Tomorrow's Energy Scenarios 2020

System Needs Assessment - Northern Ireland

SONI

Delivering a cleaner energy future

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Tomorrow's Energy Scenarios 2020 System Needs Assessment Northern Ireland

Foreword

SONI Limited is the electricity System Operator for Northern Ireland. We plan and operate the transmission system, the single electricity wholesale market (all-island) and manage and operate the flows on interconnectors with our neighbours. SONI is regulated by the Utility Regulator for Northern Ireland, who determines our funding.

We ensure that electricity is always available when and where it is needed, every second of every day and for decades to come. We do this in the most cost-effective way possible, and in the interests of all electricity users across Northern Ireland. We do so to meet the needs of all consumers, our economy and the environment. We are committed to delivering a clean energy system as a direct response to the climate crisis.

By strengthening the electricity grid, by connecting green energy projects and through our world leading innovation in managing electricity from renewable schemes, we have made a significant contribution to Northern Ireland meeting its 2020 renewable energy targets a year in advance of the timeline.

Our new corporate strategy outlines our commitment to transforming the power system for future generations, but we can't do this alone. We have applied our research and expertise to develop a series of pathways to help inform the electricity ecosystem as we make the journey together. It is through collaboration that we can support the delivery of the Economy Minister's ambition of at least 70% of electricity from renewables by 2030.

SONI is pleased to present the *Tomorrow's Energy Scenarios Northern Ireland System Needs Assessment* (TESNI SNA) 2020. This report concludes our *Tomorrow's Energy Scenarios Northern Ireland 2020* (TESNI 2020) process.

The use of scenarios acknowledges that there is no single pathway to a low carbon economy. We use scenario planning as a means to create a range of possible energy futures that capture the impact of societal, political, economic and technical changes. Our scenarios were developed taking into account the views of a broad range of stakeholders, and we are grateful to all who contributed.

Our central scenario achieves a target of 70% RES-E target by 2030 and ultimately meets Northern Ireland's estimated contribution to the UK's net-zero target for 2050. Our most ambitious scenario aims for 80% RES-E by 2030 and more rapid decarbonisation in Northern Ireland, including a net-zero energy system by 2040.

Following the publication of our scenarios in July 2020, we have modelled them on the Northern Ireland transmission network and assessed the subsequent performance of the network. A number of the needs identified will be resolved by projects proposed in the *Transmission Development Plan Northern Ireland* (TDPNI), and we also assess the performance of the transmission network with some of these projects in place.

SONI is currently consulting on the whole-system pathways required to enable anticipated 2030 RES-E targets to be delivered. This piece of work - *Shaping Our Electricity Future* - considers the integrated approach required to deliver a reliable and efficient power system and market in order to facilitate Northern Ireland's renewable energy ambitions.

Part of the analysis in *Shaping Our Electricity Future* builds upon the work performed in the SNA, and considers a number of differing approaches to resolving network needs by 2030.

The research and analysis that has informed our TESNI 2020 process was completed in advance of the COVID-19 pandemic. It is clear that the pandemic will have a significant and potentially longer-lasting impact on the Northern Ireland economy. Capturing how this will impact electricity demand will form an important part of the next TESNI cycle.

We hope you find this document informative and we very much welcome feedback from you on how we can improve this document and make it more useful.

Alan Campbell
Managing Director,
SONI Ltd.

Key Messages

The System Needs Assessment (SNA) highlights the needs of the Northern Ireland transmission system when assessed with the three scenarios developed as part of the TESNI 2020 process.

TESNI 2020 provided detailed scenario information for three years- 2025, 2030 and 2040. Correspondingly, the SNA utilises these three years for assessment of the transmission network.

The analysis performed in the SNA is based on the transmission network as it is today, but with the inclusion a number of projects that are well advanced in our grid development framework process, including the planned new North South interconnector. The new interconnector is expected to be energised by 2025 and is required to ensure efficient operation of the Single Electricity Market (SEM) and help achieve ambitious energy targets for 2030 and ultimately 2050.

A number of projects, beyond those already included in the network, are already proposed to reinforce the transmission network. These projects are listed in the most recent TDPNI. Accordingly, an assessment of the transmission network is also performed for the years 2030 and 2040 with these further projects in place. This highlights any needs they resolve, and what needs still remain.

Regardless of which scenario is considered, the transmission network in the north-west area of Northern Ireland will require reinforcement. Meeting RES-E targets for 2030 will require delivery of a number of reinforcement projects listed in TDPNI. Without these projects in place, the potential levels of generation dispatch down will make meeting RES-E targets more difficult.

