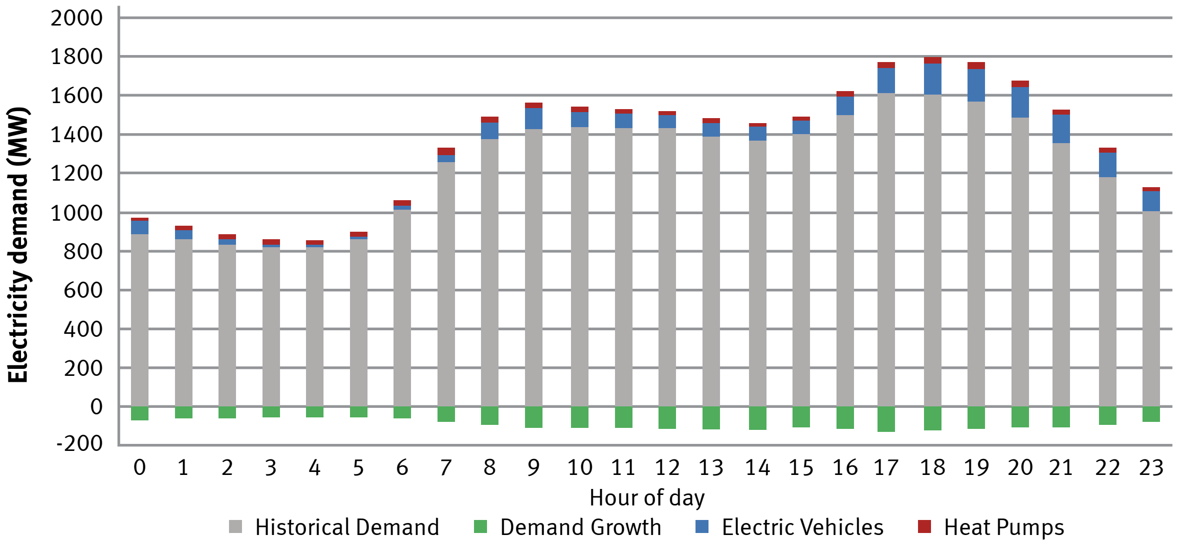


Figure 5.7: 2030 winter peak demand profile

The summer peak demand profile in 2030 has similar characteristics to the winter peak profile, with the majority of new demand resulting from electric vehicle charging. Of note again is the impact of energy efficiency improvements and low economic growth, the result of which is a reduction of base demand compared to today, particularly during the afternoon hours.

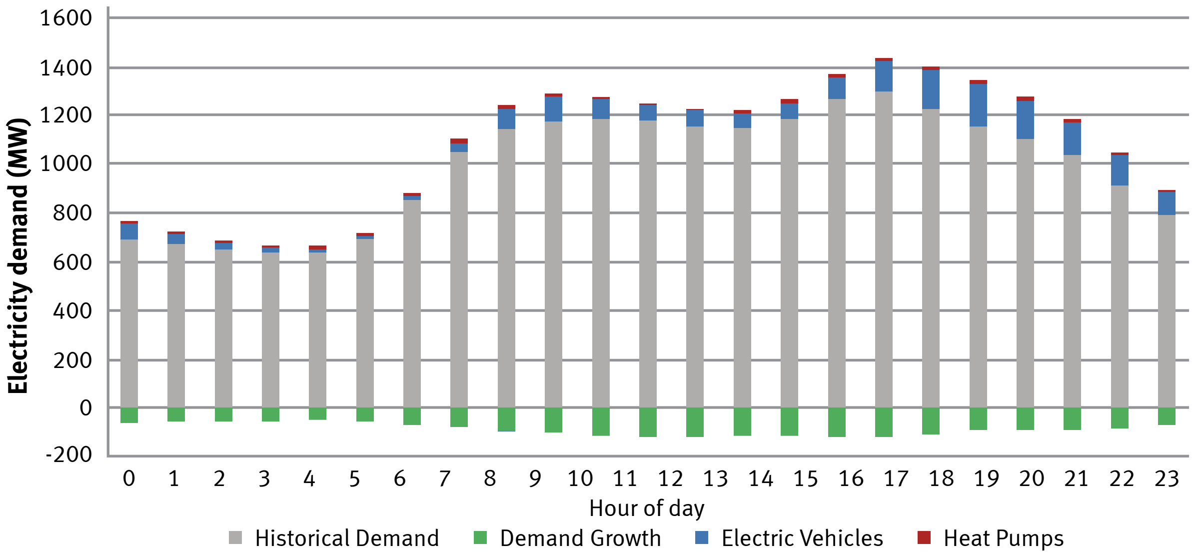


Figure 5.8: 2030 summer peak demand profile

Addressing Climate Change

A greater uptake of electric vehicles combined with the implementation of some smart charging, impacts the demand profile in **Addressing Climate Change**. Vehicle charging is distributed more evenly over the evening hours and into the early morning, shifting the usual time of peak demand from 5pm to 7pm.

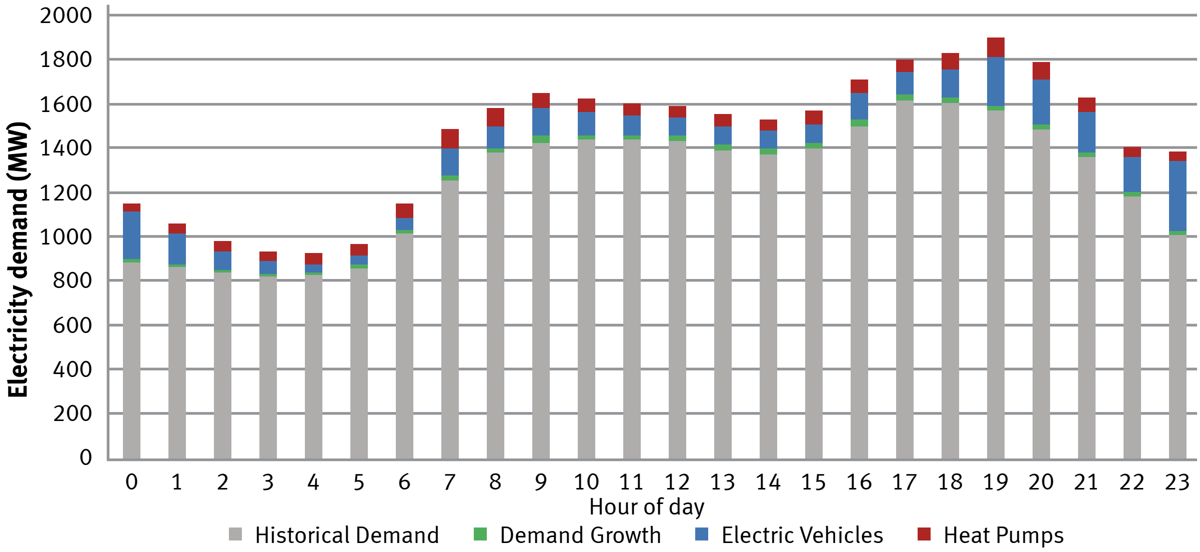


Figure 5.9: 2030 winter peak demand profile

Of note in both winter and summer is the large ramp in demand in the morning hours between 5am and 7am. This ramp occurs just after vehicle charging is at a minimum, suggesting that, with higher levels of electric vehicles, smarter charging will be required to spread the charging load more evenly across the overnight hours.

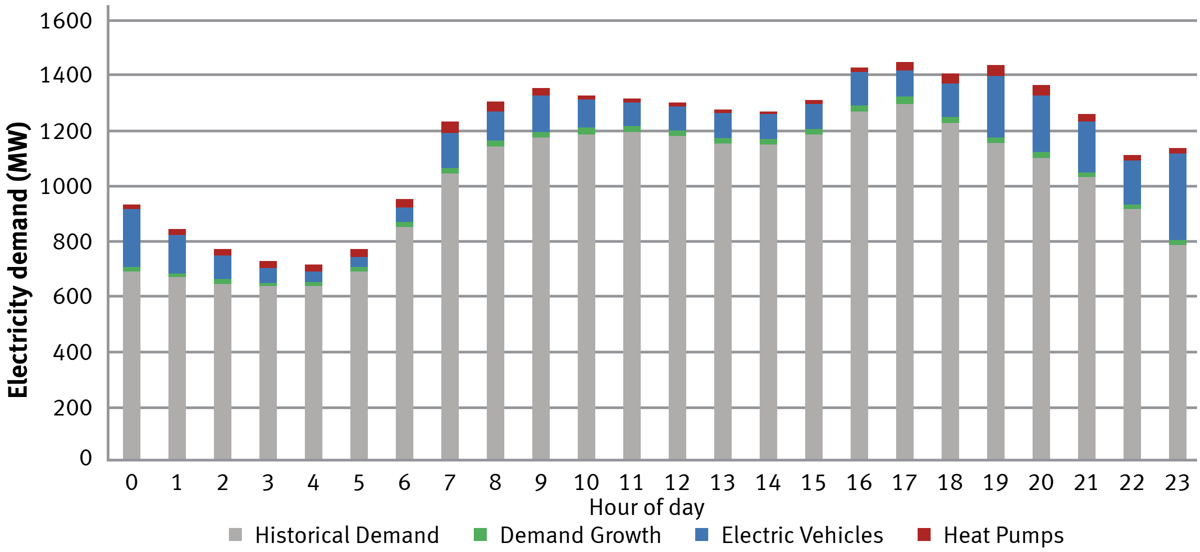


Figure 5.10: 2030 summer peak demand profile

Accelerated Ambition

With stronger government support and a subsequent earlier adoption, the impact of heat pumps on the demand profile is most pronounced in **Accelerated Ambition**. With smarter charging methodologies assumed in place for electric vehicles, the bulk of the vehicle charging is more evenly distributed across the overnight hours. This charging pattern, combined with the impact of heat pumps, shifts the time of peak demand from 5pm to 7pm.

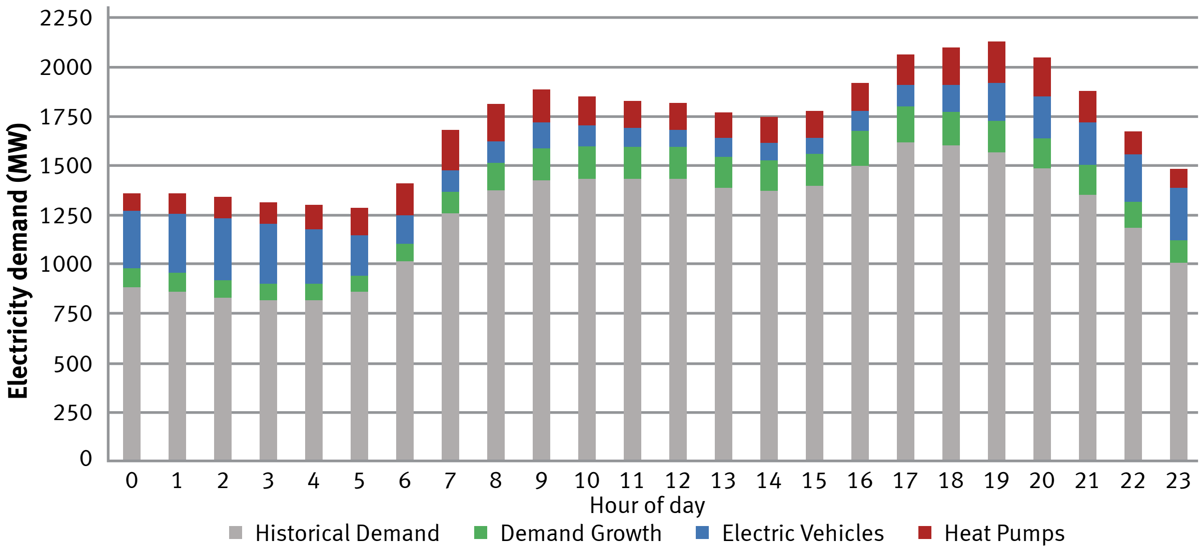


Figure 5.11: 2030 winter peak demand profile

For both winter and summer, there are two pronounced peaks during the day. In addition to the traditional evening peak, there is also a peak around 9am, primarily driven by the higher use of electric heating in the morning hours.