Further network reinforcement may also be required, depending on what RES-E targets are agreed and how the electricity system ultimately develops in response to them. Our current *Shaping Our Electricity Future* consultation explores a number of ways the transmission network could develop to meet a 70% RES-S target by 2030.

SONI is committed to early, meaningful and transparent engagement in relation to our proposed grid investments. We will be consulting with a range of key stakeholder groups, including the public, communities and landowners, before making progress on any of these projects.

Diversification of the renewable generation portfolio will also be important in meeting ambitious RES-E targets. The variable nature of renewable energy sources means that a greater spread of technology types reduces the likelihood of sudden ramps or reductions in output from renewable generation. Today, with a heavy reliance on onshore wind generation, there is a risk of reduced generation capacity margins during times of high demand and no wind. A more diverse portfolio of renewable generation would reduce this risk.

A more diverse geographical spread of renewable generations ensures that the transmission network is better utilised. This is clearly demonstrated in our central scenario, **Addressing Climate Change**. The scenario has a 70% RES-E target for 2030 and places less stress on the transmission network than our **Modest Progress** scenario, with its lower 60% RES-E target for the same year.

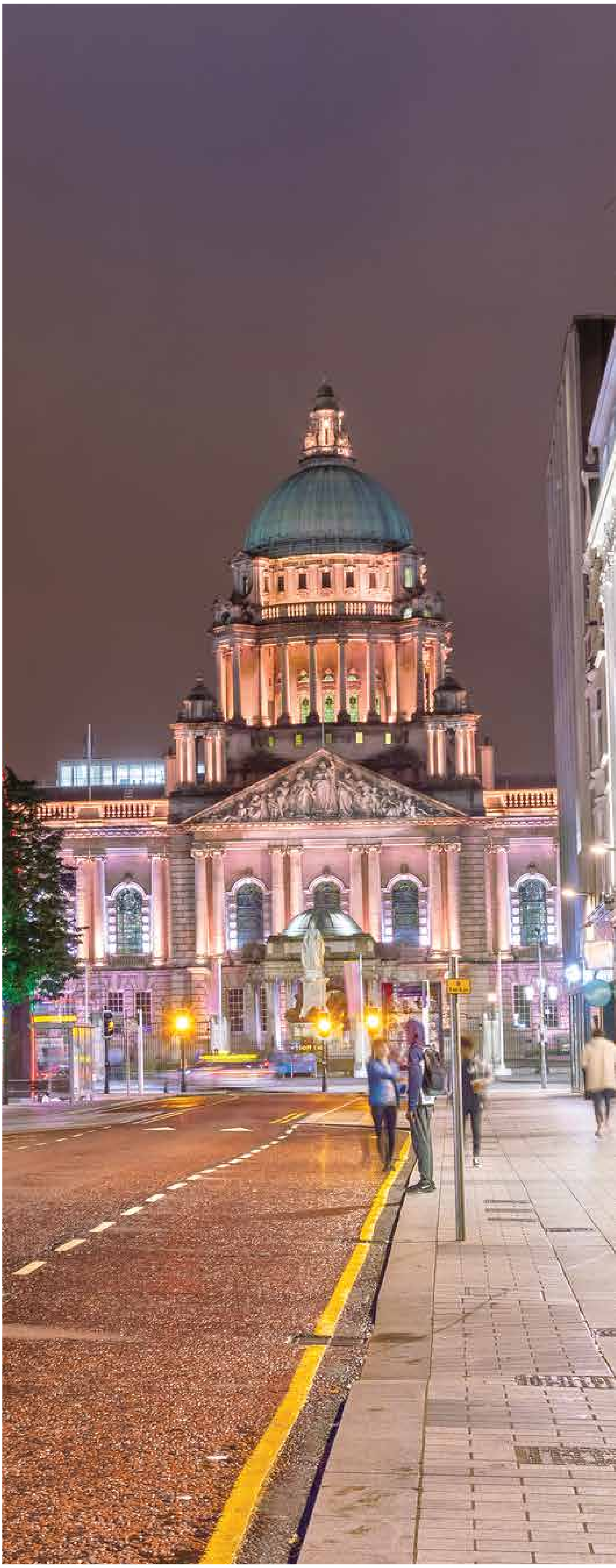
Bulk supply points- substations which take electricity from the transmission network and supply it to the distribution network to meet demand- don't experience many issues related to the growth in demand from electric vehicles and electric heating until beyond 2030. There are a couple of exceptions to this, and these are bulk supply points which already supply large demands today. By 2040, however, many bulk supply points may require the delivery of additional capacity to accommodate the growth in demand from electric heat and transport. This risk could be brought forward if government pursues ambitious requirements for these technologies, such as those assumed in our **Accelerated Ambition** scenario.

Possible development of offshore generation off the north coast of Northern Ireland, as assumed in our **Accelerated Ambition** scenario, will likely require significant transmission network reinforcement in the north-west area of Northern Ireland.

High levels of growth in large scale solar PV generation, as set out in **Addressing Climate Change** and **Accelerated Ambition** may ultimately require a clustering policy, similar to that which was used for onshore wind in Northern Ireland.

Additional transmission network capacity created by projects in the TDPNI will be important in helping maintain an acceptable voltage profile across the transmission network as levels of renewable generation increase over time. Additional support, in the form of reactive power compensation, will also be required, particularly in later years as Northern Ireland transitions away from reliance on large fossil fuelled generation.

Presently, there are a number of operational constraints governing how much renewable generation can be dispatched at any time, to ensure the stability and security of the transmission network. The scenarios, particularly in later years, see transformational changes to how electricity is generated in Northern Ireland. Accommodating this requires assumptions regarding the relaxing of these constraints. Capturing the full implications of these changes is beyond the scope of this report. Detailed analysis is required to capture further needs that may arise as a result of these changes, ensuring the stability and security of the transmission network is maintained throughout the energy transition.



Shaping our Electricity Future

SONI and EirGrid recently launched a public consultation on our *Shaping Our Electricity Future* work stream in early 2021. *Shaping Our Electricity Future* seeks to develop an integrated approach to developing a reliable and efficient power system and market. It considers three separate areas:

- The transmission network;
- System operations; and
- The electricity markets.

Consideration of the transmission network in *Shaping Our Electricity Future* shares some similarities with the SNA. Both reports assess the performance of the transmission network, and report on areas of weakness. Additionally, proposed reinforcement projects in the TDPNI are considered in the analysis in both reports.

Where *Shaping Our Electricity Future* differs is that it assesses the transmission network performance in Northern Ireland and on an all-island basis in order to find opportunities to minimise the transmission network capital investment cost to consumers and, rather than making use of multiple scenarios and study years, it considers a single scenario for 2030, based on governmental RES-E targets in both jurisdictions. In Ireland, the government has agreed a 70% RES-E target by 2030. No such target is currently agreed for Northern Ireland, but it is anticipated that a RES-E target of at least 70% by 2030 is likely, based on statements from the Economy Minister. Shaping Our Electricity Future also proposes solutions in the operations and market dimensions rather than solely on the network component.

Unlike the SNA, *Shaping Our Electricity Future* not only considers the impact that meeting these targets will have on the transmission system, but it also presents and analyses a number of approaches to resolving these needs. The consultation ultimately allows everybody to have their say on how they think we should develop the transmission network to meet 2030 RES-E targets. Therefore, needs identified in the SNA may differ from those in *Shaping Our Electricity Future*, due the differing approaches considered to develop the transmission network.

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Glossary of terms

Bulk Supply Point
A substation which takes electricity from the transmission system and supplies it to the distribution network to meet demand.

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.

Circuit
An element of the transmission system that carries electricity.

Combined Cycle Gas Turbine (CCGT)
A fossil fuelled generator that combines a steam and gas turbine to produce electricity more efficiently than other fossil fuel generation.

Constraint
The situation where available power in an area of the transmission system cannot be fully transferred to where it is needed due to congestion on the network.

Contingency
An unexpected loss of a element of the transmission system, such as a circuit, transformer or generator.

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

Distribution network [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.

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

Maintenance
A planned outage of an element of the transmission system.

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 transmission system 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.

Overload
Occurs when the amount of power transferred across an element of the transmission system exceeds the operating limit of the element.

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.

Rating
An operating limit for an element of the transmission system.

RES-E
Electricity produced using renewable sources.

Reactive power compensation
Equipment that can help regulate the voltage on the transmission system.

Renewable generation dispatch down
A reduction in renewable generation output to maintain system security or prevent potential overloading of the transmission system.

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

System Non-Synchronous Penetration (SNSP)
A metric which describes the level of non-synchronous generation that can be facilitated on the transmission system at any one time.

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 system is designed to meet. Our technical planning standards are a licence obligation and are approved by the Utility Regulator (UREGNI)

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

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

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

Uprate
Increasing the maximum power allowed on a transmission circuit by replacing the existing conductor with one of a higher rating.

Voltage phase angle difference
The difference between the voltage phase angles at either end of a transmission circuit.

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 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, 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. These scenarios allow us to assess the impact of the energy transition on the performance of the electricity transmission network.