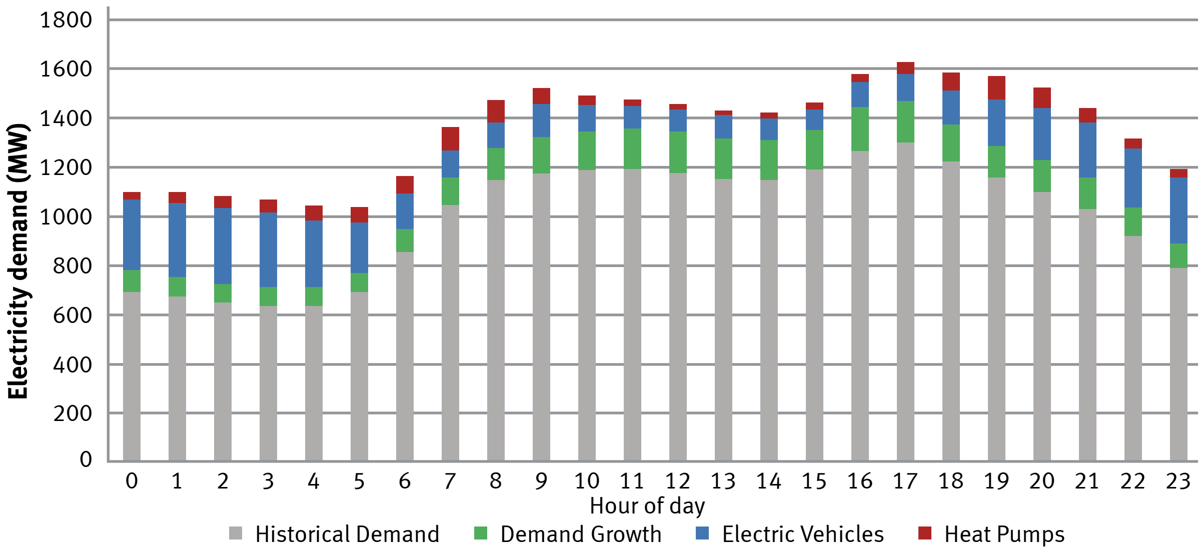


Figure 5.12: 2030 summer peak demand profile

With smarter electric vehicle charging, the rapid ramping of demand observed in the morning hours in **Addressing Climate Change** is less pronounced. However, the increase in demand resulting from heat pumps is noticeable in **Accelerated Ambition**. Unlike electric vehicle charging this demand tends to be inflexible; an increased uptake of electric heating will therefore have implications for both the transmission and distribution systems. Active network management (such as smart metering, storage and micro generation) will likely be required to mitigate the impact on the electricity systems.

5.4. Electrification

Section 4 demonstrated that primary energy use falls from today to 2050 in all three scenarios, resulting from energy efficiency improvements. Some of these improvements are brought about by the introduction of electrified heating and transport. This section has summarised our assumptions on the growth of electric vehicles and heat pumps, which will place an added demand on the electricity sector.

As a result of these changes, the electrification of energy increases out to 2050 in the three scenarios, as shown in Figure 5.13. Approximately 17% of energy is supplied via electricity today. By 2050 that figure rises to between approximately 35% in **Modest Progress** and 56% in **Accelerated Ambition**.

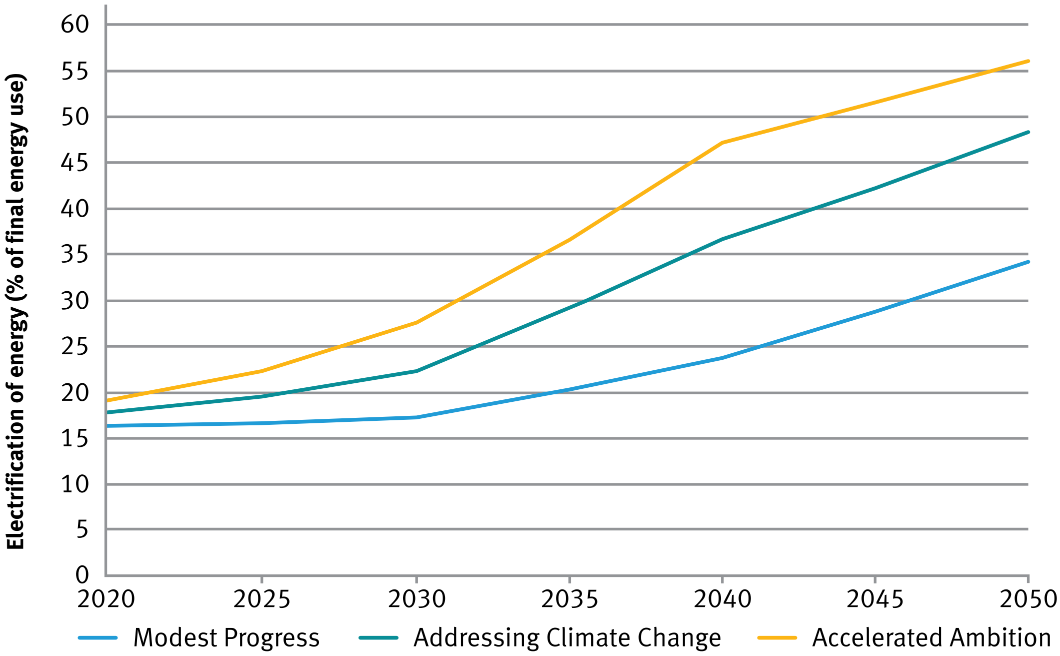


Figure 5.13: Electrification of energy in the scenarios

Of course, electricity itself is produced from a number of energy sources. Traditionally, this has been from large fossil fuelled generators. Over the last decade, however, the proportion of electricity supplied from renewable generation sources has steadily increased. As an increasing proportion of demand becomes electrified, electricity will have to continue to be sourced from renewable generation to ensure decarbonisation targets are met, and to a much greater extent than today.

Our generation assumptions for the scenarios are set out in the next section.

6. Generation

6. Generation

Section 5 detailed how the demand for electricity will change out to 2050 in our scenarios. This section sets out our assumptions on how this electricity will be supplied.

The SEF 2010 has been a successful mechanism supporting the integration of renewable electricity in Northern Ireland. It proposed a target of 40% RES-E by 2020, and this target was recently achieved during 2019. The connection of new renewable generation in Northern Ireland has slowed significantly over the last two years, driven by a number of factors including a lack of policy beyond 2020, an end to financial incentives in 2017 and a need for additional network capacity.

The DfE is working on an energy strategy that will replace the SEF 2010 and is expected to provide a road map for emissions reduction in the power sector out to 2050. Emissions from the power sector must continue to fall beyond 2020 for Northern Ireland to contribute towards the UK's 2050 Net-Zero target. The new strategy is expected to incentivise additional development in low carbon generation technology.

Our scenarios provide credible envelopes for the generation mix in Northern Ireland out to 2050. Our assumed generation portfolios are informed by the CCC's recommended principles and policies for power sector decarbonisation, stakeholder feedback from our 2019 consultation, market trends and plans to decommission existing plant.

Figure 6.1 shows how the generation portfolio changes in Northern Ireland for the three scenarios out to 2050.

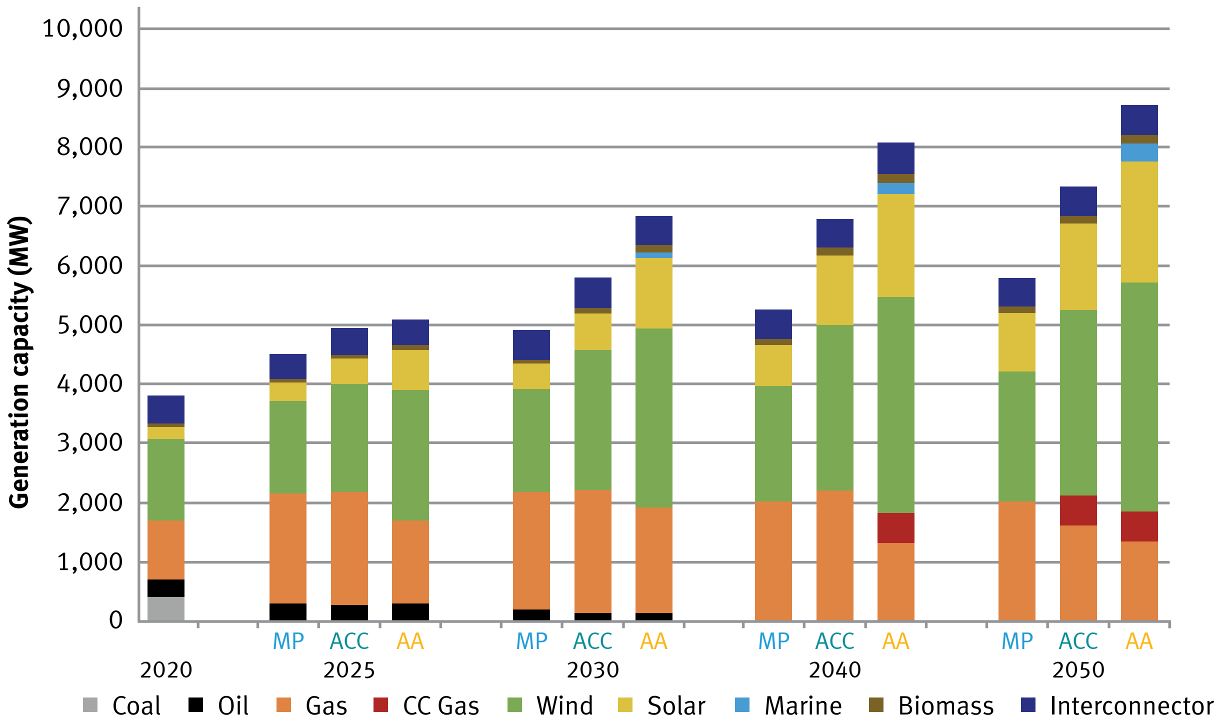
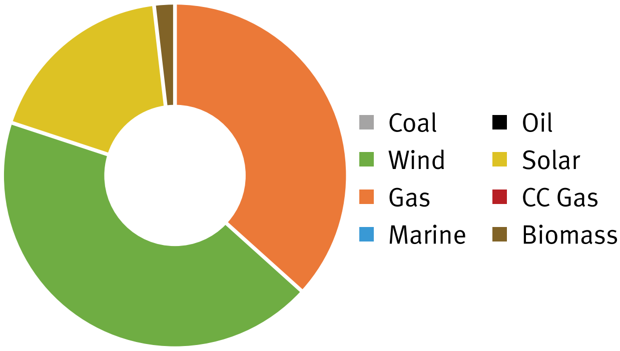


Figure 6.1: Generation portfolio in Northern Ireland

The generation portfolio in 2050 in each of our scenarios is summarised as follows:

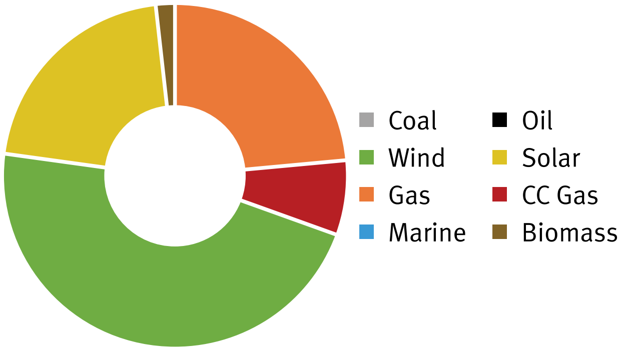
Modest Progress

- By 2050, 63% of the generation portfolio is comprised of renewable generation.
- Wind and solar are the dominant renewable technologies.
- A lack of a long-term plan, issues regarding consenting and a lack of a suitable incentive scheme means there is no development of offshore generation.



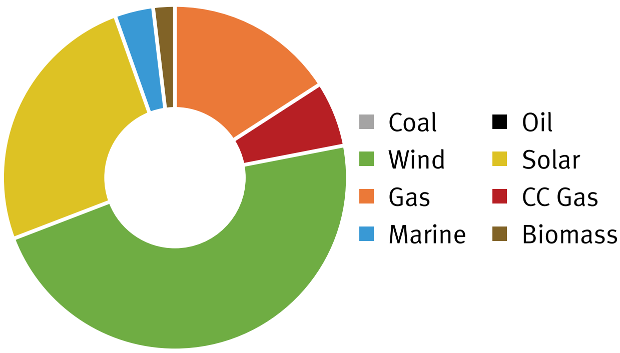
Addressing Climate Change

- By 2050, 77% of the generation portfolio is comprised of renewable or zero-carbon generation.
- Wind, both onshore and offshore, and solar are the dominant renewable technologies.
- A CCS CCGT is assumed in place by 2050.



Accelerated Ambition

- By 2050, 84% of the generation portfolio is comprised of renewable or zero-carbon generation.
- Wind, both onshore and offshore, makes up almost half of the portfolio.
- A CCS CCGT is assumed in place by 2040.
- Marine generation develops in this scenario only



6.1. Renewable generation

6.1.1. Onshore wind

Onshore wind is the most prevalent renewable generation technology in Northern Ireland, and is comprised of a combination of large-scale wind farms connected to the transmission and distribution grids and some 200 MW of small scale and micro-generation connected to the low voltage grid. Current and future projections on the cost of energy from onshore wind suggest that it is cost competitive against conventional generation technology.

Over 800 MW of onshore wind generation has connected over the last decade. We assume that onshore wind continues to be a highly cost competitive generation source and will remain the dominant renewable generation technology in Northern Ireland. Figure 6.2 shows the increase in onshore wind generation capacities in each scenario out to 2050.

No large-scale wind generation has connected in Northern Ireland since 2018. In **Modest Progress**, it is assumed that new connections continue to be effectively stalled until near 2025, after which improved economic conditions allow new developments to proceed. In both **Addressing Climate Change** and **Accelerated Ambition** scenario, a combination of new incentives, timely infrastructure delivery and repowering (for our assumptions on repowering, see **Appendix B**) of older wind farms allows for a significant increase in installed capacity out to 2030 and beyond. In **Accelerated Ambition**, there is a rapid increase in additional capacity to help meet an anticipated ambitious emissions target for 2030.