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/

1.2. The System Needs Assessment and the planning process

Figure 1.1 demonstrates how the SNA fits into our planning process. Following the publication of TESNI 2020, we have a robust set of scenarios with which to assess future needs. The SNA implements these scenarios on the transmission network, and tests the network against a set of performance standards. This allows us to identify grid development needs arising on the transmission network into the medium and longer term. Needs that arise from this assessment form part of the input to our grid development process.

Figure 1.1: How TESNI is used in transmission network planning

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.

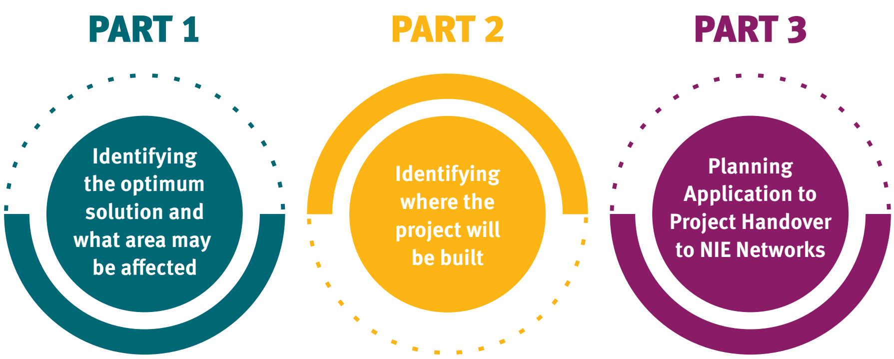


Figure 1.2: The grid development process in Northern Ireland

The SNA, by identifying future needs which may arise as the Northern Ireland energy system decarbonises, provides input to Part 1 of our grid development process.

2. Inputs to the SNA

2. Inputs to the SNA

2.1. The Scenarios

Click to view

In July we published TESNI 2020, outlining three credible future pathways for the supply and consumption of electricity in Northern Ireland out to 2050.

Key highlights from each scenario are listed below. Full details on the scenarios are available in TESNI 2020. Each scenario will be modelled on the transmission network for three study years - 2025, 2030 and 2040. This allows needs arising in the short, medium and long term to be assessed.

Modest Progress

- 60% of electricity from renewables by 2030
- Low economic growth over the next decade
- A ban on new petrol and diesel cars by 2040
- Slow transition to electric heating
- No development of offshore renewable generation
- Achieves the core emissions reduction contribution for NI set out by the CCC for 2050

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
- Slow initial transition to electric heating, pace increases beyond 2030
- Development of offshore wind generation from 2030
- Achieves NI contribution to UK net-zero emission target set out by the CCC by 2050

Accelerated Ambition

- 80% of electricity from renewables by 2030
- Modest economic growth to 2030, but increasing towards the end of the decade
- A ban on new petrol and diesel cars by 2032
- Faster transition to electric heating from 2025
- Development of offshore wind generation and marine generation from 2030
- Delivers a net-zero power system in NI by 2040

2.2. The Northern Ireland transmission network

The Northern Ireland transmission network is shown in figure 2.1. The network consists of a 275 kV double circuit ring in the east, with a spur to the north-west. Underlying this is 110 kV infrastructure, most prominent in northern and western areas. Three large thermal power stations are located close to the largest demand centres.

Over the last decade, large amounts of renewable generation capacity have connected in Northern Ireland, in response to a government target of 40% RES-E by 2020. In common with many transmission networks, which were designed and constructed before the recent push towards renewable generation development, areas suitable for renewable generation tend to be remote from the strongest areas of the transmission network. This can be clearly seen in figure 2.1, where the majority of the renewable generation is located in the north and west and is generally remote from the 275 kV network towards the east.