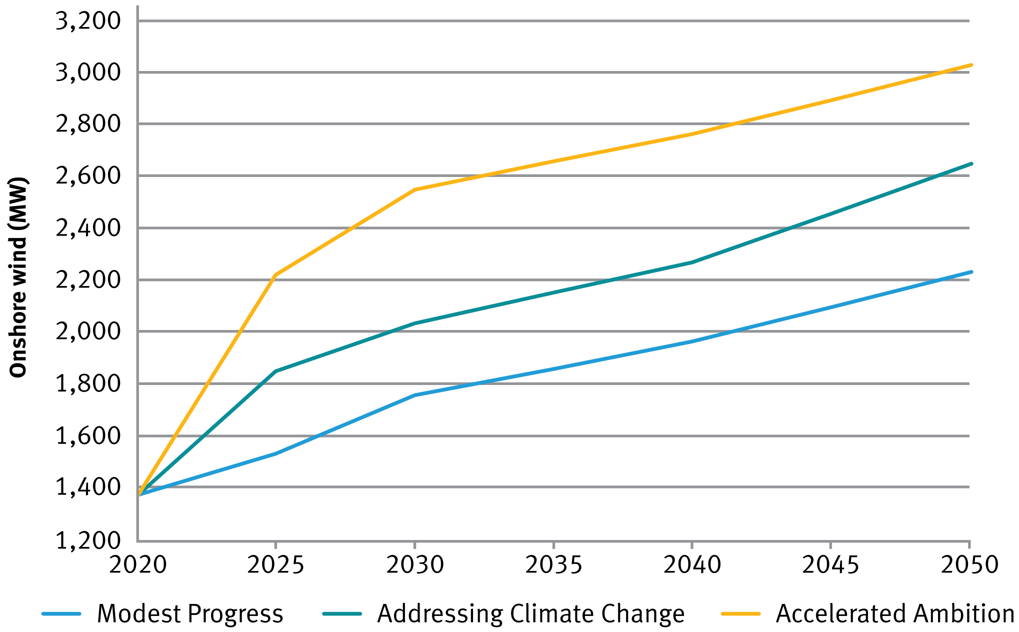


Figure 6.2: Onshore wind installed capacity

Locational information on onshore wind is provided in Table A.1 in **Appendix A**.

6.1.2. Offshore wind

Currently, there are no offshore wind generation connections forecast in Northern Ireland. Previous plans for an offshore wind farm near County Down were withdrawn in 2014.

In GB, offshore wind dominates the future growth of renewable generation. Turbine improvements and falling costs, combined with the development of an Offshore Wind Sector Deal, provide an increase in certainty that offshore developments will proceed in the future. A recent DoE report found that the Northern Irish coastline is not suitable for fixed foundation offshore wind farm development located within 13 km of the coast; as such, the site planned for the County Down wind farm was excluded from the Crown Estate's most recent offshore leasing round.

This does not mean that offshore wind development cannot occur in Northern Irish waters in the future, particularly given the advances being made in alternative technologies, such as floating wind platforms.

To deliver offshore wind generation in Northern Ireland, it is expected that strong government policy will be required to enable such developments. Additionally, experience in GB can be used to help minimise the cost of offshore development to Northern Irish consumers. In **Modest Progress**, we assume that conditions remain unfavourable for offshore wind generation in Northern Ireland. In **Addressing Climate Change** and **Accelerated Ambition**, it is assumed conditions have changed and an offshore wind farm is developed by 2030, with additional development further into the future.

The installed capacity of offshore wind in the scenarios is shown in Figure 6.3.

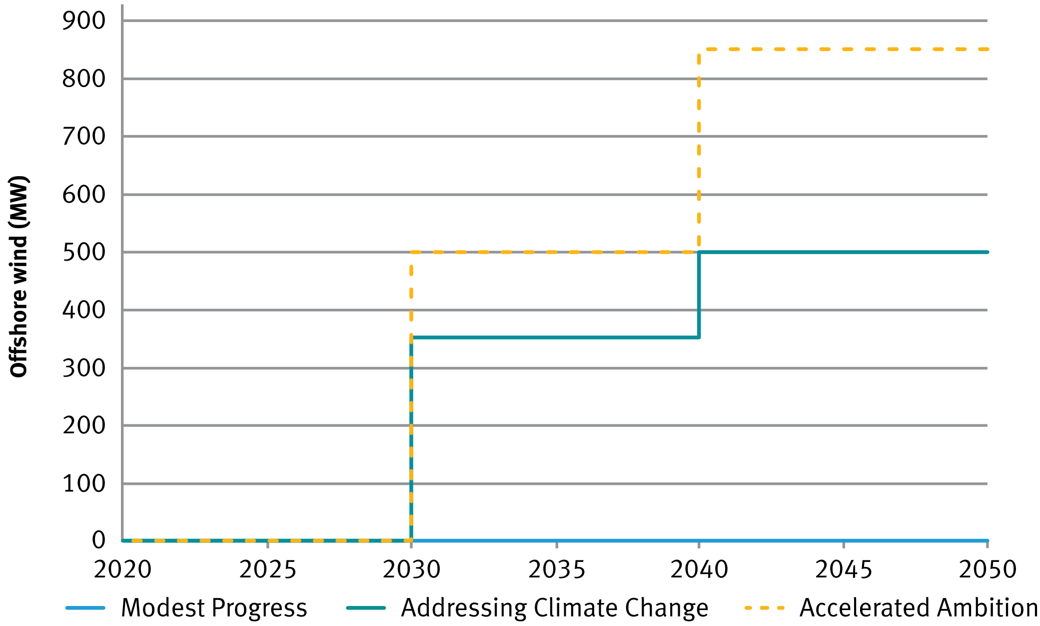


Figure 6.3: Offshore wind installed capacity

Locational information on offshore wind is provided in Table A.2 in **Appendix A**.

6.1.3. Solar photovoltaics

As set out in the GCS, there is approximately 250 MW of solar PV generation connected in Northern Ireland. A little over half of this capacity is large scale PV connected to the transmission or distribution systems, with the remainder being micro-generation solar PV mainly situated on rooftops.

The total solar PV capacity in the scenarios is shown in Figure 6.4. Locational information on solar PV is provided in Table A.3 in **Appendix A**.

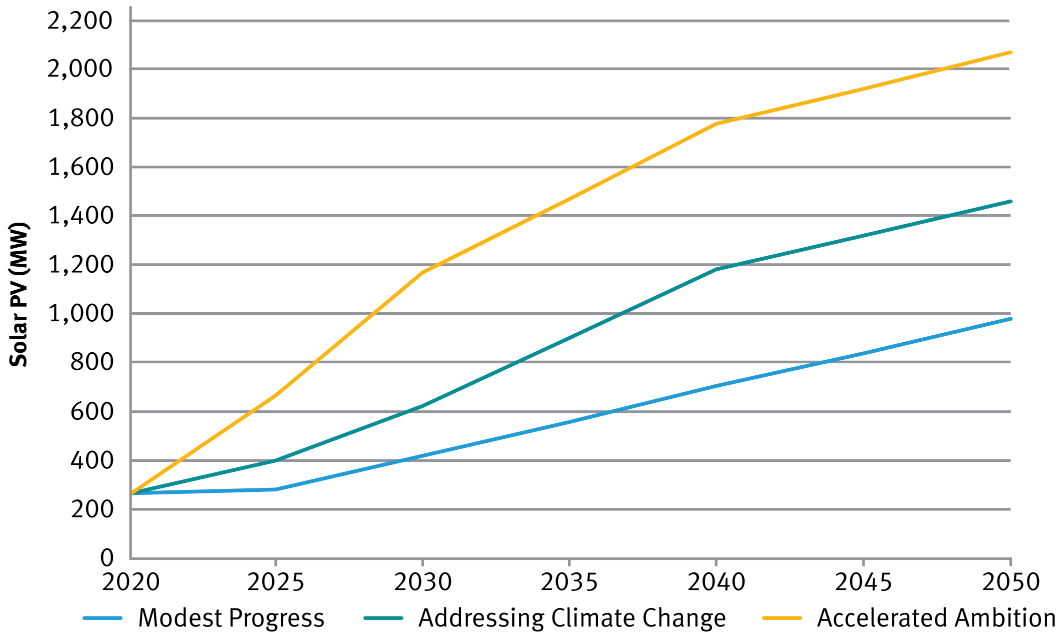


Figure 6.4: Solar PV installed capacity

6.1.4. Micro-generation

Micro-generation functions as a self-consumption technology in some applications, allowing home and business owners to meet some of their own electricity demand. The effect of the self-consumption is that electricity demand may reduce on the transmission and distribution system.

The Micro-NIRO mechanism encouraged the use of renewable generation with a capacity of less than 50 kW to connect to the grid as part of the Northern Ireland Renewable Obligation (NIRO) scheme. The Micro-NIRO includes technologies such as wind turbines, hydro and solar PV. The Micro-NIRO helped rooftop solar PV become one of the most prominent forms of micro-generation in Northern Ireland, leading to an installed capacity of around 100 MW.

In our scenarios, micro PV comprises the majority of all micro generation developed. The installed capacity of micro PV projected in each scenario is shown in Figure 6.5.

With favourable economic conditions and incentives from policies such as the Future Homes Standard, growth in micro PV capacity is highest in **Accelerated Ambition**. Conversely, in **Modest Progress**, uptake is initially very low as unfavourable market conditions means larger grid scale technology is used to deliver RES-E targets by 2030.

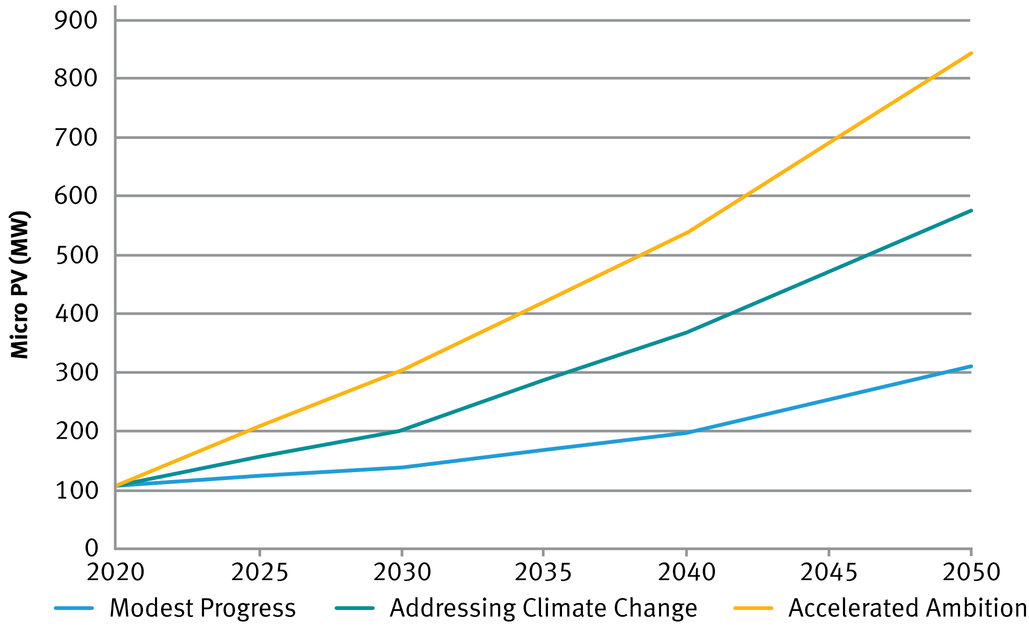


Figure 6.5: Micro PV installed capacity

6.1.5. Biomass and energy from waste

In Northern Ireland, we estimate there to be 64 MW of generation capacity powered by biomass, biogas and landfill gas, and 15 MW of generation capacity powered by waste. This is highlighted in the GCS. We assume a modest growth in biomass across all scenarios. We assume that all biomass generation meets sustainability criteria[28], such as restrictions on fuel types and meeting emissions reductions relative to fossil fuel equivalents. We have assumed that additional waste units will become operational over time in each scenario.

Figure 6.6 shows the cumulative installed capacity from biomass and waste for the three scenarios out to 2050.

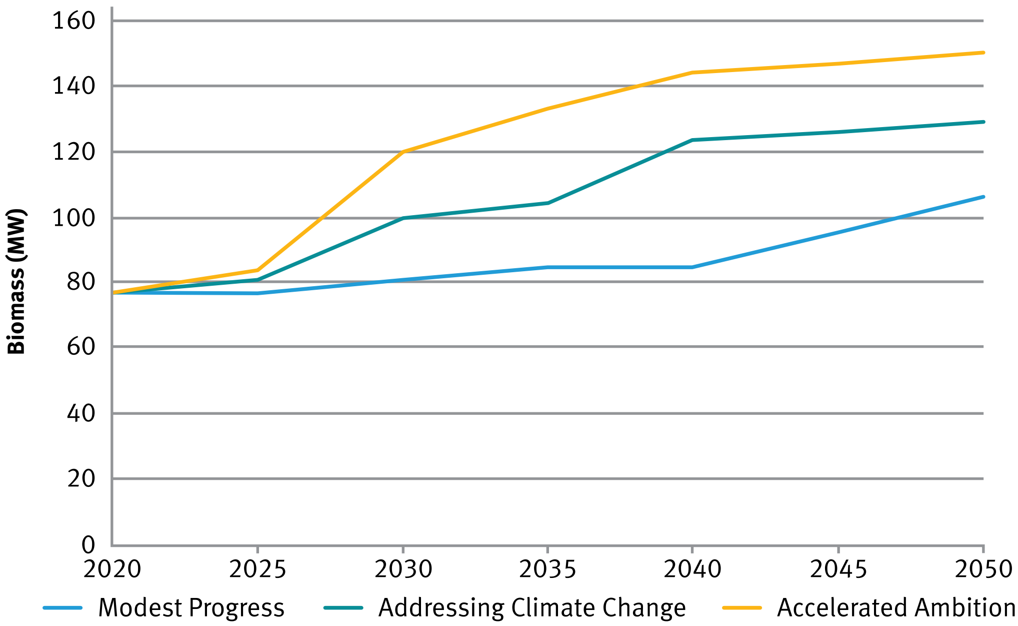


Figure 6.6: Biomass and energy from waste installed capacity

6.1.6. Marine

The Crown Estate has previously awarded development rights off the north coast of Northern Ireland for two tidal energy projects. One project subsequently did not proceed and, to date, no grid connection offer is in place for the remaining project. With the relative immaturity of tidal generation as a renewable energy source, we assume that tidal energy proceeds only in **Accelerated Ambition**.