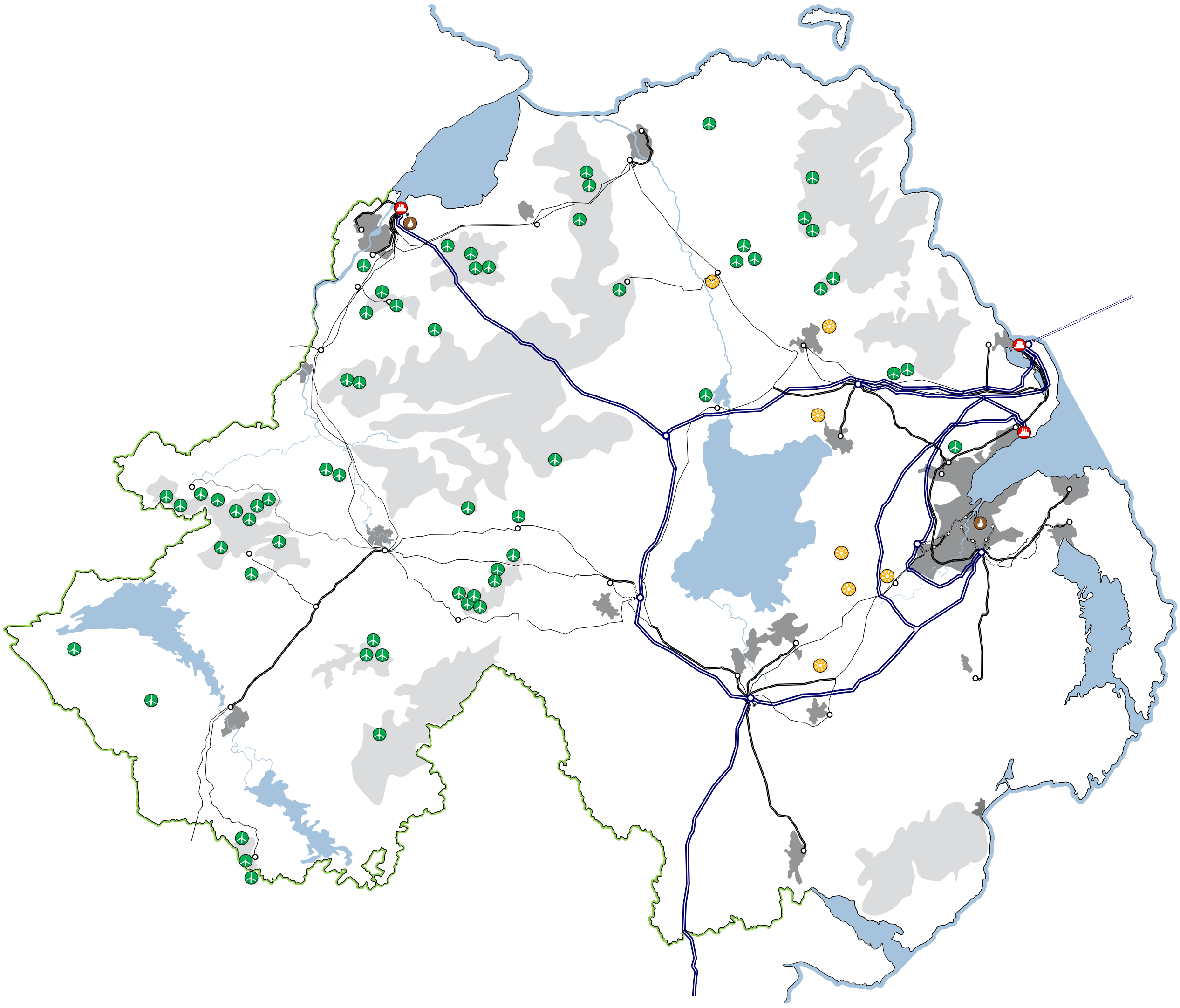


Figure 2.1: The Northern Ireland transmission network in 2020

Table 2.1 lists the installed renewable generation capacities, by technology type, as of 2020. The majority of the total renewable generation connected in Northern Ireland comprises onshore wind. In recent years, a significant amount of PV generation has progressed.