Figure 6.7 shows the capacities assumed out to 2050. Locational information on marine generation is provided in Table A.4 in **Appendix A**.

28 UK Government, https://www.gov.uk/guidance/sustainability-standards-for-electricity-generation-from-biomass

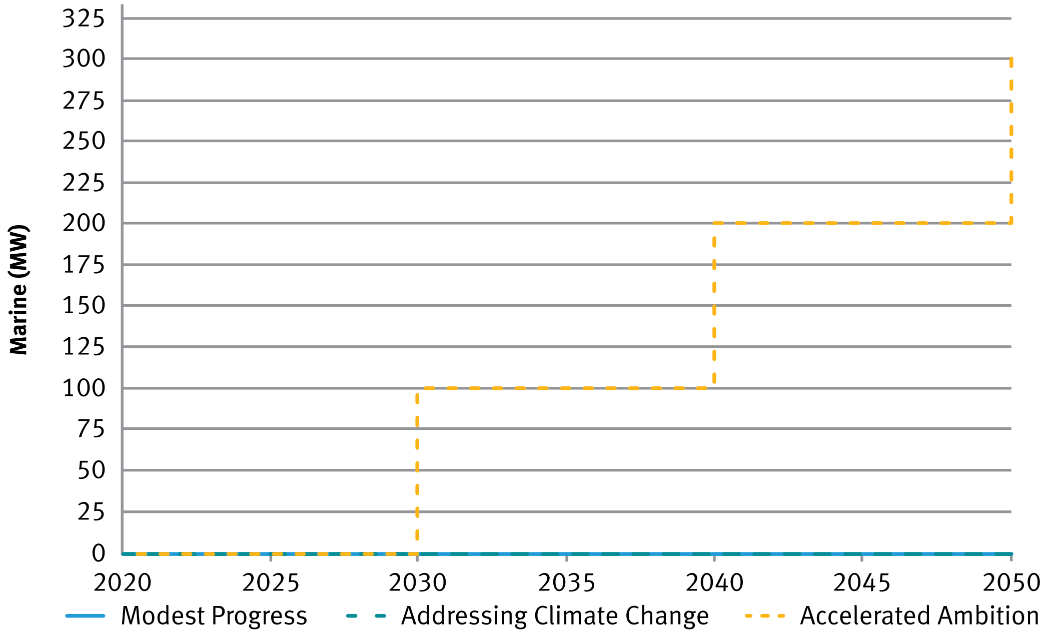


Figure 6.7: Marine (wave and tidal) installed capacity

6.1.7. Hydro Small Scale

The capacity of small-scale hydro in Northern Ireland is approximately 6 MW and consists primarily of a large number of small run-of-the-river projects. While hydro is a well-developed renewable technology, the lack of suitable new locations in Northern Ireland brings limitations. Therefore 6 MW is assumed across the scenarios from 2025 to 2050.

6.1.8. RES-E

A number of technologies are considered when determining the RES-E percentage:

- Renewable generation (wind, water, solar, biomass); and
- Energy from waste is assumed to be 50% renewable.

The assumed capacity factors for the technologies are shown in Table 6.1. The range of average onshore wind capacity factors is as a result of the differing uptake of onshore wind generation and the differing assumptions regarding the repowering of existing sites in each scenario. For our assumptions on repowering, see **Appendix B**.

Table 6.1: Average renewable resource capacity factors

Technology	Onshore wind	Offshore wind	Solar PV	Biomass & waste	Hydro	Marine (wave & tidal)
Capacity factor (%)	31 - 39	45	11	85	35	26

Our three scenarios deliver 60%, 70% and 80% RES-E by 2030. Figure 6.8 shows the RES-E percentage for each scenario out to 2050.

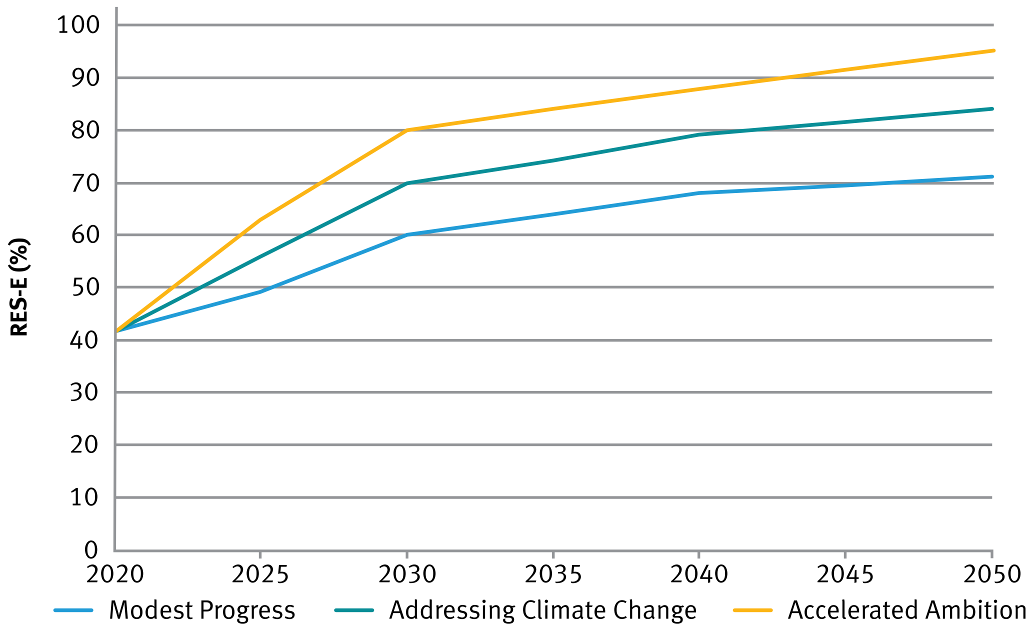


Figure 6.8: Electricity sourced from renewable energy sources

Achieving the RES-E targets set out in the scenarios requires a step change in growth of renewable generation capacity. This is especially true for **Accelerated Ambition**, given high demand growth resulting from significant electrification of heating and transport.

6.2. Fossil fuel generation

Fossil fuel generation has been the foundation of the industrial revolution. However, there is a global awakening to the effect that fossil fuel-based emissions are having on our health and climate. Major technological advancements have resulted in renewable generation technology being increasingly cost competitive with fossil fuel-based generation.

A major advantage of fossil fuel generation is that it produces a dependable supply of electricity. Fossil fuel plants are flexible and fully dispatchable; this type of generation can provide security of supply when wind and solar resources are not available.

Conversely, fossil fuels are subject to large price uncertainties, owing to the geopolitical nature of the resources. Although more capital-intensive than fossil fuels energy types, renewable technologies provide long term price certainty and a hedge against fluctuations in global commodity prices. Additionally, they have zero emissions, and current and future trends suggest more integration of renewable generation is needed if decarbonisation targets are to be met. As a consequence, the running hours or capacity factors of fossil fuel generation will continue to reduce.

To ensure that power system security of supply standards are met, SEM auctions for capacity allow fossil fuel plants with low capacity factors to recover costs. For the 2019/2020 T-1 capacity auction[29], 84% of the de-rated capacity was provided by gas and steam turbines, the remainder coming from interconnection, demand-side units, pumped hydroelectric storage, hydro and wind. T-4 capacity auctions are also held on an annual basis; these auctions encourage new capacity to be delivered in four years' time, following the auction.

The output from the auctions and de-rating factors are considered with the framework of the scenarios to ensure that the scenarios supply and demand are met for each hour according to the security of supply standards. The 2023/2024 T-4 capacity auction is due to complete towards the end of the TESNI 2020 process. The results will be available on the SONI website[30], but will not inform the scenarios in TESNI 2020.

29 See http://lg.sem-o.com/ISEM/Pages/ISEMCapacityMarket.aspx for information on capacity auctions.
30 See http://www.soni.ltd.uk/newsroom/press-releases/t-4-20232024/

The following sections will describe how fossil fuel technologies are considered within each scenario.

6.2.1. Coal

Historically, coal-fired generation has provided consistent base load power in Northern Ireland. Coal-fired generation is a high emissions technology. The European Union's Industrial Emissions Directive[31] (IED) sets limits on pollutant emissions from industrial installations. There would be high retrofit costs to enable coal-fired generation to comply with the IED. Present UK policy is to end all unabated[32] coal fired generation in GB by 2025, and we assume such a policy will be adopted in Northern Ireland. Phase-out of coal-fired generation is reflected in our scenarios with no coal generation assumed in all study years from 2025.

6.2.2. Oil

Typically, oil-fired generation provides peaking capacity to the system. In recent years, it has provided rapid start up generation, giving capacity at short notice. The overall capacity of distillate oil generation is expected to reduce over the next two decades. The timing of changes to the oil fleet varies depending on the scenario storyline, changes in the peak demand and availability of alternative peaking capacities such as battery technologies, demand side response, interconnection or other flexibility options.

In **Addressing Climate Change** and **Accelerated Ambition**, two of the seven existing distillate oil units are assumed to be still in operation by 2030. **Modest Progress** assumes that by 2030 three units remain. By 2040 all distillate oil generation is assumed to have ceased operation, with **Accelerated Ambition** seeing all units out of operation by 2035. The installed capacity of distillate oil generation in the scenarios is shown in Figure 6.9.

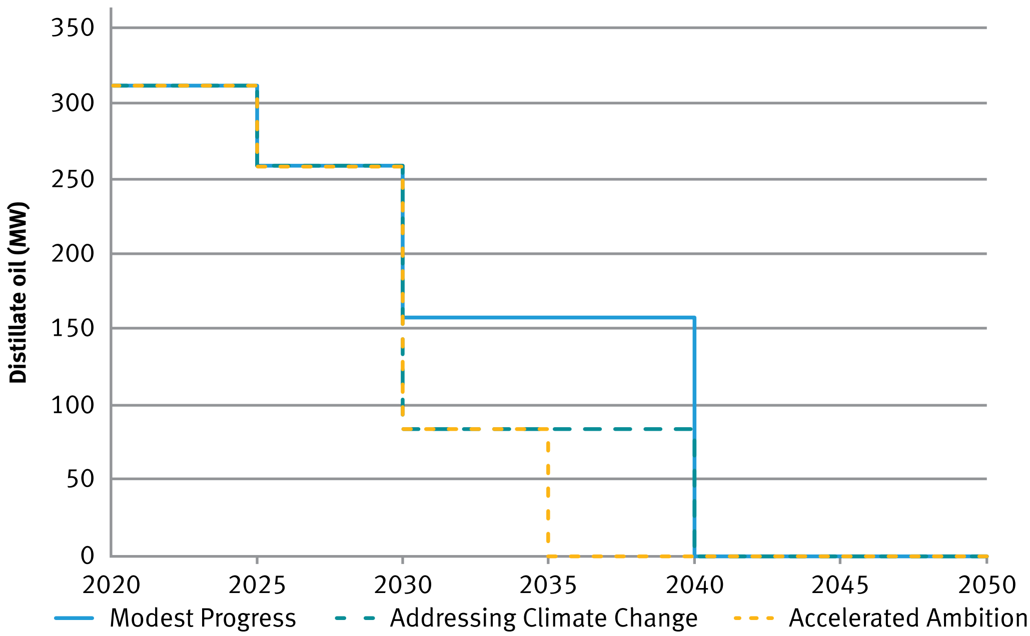


Figure 6.9: Distillate oil generation installed capacities

31 European Union, The Industrial Emissions Directive, 2012/75/EU

32 Unabated generation is generation where emissions are not treated to remove CO_2 and other pollutants.

6.2.3. Gas

Gas fuelled power stations are a lower carbon alternative to coal-fired power stations. Fuel price forecasts, such as the IEA World Energy Outlook 2018[33] Sustainable Development Scenario, show that low carbon scenarios result in increased carbon costs. This makes gas power generation more cost effective than coal power stations for base load generation. Gas is often viewed as a transition fuel in the pathway to a low carbon economy. Gas power plants will continue to have a strong role in maintaining the demand and supply balance within the context of Northern Ireland's scenarios out to 2050.

In 2018, the gas-fired generation was 45.6% of the overall fuel mix. Gas-fired generation consists of combined cycle gas turbines (CCGTs), open cycle gas turbines (OCGTs) and combined heat and power (CHP). Gas-fired generation will operate to ensure security of supply in Northern Ireland following planned closures of major coal-fired units. Flexible gas-fired generation is also expected to help manage the integration of high levels of intermittent renewables, by providing rapid start/stop capabilities. In advance of this, two-shifting of CCGTs can be utilised, which is where they operate with a daily start/stop regime to meet peaks in demand and renewable generation output. Two-shifting, however, has implications for generation that is designed to operate as base load, and can lead to increased operational issues as well as a reduction in efficiency of the generator.

A new 500 MW CCGT is assumed to connect in both **Modest Progress** and **Addressing Climate Change** before 2030, as shown in Figure 6.10. In **Accelerated Ambition**, we assume that one of the existing CCGTs is decommissioned and replaced with a new CCGT fitted with carbon capture and storage technology by 2040. A similar assumption is made for 2045 in **Addressing Climate Change**.

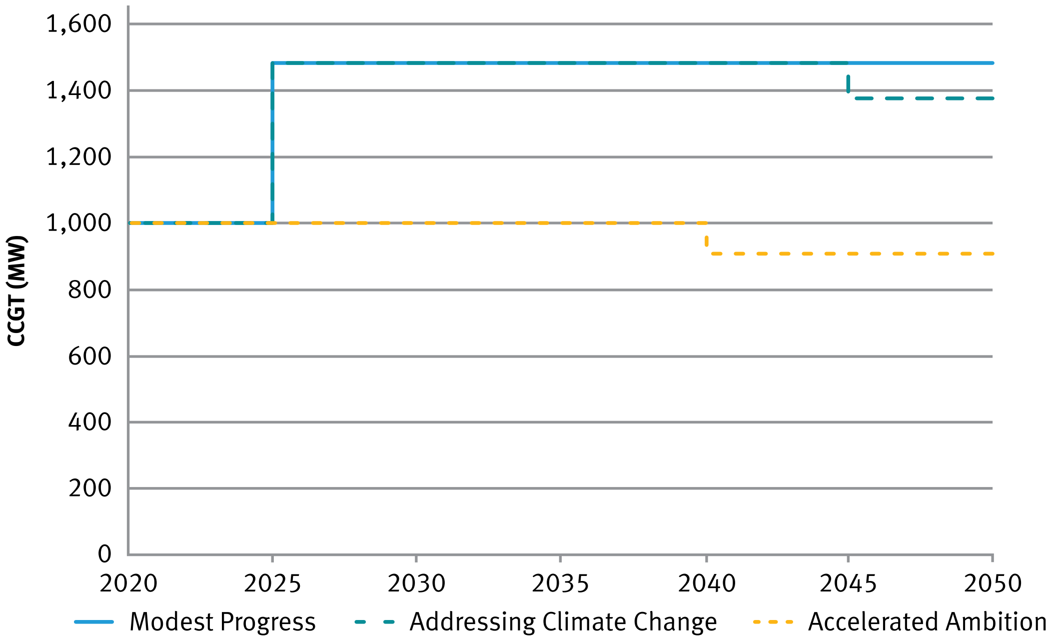


Figure 6.10: CCGT installed capacity

Figure 6.11 shows that new OCGT capacity is assumed to be installed by 2030 in all scenarios. With the lowest installed capacity of CCGT and largest quantities of intermittent renewable generation, **Accelerated Ambition** sees significant developments of new gas-fired OCGT units.

33 See https://www.iea.org/reports/world-energy-outlook-2018

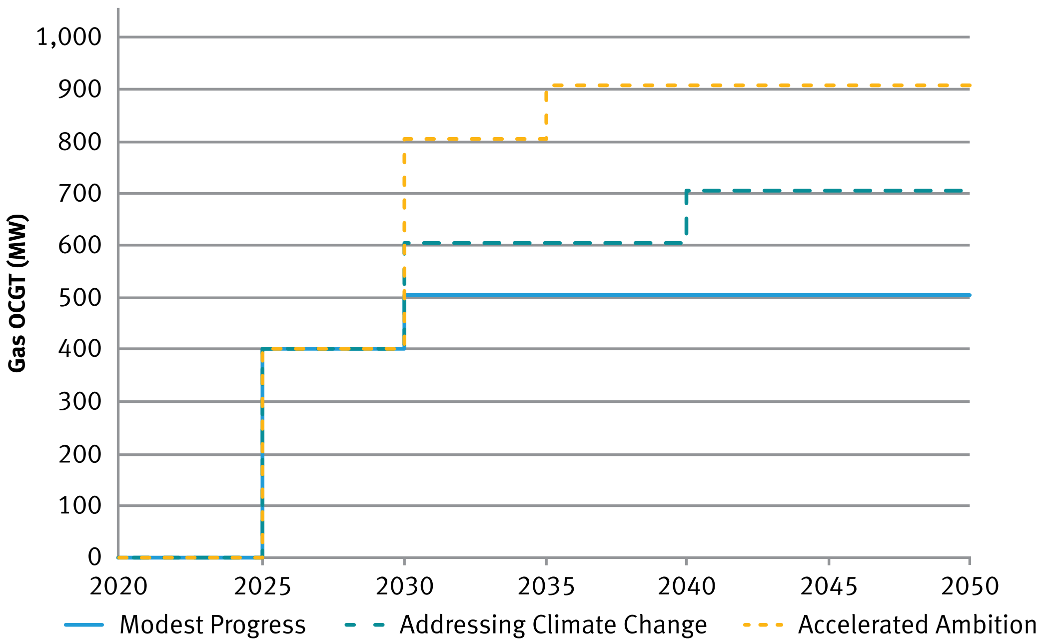


Figure 6.11: OCGT installed capacity

Locational information on gas generation is provided in Table A.5 in **Appendix A**.

6.2.4. Carbon capture utilisation and storage

Carbon Capture and Storage (CCS) is the process of capturing, transporting and storing carbon dioxide before it is released into the atmosphere. CCS is a technology which may be required to take the power system to net-zero emissions. The economics of CCS mean that a high utility of the CCS process is required, along with a suitable infrastructure to store the compressed gas. Up to 100% of emissions released from burning fossil fuels in generation can be captured from the flue. Carbon transportation is via pipeline or ship, with geological formations, such as depleted oil and gas fields, acting as storage sites. The CCC has recommended that carbon capture technology is investigated as a potential method for decarbonising Northern Ireland's power sector.

In the electricity sector, it is assumed that CCS is deployed on new or existing CCGTs. We assume that CCS is operational in **Accelerated Ambition** by 2040. It is deployed on a new CCGT, which replaces one of the existing CCGTs, and therefore emissions are captured from 50% of the gas generation fleet. In **Addressing Climate Change**, we assume a similar change occurs in 2045.

The non-deployment of CCS in **Modest Progress** reflects uncertainty factors regarding what policy, regulatory, legal and business model frameworks make CCS commercially viable. It is an emerging technology, requiring strong government policy and support to underpin the significant capital expenditure; we assume such support is not available in **Modest Progress**.

6.3. Interconnection

Interconnection facilitates the transport of electricity between two transmission systems. It can provide multiple benefits, such as:

- The integration of renewable generation through the reduction of generator dispatch down;
- A reduction in the wholesale price of electricity;
- Improvement to capacity adequacy; and
- Facilitation of the sharing of reserve.

Northern Ireland is presently interconnected to GB through the Moyle High Voltage Direct Current (HVDC) interconnector. Ireland and Northern Ireland are also connected through a High Voltage Alternating Current (HVAC) connection. EirGrid and SONI are currently progressing the North South Interconnector, which will increase the total transfer capacity between Ireland and Northern Ireland to 1,100 MW.

In the context of the SEM, it is worth noting the existing and planned interconnectors between Ireland and GB and Ireland and France, namely:

- The existing East-West interconnector between Ireland and GB;
- The planned Greenlink interconnector between Ireland and GB; and
- The planned Celtic interconnector between Ireland and France.

As we dispatch the electricity system on an all-island basis, additional interconnection capacity assumed for TESNI 2020 has been informed by the interconnection assumptions used by EirGrid in their TES 2019 report[34], as well as additional opportunities[35] identified in ENTOS-E's TYNDP 2018.

Figure 6.12 shows the annual HVDC interconnector flows in our scenarios. As the capacity of renewable generation increases in our scenarios, we expect the SEM to become a net exporter.

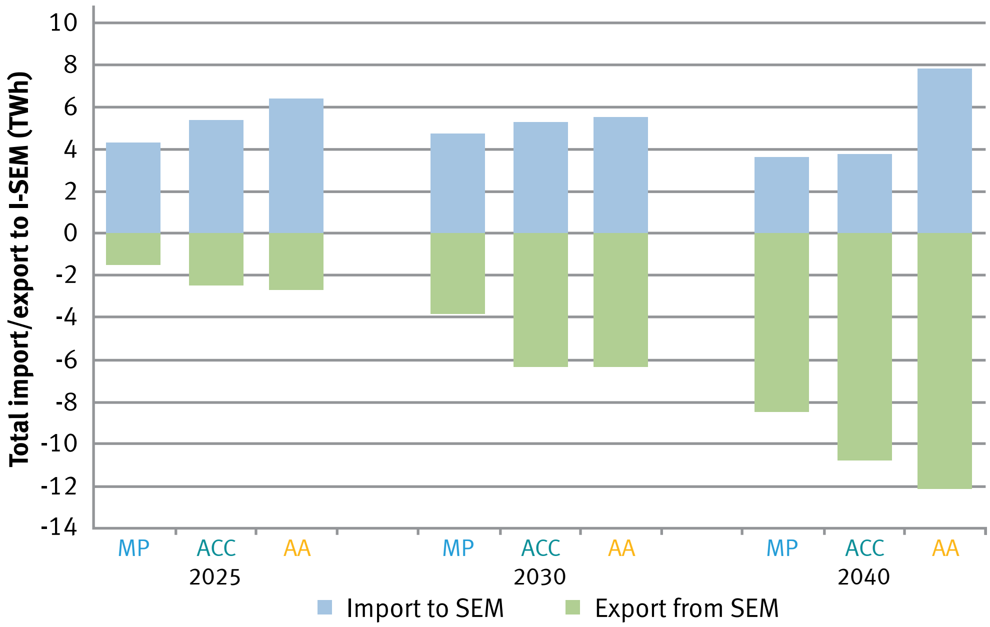


Figure 6.12: HVDC interconnector annual flows in the scenarios

34 TES 2019, http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-TES-2019-Report.pdf
35 TYNDP 2018, https://tyndp.entsoe.eu/tyndp2018/power-system-2040/

6.4. Storage and Demand Side Management

Sources of flexibility are required to ensure variable renewable generation can be integrated into the electricity system in a secure and efficient manner.

For TESNI 2020, storage and demand side management (DSM) volumes are informed by analysing capacity adequacy, flexibility and reserve requirements on an all-island basis. In this regard, TESNI 2020 should be consulted together with EirGrid's TES 2019.

Capacity adequacy is evaluated as detailed in the GCS.

Flexibility is evaluated based on the potential ramps associated with the total output of the installed variable renewable generation capacity. Flexibility can be provided by energy storage, interconnection and fast starting generation.

As well as DSM and battery energy storage (BES), other sources of upward reserve include interconnection at zero export, interconnection with headroom when importing and part-loaded conventional generation.

Figure 6.13 shows the capacities assumed for BES and DSM in the scenarios.

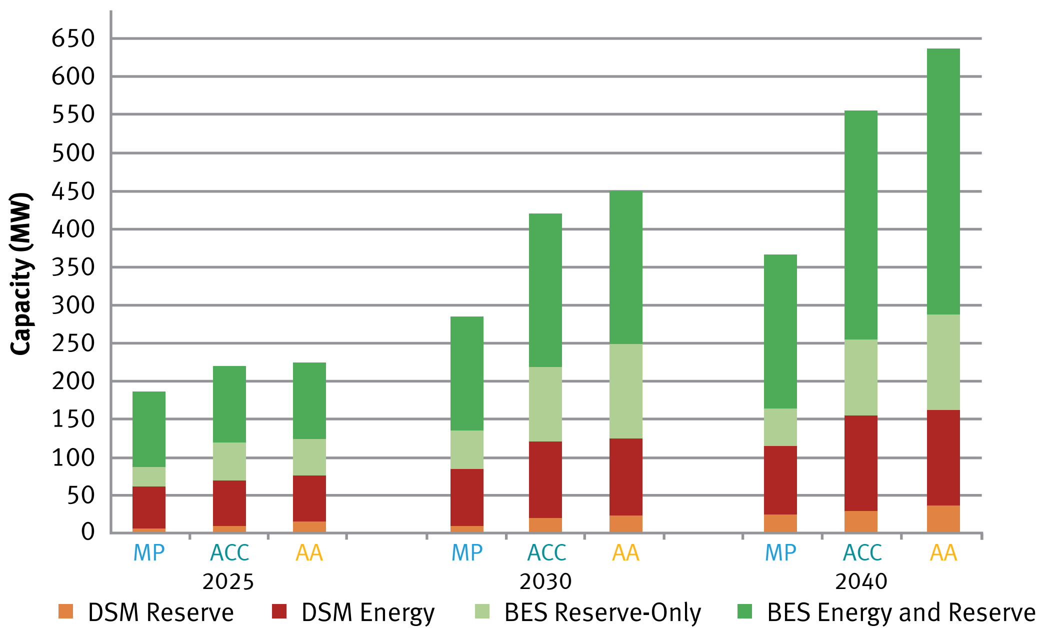


Figure 6.13: Storage and DSM installed capacity in the scenarios

7. Gas

7. Gas

Figure 7.1 shows the contribution and composition of gas in our scenarios out to 2050.