Table 2.1: Renewable generation capacity in 2020

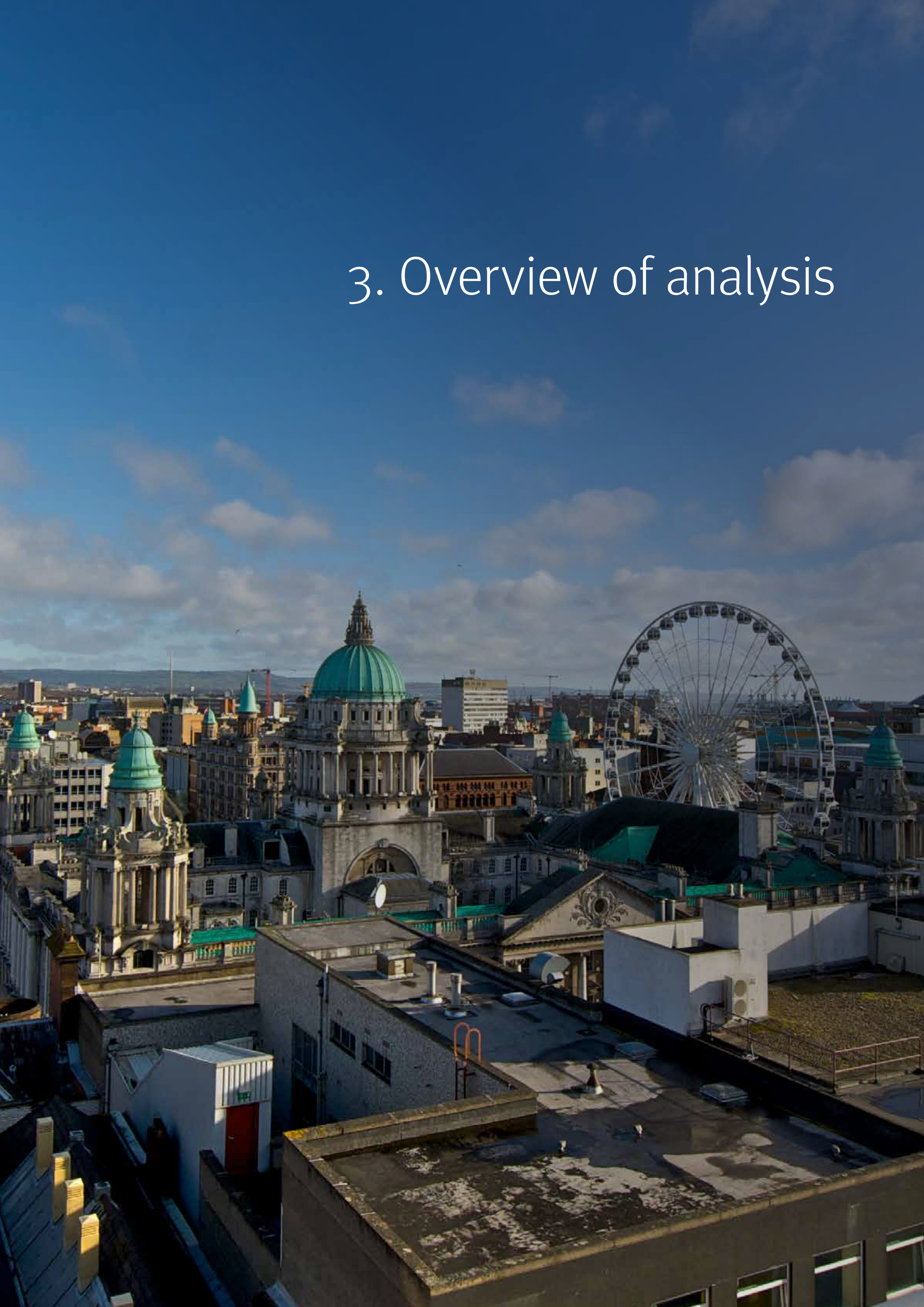
Renewable generator type	Installed capacity (MW)
Onshore wind- large scale	1,089
Onshore wind- small scale	153
Offshore wind	0
PV- large scale	117
PV -small scale and micro	114
Biomass	77
Hydro	6
Marine	0

In response to the connection of large quantities of renewable generation, a number of reinforcement projects are proposed. They are detailed in the TDPNI. For the purposes of the analysis in this report, several of these projects are assumed complete by 2025, due to how far they have progressed through our grid development framework process. These projects will be included in the transmission network models for all study years assessed in this report. The projects are listed in table 2.2. Full details on the projects can be found in the TDPNI.

Table 2.2: TDPNI projects included in the transmission network

TDPNI projects included in transmission network
Airport Road 110/33 kV bulk supply point
Ballylumford to Eden 110 kV double circuit uprate
Dromore to Omagh 110 kV double circuit uprate
Coolkeeragh to Magherafelt 275 kV double circuit uprate
New 400 kV North South interconnector
Agivey renewable generation cluster
Kells renewable generation cluster

3. Overview of analysis



3. Overview of analysis

The scenarios are modelled on the transmission network for the three study years- 2025, 2030 and 2040. The transmission network configuration used in the analysis is the network as it is today, plus any projects listed in table 2.2. The hourly dispatches used in the analysis are those generated as part of the dispatch modelling performed for TESNI 2020. The performance of the transmission network is assessed against requirements described in the Northern Ireland Transmission System Security and planning Standards (TSSPS).

A number of assessments are carried out, and they are described in the following subsections.

3.1. Scenarios summary

For each study year, a summary of the scenario changes and analysis results are provided. The main element is a map for each scenario. The map highlights circuit and bulk supply point overloads, as well as existing and new generation capacity. An example of the map, and description of the various elements, is shown in figure 3.1.