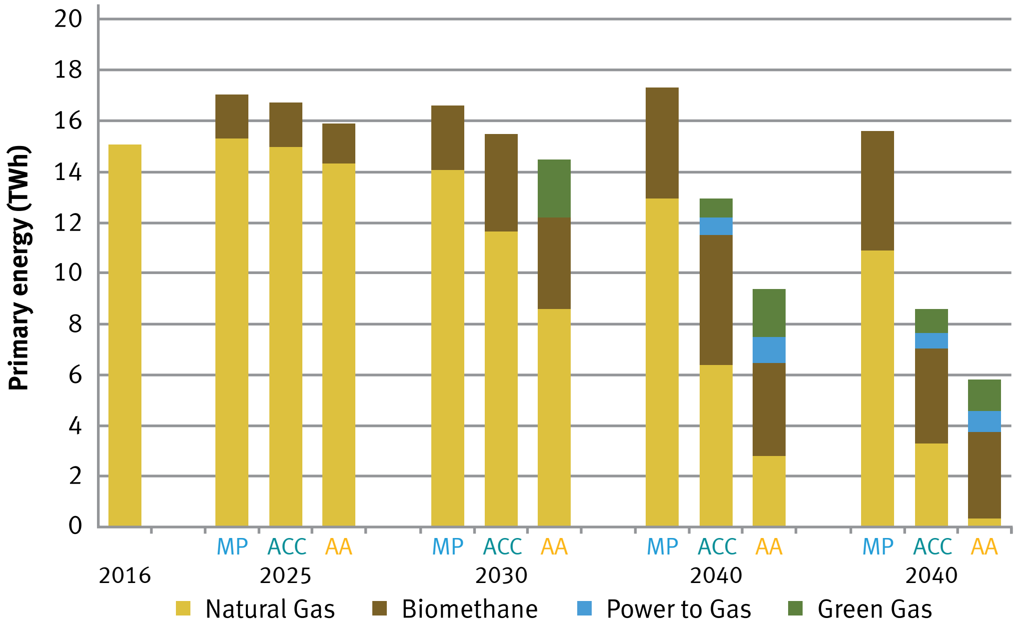


Figure 7.1: Sources of gas in the scenarios

Natural gas continues to play a prominent role in **Modest Progress** out to 2050, as it is assumed required policies and supports are not in place to enable many new technologies which deliver low carbon gas to progress. Additionally, with lower emission reduction and RES-E targets, **Modest Progress** sees a much greater share of electricity produced from gas-fired generation than in other scenarios.

The role of natural gas declines in both **Addressing Climate Change** and **Accelerated Ambition**, and by 2050 has a minimal contribution in **Accelerated Ambition**.

Biomethane is a gas which is naturally produced by anaerobic digestion of organic material. It is a low carbon source of energy as it utilises gases produced from the digestion process that would otherwise be released into the atmosphere naturally. Today, the majority of inputs to anaerobic digestion are silage and whole crops such as maize. Given the large share of livestock-based agriculture within the agriculture sector in Northern Ireland, there is potentially a large supply of manure available to enable significant biomethane production.

Biomethane can also be produced through biomass gasification. This process involves the burning of carbonaceous biomass materials, converting them into gas.

Since 2016, both anaerobic digestion and gasification processes are currently in operation in Northern Ireland today. We assume biomethane plays a role in all scenarios, particularly from 2030 onwards.

Power to Gas is another technology which could play a role in the energy transition. Power to Gas essentially allows energy from renewable generation to be utilised in final consumption even if there is no electrical demand for it at a given point in time. Excess renewable electricity is converted into an alternative energy carrier such as hydrogen or synthetic methane. This energy can then be used to meet gas demand. Alternative, it can be stored within the gas system for use at a later period, typically between seasons.

To be viable in terms of emissions reduction, it requires significant levels of excess renewable electricity generation on the system. It also requires significant investment. As such, we assume it develops in later years in both **Addressing Climate Change** and **Accelerated Ambition**.

8. Decarbonisation

8. Decarbonisation

To assess the level of decarbonisation in our scenarios, we model them within an all-island power system dispatch model. This allows us to include operational constraints, which reflect how we schedule and dispatch generation to ensure system security is maintained. Details on the dispatch modelling, including the assumed operational constraints, are provided in **Appendix C**.

Figure 8.1 shows the total CO_2 emissions in the power sector for each of the scenarios. It also includes historic[36] data from 2010 to 2017, indicated in black. In all scenarios there is a significant decrease in emissions out to 2030.

Demand in **Modest Progress** is lower in 2030 than in the other two scenarios as a result of lower underlying growth and a slower uptake in electric vehicles and electric heating. In spite of this, emissions in 2030 are higher in **Modest Progress**. The higher RES-E targets for 2030 in both **Addressing Climate Change** and **Accelerated Ambition** results in lower emissions in these scenarios, despite there being higher demand for electricity.

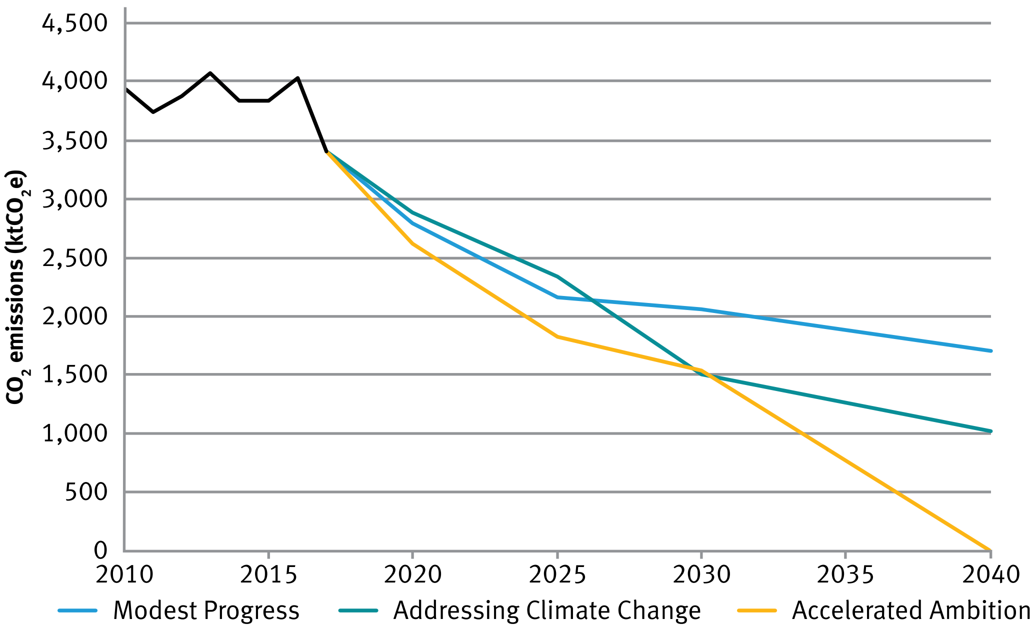


Figure 8.1: Total power sector CO_2 emissions in the scenarios

With a high level of renewable gas as set out in **Section 7**, an assumed carbon capture and storage generator in place and a high level of RES-E, the power system is fully decarbonised by 2040 in **Accelerated Ambition**.

In spite of **Accelerated Ambition** achieving 80% RES-E by 2030, compared to 70% in **Addressing Climate Change**, total emissions in both scenarios are very similar in 2030. This is as a result of the higher underlying demand growth in **Accelerated Ambition**, and the faster transition to electric vehicles and electric heating.

Figure 8.2 shows the total CO_2 emission intensity in the power sector for each of the scenarios. It again includes historic data from 2010 to 2017, indicated in black. Taking into account the CO_2 emission intensity for each scenario demonstrates that emissions per unit of electricity demand in 2030 are lower in **Accelerated Ambition** than in **Addressing Climate Change**.

36 Data from https://www.daera-ni.gov.uk/publications/northern-ireland-carbon-intensity-indicators-2019

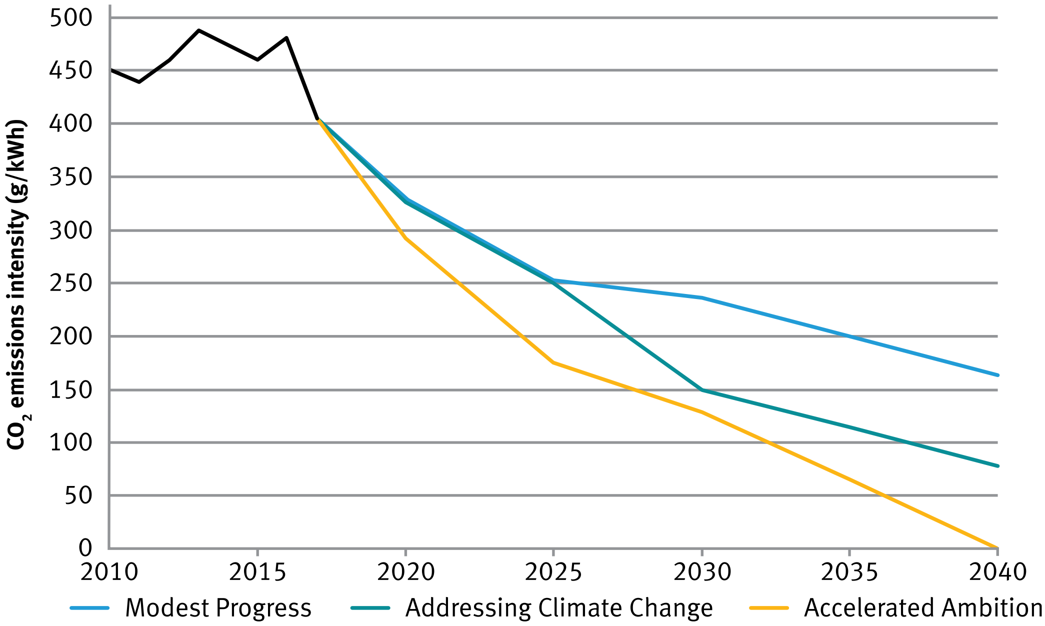


Figure 8.2: Total power sector CO_2 emission intensity in the scenarios

9. Generation dispatch down

9. Generation dispatch down

The All-Island Quarterly Wind Dispatch Down[37] report identified that in 2019, 10.7% of available generation from large scale wind farms in Northern Ireland was subject to 'dispatch down'. This is required for several reasons, including:

- Preventing possible overloading of the transmission system by constraining generation; and
- Maintaining system security and stability through curtailment of generation.

We use a metric called the System Non-Synchronous Penetration (SNSP), which describes the level of non-synchronous generation that can be facilitated on the system at any one time. Through the Delivering a Secure, Sustainable Electricity System (DS3), we have increased the SNSP from 50% to 65%. This has allowed for a larger utilisation of variable renewable energy sources, contributing to the decarbonisation of the power system and achieving greater value for consumers. To enable the ambitious levels of decarbonisation in our scenarios, the level of variable renewable generation on the system will have to be increased further. As part of our 2020-25 Strategy, we are targeting an increase of the SNSP to 95% by 2030.

On a large electricity system, such as the continental European transmission grid, levels of renewable dispatch down tend to be low, as Member States are strongly interconnected and there is a varied portfolio of renewable generation and varied weather patterns over large regions. The all-island transmission system, comprising Northern Ireland and Ireland, is small in comparison, with limited interconnection capacity to neighbouring systems. Unlike in continental Europe, the renewable energy portfolio is dominated by wind generation. As a result, renewable dispatch down is much higher, as it is harder to balance available renewable generation output with demand while adhering to operational constraints, and there is less capacity to export excess generation.

Our modelling allows the level of renewable dispatch down to be assessed in our scenarios into the future. Details on the dispatch modelling process, including assumed operational constraints, are provided in **Appendix C**. We can assess what proportion of that is simply an oversupply of renewable generation. Oversupply of renewable generation is when there is an excess of renewable electricity generation available versus electricity demand, and that generation cannot be exported or stored. As the level of renewable generation capacity increases over time in our scenarios, we expect oversupply of generation to increase.

Figure 9.1 shows the levels of renewable dispatch down in our scenarios. Figure 9.1 also indicates what proportion of the renewable dispatch down is related to oversupply of RES.

Renewable dispatch down is assessed and presented on an all-island basis; it does not include dispatch down associated with network constraints.