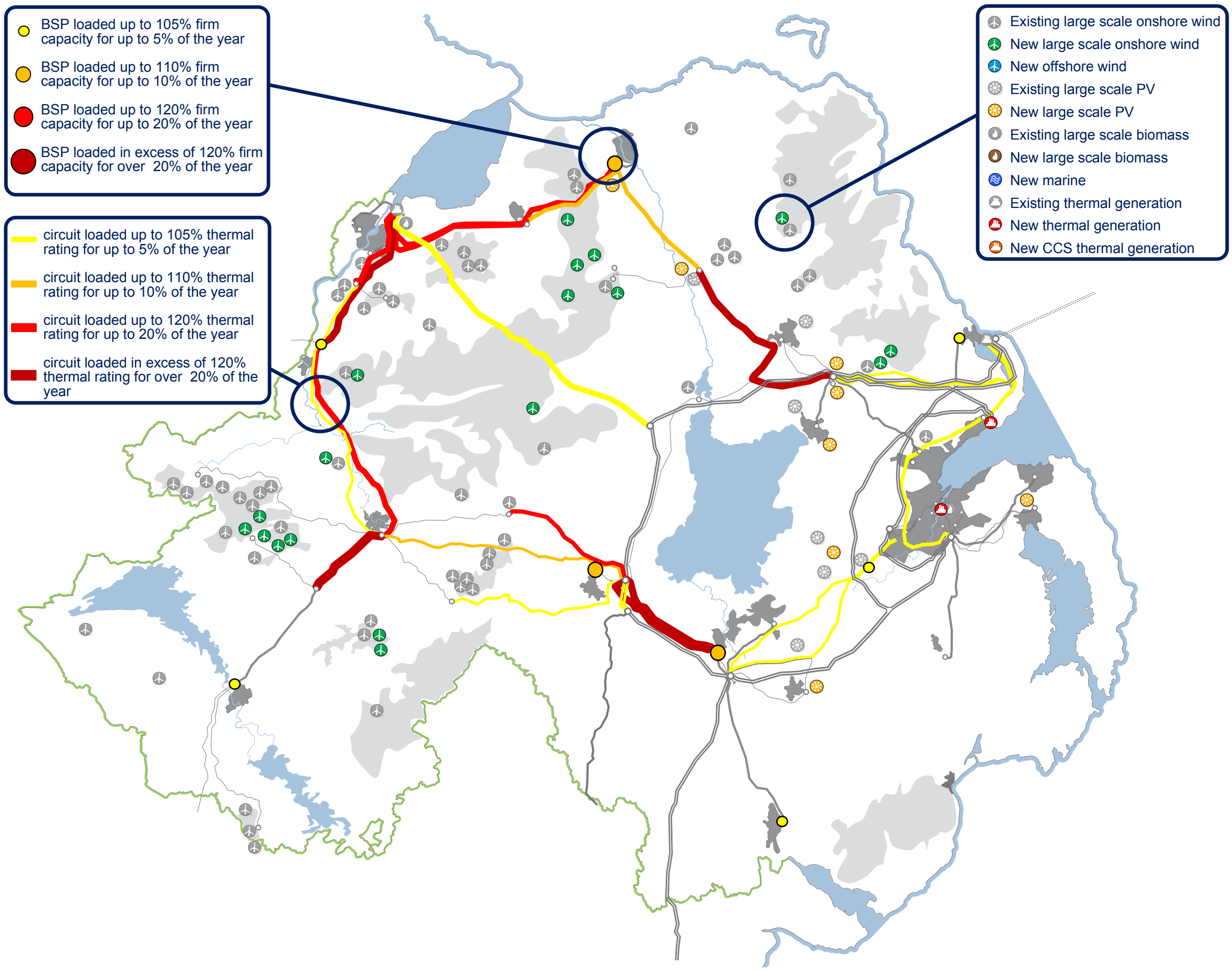


Figure 3.1: Example of scenario results map

3.2. Transmission circuit overloads

TSSPS requirements assessed

- Loss of single transmission circuit (N-1) all year round
- Loss of 275 kV double circuit on one tower (N-DC) all year round

The TSSPS requires that the network is assessed for N-1 conditions, including N-DC, all year round. For every hour of each study year the highest circuit loadings are recorded, after taking all potential contingencies into account. For a select number of circuits, load duration curves are presented; an example of one, with key information points highlighted, is shown in figure 3.2