37 http://www.eirgridgroup.com/site-files/library/EirGrid/2019-Qtrly-Wind-Dispatch-Down-Report.pdf

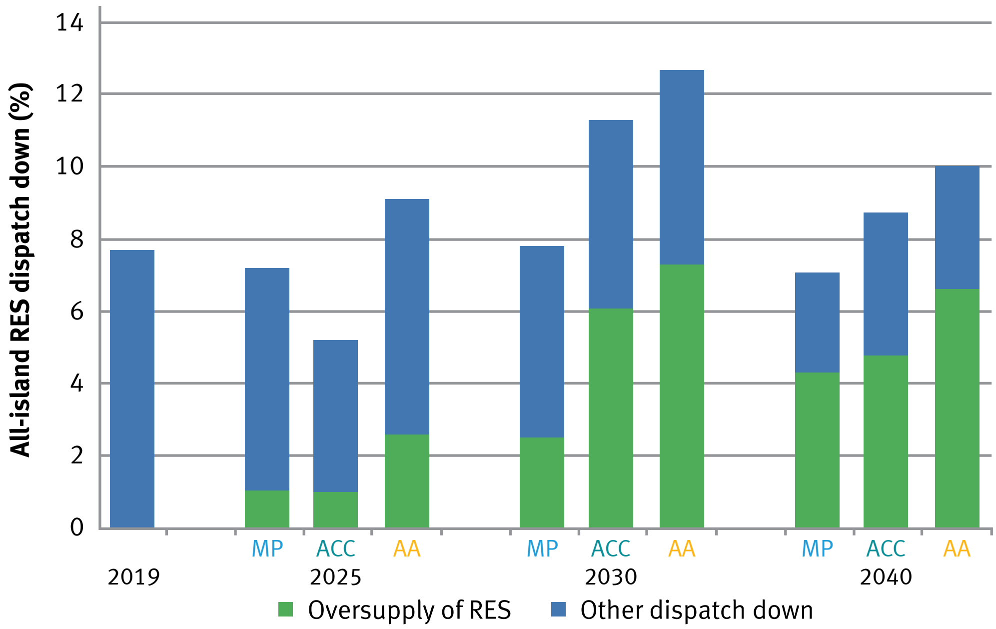


Figure 9.1: Total all-island dispatch down in the scenarios

With the inclusion of the new North-South Interconnector, the level of dispatch down falls in 2025 except in **Accelerated Ambition**, as a result of the rapid growth in renewable generation capacity in this scenario. By 2030, both **Addressing Climate Change** and **Accelerated Ambition** show high levels of dispatch down, driven again by the high capacities of renewable generation in these scenarios. Additionally, over 50% of all dispatch down is related to an oversupply of renewable generation versus demand in these scenarios in 2030.

By 2040, the level of dispatch down falls in all scenarios, driven by an increase in interconnection with neighbouring systems and addressing operational constraints. However, dispatch down related to the level of oversupply of renewable generation continues to remain high.

Ultimately, future markets will determine how this excess of available electricity from renewable generation can be best utilised.

We do not analyse the level of dispatch down resulting from network constraints as part TESNI 2020, however, the forthcoming TESNI 2020 System Needs Assessment will highlight areas of the transmission grid at risk of overloading.

10. Next Steps

10. Next Steps

We will now use the final scenarios, detailed in this report, to conduct a number of different power system studies for each scenario out to 2040. These studies will help us identify any future needs on the transmission system brought about by changes in electricity generation, electricity demand, electricity storage or interconnection.

The results will be presented in TESNI 2020 System Needs Assessment report which will be published later in the year. This report will conclude the current scenario development cycle.

For more information on TESNI 2020, please visit our website. Alternatively, you can email your views on TESNI 2020 to **scenarios@soni.ltd.uk** and one of our team will be in touch.

Appendix A

Appendix A

This section outlines the assumptions regarding where various demand and generation technologies may connect in the future. Modelling future locations enables us to identify potential areas of stress on the network which require further investigation.

For TESNI 2020, we use the eleven council areas in Northern Ireland to communicate the demand and generation information. For generation, the council area describes the point of connection of the generation to the transmission grid; it may not reflect the location of the generation itself. The council areas are shown in Figure A.1.

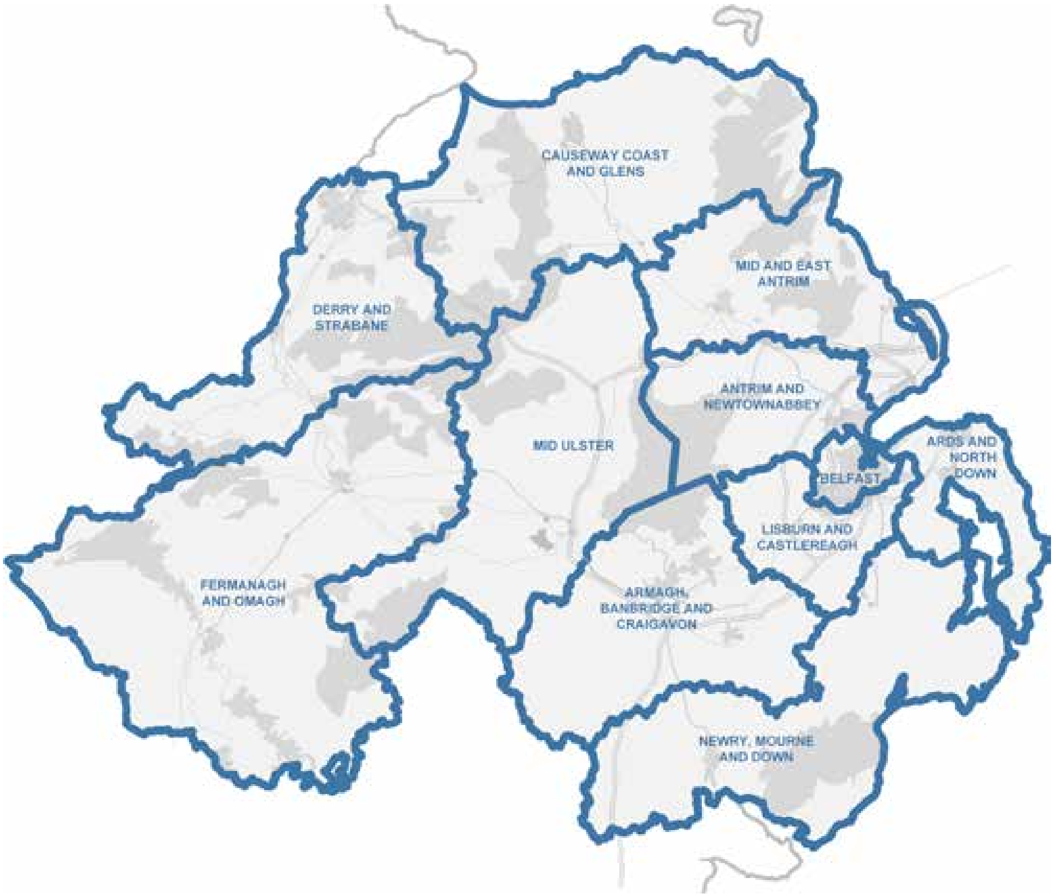


Figure A.1: Council areas in Northern Ireland

A.1. Onshore wind

The distribution of onshore wind per council area in Northern Ireland, for each scenario, is displayed in Table A.1.

Table A.1: Onshore wind locations and capacity (MW)

	2025			2030			2040		
Council Area	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Antrim and Newtownabbey	26	50	51	50	52	51	50	52	54
Ards and North Down	6	7	7	7	7	7	7	8	7
Armagh, Banbridge & Craigavon	15	17	18	18	22	18	18	22	18
Belfast	4	4	4	4	4	4	4	4	4
Causeway Coast and Glens	396	403	531	388	451	619	489	510	638
Derry and Strabane	324	375	388	375	377	469	403	467	543
Fermanagh and Omagh	492	603	676	637	712	717	715	795	816
Lisburn and Castlereagh	6	6	7	7	7	7	7	7	7
Mid and East Antrim	131	133	184	133	139	184	133	139	191
Mid Ulster	115	236	291	119	246	411	119	246	429
Newry, Mourne and Down	14	14	55	15	17	55	15	17	55
Total	**1529**	**1848**	**2212**	**1753**	**2034**	**2542**	**1960**	**2267**	**2762**

A.2. Offshore wind

The distribution of offshore wind per council area in Northern Ireland, for each scenario, is displayed in Table A.2.

Table A.2: Offshore wind locations and capacity (MW)

	2025			2030			2040		
Council Area	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Antrim and Newtownabbey	0	0	0	0	0	0	0	0	0
Ards and North Down	0	0	0	0	0	0	0	0	0
Armagh, Banbridge & Craigavon	0	0	0	0	0	0	0	0	0
Belfast	0	0	0	0	0	0	0	0	0
Causeway Coast and Glens	0	0	0	0	0	0	0	0	350
Derry and Strabane	0	0	0	0	0	0	0	0	0
Fermanagh and Omagh	0	0	0	0	0	0	0	0	0
Lisburn and Castlereagh	0	0	0	0	350	500	0	500	500
Mid and East Antrim	0	0	0	0	0	0	0	0	0
Mid Ulster	0	0	0	0	0	0	0	0	0
Newry, Mourne and Down	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**350**	**500**	**0**	**500**	**850**

A.3. Solar PV

The distribution of solar PV per council area in Northern Ireland, for each scenario, is displayed in Table A.3.

Table A.3: Solar PV locations and capacity (MW)

	2025			2030			2040		
Council Area	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Antrim and Newtownabbey	61	80	126	86	117	216	135	210	307
Ards and North Down	12	23	49	25	44	99	53	100	158
Armagh, Banbridge & Craigavon	23	43	92	49	83	186	101	186	287
Belfast	18	22	29	19	28	42	28	51	75
Causeway Coast and Glens	62	81	129	88	120	219	137	215	315
Derry and Strabane	9	12	15	10	15	22	15	27	40
Fermanagh and Omagh	9	12	15	10	15	22	15	27	40
Lisburn and Castlereagh	53	75	119	78	110	208	127	203	301
Mid and East Antrim	16	26	52	29	47	100	56	100	156
Mid Ulster	10	13	17	11	17	25	16	30	44
Newry, Mourne and Down	13	16	21	14	20	30	20	37	54
Total	**285**	**399**	**665**	**421**	**617**	**1169**	**702**	**1185**	**1777**

A.4. Marine

The distribution of marine generation per council area in Northern Ireland, for each scenario, is displayed in Table A.4.

Table A.4: Marine locations and capacity (MW)

	2025			2030			2040		
Council Area	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Antrim and Newtownabbey	0	0	0	0	0	0	0	0	0
Ards and North Down	0	0	0	0	0	0	0	0	0
Armagh, Banbridge & Craigavon	0	0	0	0	0	0	0	0	0
Belfast	0	0	0	0	0	0	0	0	0
Causeway Coast and Glens	0	0	0	0	0	100	0	0	200
Derry and Strabane	0	0	0	0	0	0	0	0	0
Fermanagh and Omagh	0	0	0	0	0	0	0	0	0
Lisburn and Castlereagh	0	0	0	0	0	0	0	0	0
Mid and East Antrim	0	0	0	0	0	0	0	0	0
Mid Ulster	0	0	0	0	0	0	0	0	0
Newry, Mourne and Down	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**100**	**0**	**0**	**200**

A.5. Gas generation

The distribution of gas generation per council area in Northern Ireland, for each scenario, is displayed in Table A.5.

Table A.5: Gas generation locations and capacity (MW)

	2025			2030			2040		
Council Area	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Antrim and Newtownabbey	0	0	0	0	0	0	0	0	0
Ards and North Down	0	0	0	0	0	0	0	0	0
Armagh, Banbridge & Craigavon	0	0	0	0	0	0	0	0	0
Belfast	0	0	0	0	100	0	0	100	100
Causeway Coast and Glens	0	0	0	0	0	0	0	0	0
Derry and Strabane	408	408	408	408	408	408	408	408	408
Fermanagh and Omagh	0	0	0	0	0	0	0	0	0
Lisburn and Castlereagh	480	480	0	480	480	0	480	480	0
Mid and East Antrim	998	998	998	1098	1098	1398	1098	1198	1305
Mid Ulster	0	0	0	0	0	0	0	0	0
Newry, Mourne and Down	0	0	0	0	0	0	0	0	0
Total	**1886**	**1886**	**1406**	**1986**	**2086**	**1806**	**1986**	**2186**	**1813**

A.6. Heat Pumps

The uptake of heat pumps per council area in Northern Ireland, for each scenario, is displayed in Table A.6.

Table A.6: Installed heat pumps per council area (1000s)

	2025			2030			2040		
Council Area	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Antrim and Newtownabbey	1.4	3.5	7.8	2.2	5.7	12.6	12.3	26.0	35.4
Ards and North Down	1.4	3.7	9.3	2.2	5.8	14.1	12.9	30.4	40.6
Armagh, Banbridge & Craigavon	1.9	5.0	11.8	3.1	7.9	17.7	17.6	36.8	49.9
Belfast	2.3	5.6	12.3	3.6	9.6	28.2	19.9	50.1	83.2
Causeway Coast and Glens	1.0	3.1	8.5	1.6	4.5	11.9	10.4	26.6	34.7
Derry and Strabane	1.1	2.9	7.0	1.8	4.7	11.9	10.3	23.4	34.5
Fermanagh and Omagh	0.9	2.6	7.0	1.4	3.8	9.3	8.7	21.2	26.8
Lisburn and Castlereagh	2.0	4.6	9.6	3.2	7.8	14.7	16.8	31.8	39.8
Mid and East Antrim	1.0	2.8	7.2	1.6	4.4	11.3	9.8	23.5	32.7
Mid Ulster	1.2	3.3	8.3	2.0	5.1	11.3	11.6	25.2	31.9
Newry, Mourne and Down	1.8	4.6	10.7	2.9	7.4	15.4	16.4	33.8	42.8
Total	**16.0**	**41.8**	**99.5**	**25.5**	**66.6**	**158.5**	**146.8**	**329.0**	**452.4**

A.7. Electric vehicles

The distribution of electric vehicles per council area in Northern Ireland, for each scenario, is displayed in Table A.7.

Table A.7: Electric vehicles locations and capacity (1000s)

	2025			2030			2040		
Council Area	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Antrim and Newtownabbey	2.6	4.8	6.4	11.8	20.4	27.9	47.1	70.2	89.7
Ards and North Down	3.3	6.0	8.1	14.9	25.8	35.2	59.0	88.2	112.0
Armagh, Banbridge & Craigavon	4.1	7.4	9.9	18.2	31.5	43.0	72.4	110.3	133.9
Belfast	4.5	8.2	11.0	20.4	35.2	48.0	80.9	112.3	169.7
Causeway Coast and Glens	3.2	5.8	7.8	14.3	24.7	33.7	56.3	85.9	104.2
Derry and Strabane	2.5	4.5	6.1	11.2	19.4	26.5	44.5	65.9	85.4
Fermanagh and Omagh	2.7	4.9	6.5	12.0	20.7	28.3	47.2	74.7	83.5
Lisburn and Castlereagh	2.9	5.3	7.2	13.3	23.0	31.3	53.3	79.5	101.3
Mid and East Antrim	2.7	4.9	6.6	12.1	20.9	28.5	47.7	72.8	88.6
Mid Ulster	2.9	5.3	7.2	13.2	22.8	31.1	52.1	80.9	94.2
Newry, Mourne and Down	3.6	6.6	8.8	16.3	28.1	38.3	64.7	99.3	118.7
Total	**35.0**	**63.7**	**85.6**	**157.6**	**272.6**	**371.7**	**625.1**	**939.9**	**1181.0**

Appendix B

Appendix B

The earliest wind generation in Northern Ireland was connected in the mid-1990s; by 2030 almost 30% of the existing installed fleet will exceed 20 years of service. Effective policy for repowering existing wind farms will be an important enabler for decarbonisation of the electricity system and is vital if targets for onshore wind are to be met.

Due to the topography of the transmission network in Northern Ireland, onshore wind generators were initially connected to the distribution network. The earliest wind farms were connected under the Non Fossil Fuel Obligation (NFFO) policy. As the number of connections increased throughout the 2010s, a clustering policy was introduced, whereby neighbouring wind farms would be connected at a common point, which itself was then connected to the transmission network. The vast majority of recent wind farm connections have connected through such an arrangement.

Clusters comprise a 110/33 kV substation, connected to the transmission network. In some cases, the substation is connected directly into the transmission network. In other cases, this substation is connected to the transmission system via a dedicated circuit.

When considering wind farm repowering, it is important to take into account potential capacity limitations on both the distribution system and at clustering sites. Larger turbines can be installed that will provide energy for lower cost; however, network capacity restrictions may limit the number of larger turbines that could be accommodated at an existing site. New onshore wind generation is assumed to achieve approximately 4% higher capacity factors when compared with the existing fleet.

For TESNI, Table B.1 sets out our assumptions for wind repowering.

Table B.1: Onshore wind farm repowering assumptions

Wind farm connection	Modest Progress	Addressing Climate Change	Accelerated Ambition
Distribution - NFFO	Repowered with larger turbines giving increased MEC	Repowered with larger turbines giving increased MEC	Repowered with larger turbines giving increased MEC
Distribution - other	Repowered with equivalent turbines giving equivalent MEC	Repowered with larger turbines giving equivalent MEC	Repowered with larger turbines giving increased MEC
Cluster - via cluster connection circuit	Repowered with equivalent turbines giving equivalent MEC	Repowered with larger turbines giving equivalent MEC	Repowered with larger turbines giving increased MEC
Cluster - at transmission network	Repowered with equivalent turbines giving equivalent MEC	Repowered with larger turbines giving increased MEC	Repowered with larger turbines giving increased MEC
Transmission	Repowered with equivalent turbines giving equivalent MEC	Repowered with larger turbines giving increased MEC	Repowered with larger turbines giving increased MEC

As wind turbine technology becomes more advanced, capacity factors are expected to increase further. Average capacity factors in future scenarios will therefore depend on the age profile of the fleet. As new onshore wind capacity connects, average capacity factors will improve, as illustrated in Figure B.1. Improving capacity factors increase the cost competitiveness of onshore wind as a form of renewable generation.

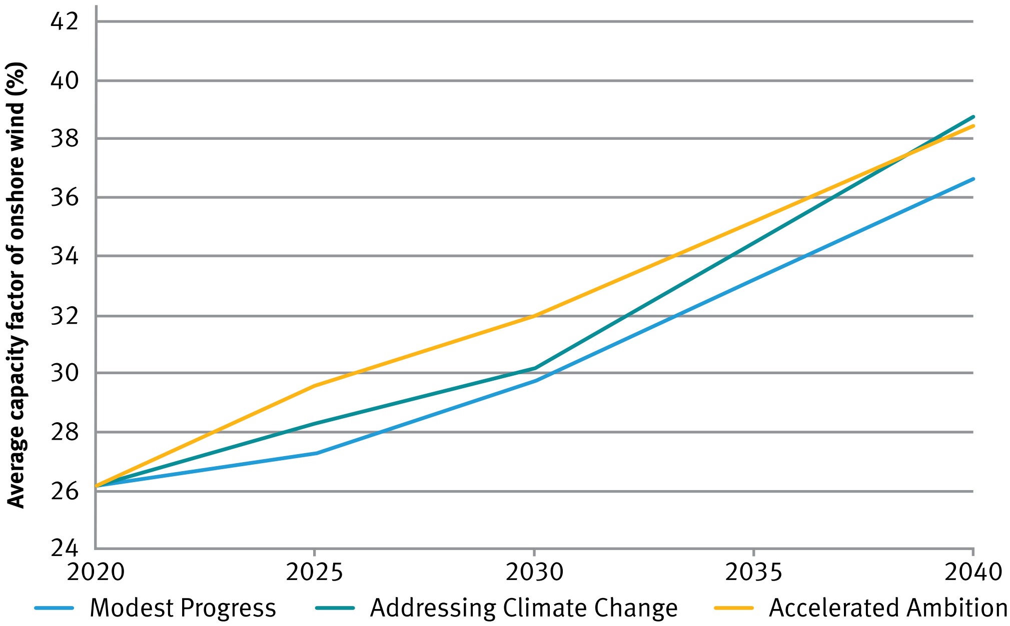


Figure B.1: Average onshore wind farm capacity factors

Figure B.2 shows the assumed connection arrangement of the onshore wind for the three scenarios. The vast majority continues to be connected through either the distribution network or through clustering substations.

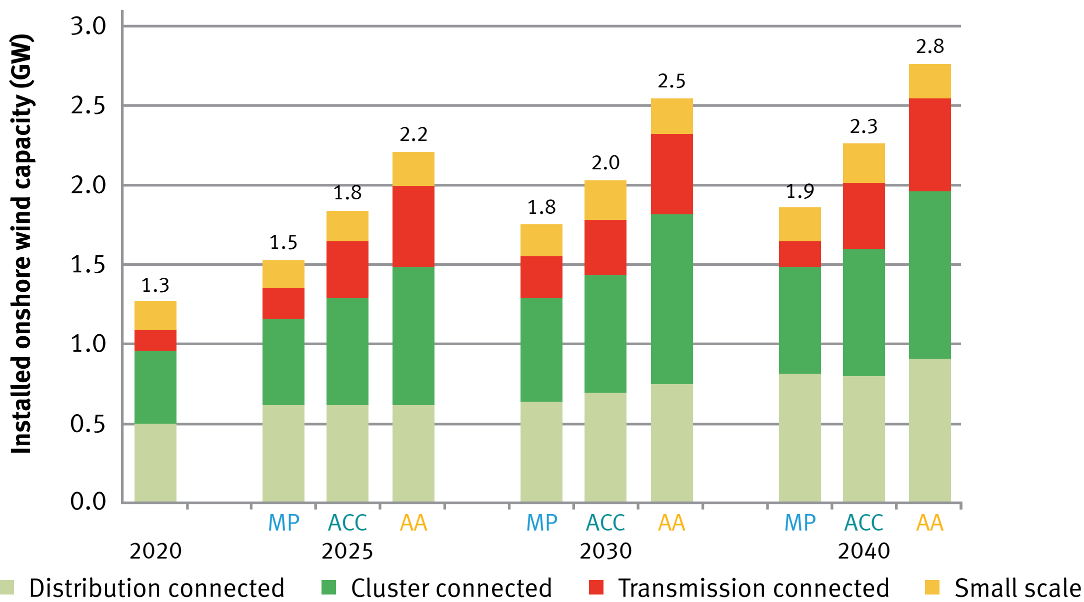


Figure B.2: Onshore wind installed capacity

Appendix C

Appendix C

As TSO, SONI has obligations with regard to the process of scheduling and dispatching resources to meet electricity demand. This includes ensuring operational security, the efficient operation of the SEM and providing transparency via reporting and monitoring.

Part of this process involves employing operational constraints, which are rule sets that ensure a dispatch produces is technically feasible, within safe and secure operating boundaries, and flexible enough for operators to respond to forecast errors and real time events.

For TESNI, we perform dispatch modelling for three scenario years - 2025, 2030 and 2040. We align our scenarios with EirGrid's TES 2019 scenarios, as detailed in **Section 2.4**.

To achieve the high RES-E targets in **Addressing Climate Change** and **Accelerated Ambition**, changes to how we ensure operational security during the dispatch process are required. For example, the operational constraints may need to be adapted over time. This can be achieved in a myriad of ways. For example, an operational constraint could be satisfied through the use of new resources and/or by retrofitting existing assets. The operational constraint could even be removed entirely through the installation of new technologies in appropriate network locations.

A programme of work, replacing DS3, is being undertaken to identify the operational change required in order to achieve RES-E and emissions reduction targets. TESNI 2020 does not in any way outline the preferred or optimal path for operational constraints, but does make assumptions to enable targets to be met. Table C.1 provides an overview of the assumptions used in the dispatch modelling.

It is assumed that the SNSP limit increases over time. Our 2020-25 Strategy targets 95% SNSP by 2030, and this is assumed to be achieved in **Addressing Climate Change** and **Accelerated Ambition**. The operational RoCoF limit increases to 1 Hz/s in all scenarios and study years. The inertial limit decreases over time. In **Addressing Climate Change** and **Accelerated Ambition**, synchronous condensers are included in the RoCoF constraint, helping to reduce curtailment associated with inertial requirements.

It is also assumed that conventional generators continue to lower their minimum generation level. This helps to reduce curtailment associated with the minimum number of conventional units dispatched. Across all scenarios, it is assumed that the minimum number of conventional generators required to be dispatch reduces significantly from today.

Table C.1: TESNI dispatch modelling assumptions

	2025			2030		
	MP	ACC	AA	MP	ACC	AA
SNSP upper limit (%)	75	80	85	85	95	95
Inertial lower limit (MWs)	17,500	15,000	15,000	15,000	None	None
RoCoF upper limit (Hz/s)	1	1	1	1	1	1
Limit on reserve from non-synchronous sources	No	No	No	No	No	No
Reductions from today in the minimum generation output of large thermal units	Yes	Yes	Yes	Yes	Yes	Yes
Inertia provision from non-generation resources	No	No	No	No	Yes	Yes
Jurisdictional reserve requirements	No	No	No	No	No	No
Minimum number of conventional units, Ireland	3	3	3	2	2	2
Minimum number of conventional units, Northern Ireland	2	2	2	2	2	1

There is no limit on the reserve allowed from non-synchronous technologies such as battery storage, demand side management and interconnection, which helps reduce the dispatch down associated with reserve requirements.

A reduction in limits from some existing operational constraints by 2025 is related to the delivery of the North South Interconnector and delivery of new Control Room tools, among others. For 2040, no operational constraints are included.

Appendix D

Appendix D

The following tables summarise some of the key generation and demand components of TESNI 2020.

Table D.1: Generation mix (MW)

	2025			2030			2040		
Technology/Fuel	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
OCGT (gas)	405	405	405	505	605	805	505	705	905
Distillate oil	258	258	258	158	84	84	0	0	0
CCGT	1,481	1,481	1,001	1,481	1,481	1,001	1,481	1,481	408
CCGT (CCS)	0	0	0	0	0	0	0	0	500
Coal	0	0	0	0	0	0	0	0	0
Renewables	1,896	2,334	2,966	2,261	3,107	4,437	2,753	4,081	5,739
Total	**4,040**	**4,478**	**4,630**	**4,405**	**5,277**	**6,327**	**4,739**	**6,267**	**7,552**

Table D.2: Renewable generation mix (MW)

	2025			2030			2040		
Technology	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Onshore wind	1,529	1,848	2,212	1,753	2,034	2,542	1,960	2,267	2,762
Offshore wind	0	0	0	0	350	500	0	500	850
Solar PV	284	399	665	421	617	1,169	702	1,185	1,777
Biomass	77	81	83	81	100	120	85	123	144
Hydro	6	6	6	6	6	6	6	6	6
Marine	0	0	0	0	0	100	0	0	200
Total	**1,896**	**2,334**	**2,966**	**2,261**	**3,107**	**4,437**	**2,753**	**4,081**	**5,739**

Table D.3: Demand mix (TWh)

	2025			2030			2040		
TER	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**	**MP**	**ACC**	**AA**
Transport	0.23	0.24	0.24	0.52	0.73	1.03	1.84	1.88	2.40
Residential	2.67	2.79	3.07	2.61	2.79	3.19	2.95	3.63	4.13
Industrial	2.72	3.35	3.94	2.60	3.54	4.43	2.41	3.83	4.93
Tertiary	1.96	1.90	1.91	1.91	1.82	1.82	1.80	1.80	1.94
Losses	0.94	1.00	1.07	0.93	1.04	1.18	1.04	1.23	1.43
Total	**8.52**	**9.28**	**10.23**	**8.57**	**9.92**	**11.65**	**10.04**	**12.37**	**14.83**

Notes:

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