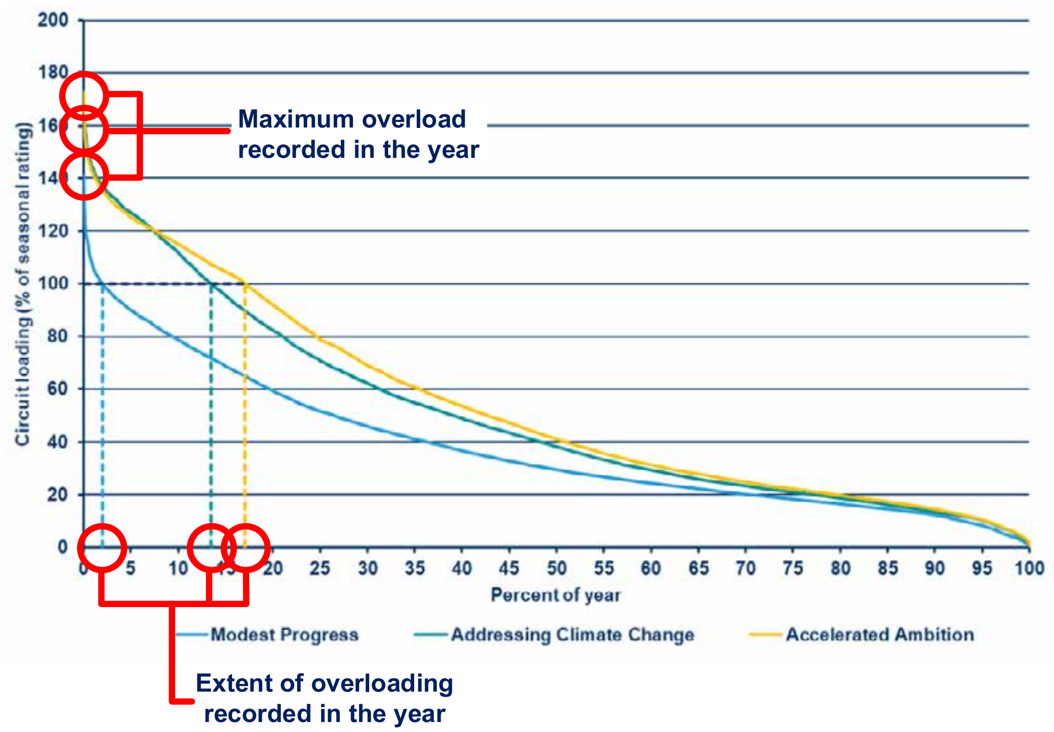


Figure 3.2: Example of graph showing circuit loading

The results of the N-1 analysis are indicated on the summary maps, an example of which is shown in **section 3.1**. All transmission circuits subject to overloading are highlighted. The maximum possible overload and the extent of the overloading are considered when indicating the severity of the risk to the circuit; figure 3.1 indicates how this risk is indicated.

During maintenance season, the network should also be assessed for the loss of single transmission circuit during the prior planned outage of another circuit (N-M-T). This assessment is not performed here, as the analysis requires economic redispatch of generation for each planned circuit outage.

3.3. Phase angle analysis

At times of high generation in the north-west area, the loss of the Coolkeeragh to Magherafelt 275 kV double circuit can result in a large voltage phase angle difference between Coolkeeragh and Magherafelt. If the difference exceeds 20°, the double circuit cannot be reclosed. Resolving this issue would typically require a redispatch of generation across the country.

The results of the phase angle analysis are represented on a graph, similar to the circuit loading graph in figure 3.2. The graph shows the highest phase angle difference recorded in the scenario and study year, and the extent of the time the phase angle difference exceeds 20°.

3.4. Bulk supply point overloads

TSSPS requirements assessed

- Loss of single transmission circuit (N-1) all year round

Bulk supply points in Northern Ireland typically consist of two 110/33 kV transformers, which are either radially connected to grid supply point substations via 110 kV circuits, or form part of substations integrated within the 110 kV network. All of this equipment is part of the transmission network, and therefore is assessed for N-1 conditions all year round.

The results of the N-1 analysis are presented in a tabular format for each study year, with an indication of the main driver behind any overloading listed. The results are also indicated on the summary maps, like the example map in **section 3.1**. Similar to the transmission circuits analysis, the maximum possible overload and the extent of the overloading are considered when indicating the severity of the risk to the bulk supply point; figure 3.1 again indicates how this risk is indicated.

3.5. Voltage profile

TSSPS requirements assessed

- No voltage step greater than 6% for N-1 event
- No voltage step greater than 10% for N-DC event
- No post contingency voltage lower than 0.9 p.u.

With increased levels of renewable generation across all scenarios, an accurate assessment of the voltage performance of transmission network is hard to provide, owing to the uncertainties introduced through the following:

- The reactive power capability, the point of connection to the transmission network and the voltage connection level of a new generator will all influence the voltage performance across the transmission network.
- The large increase in small-scale renewable generation connections across the country.
- The development of electric heat and transport, given a lack of historical operating data of such technologies in this country.
- The impact of high levels of renewable generation connections on the existing network; heavily loaded circuits will absorb large quantities of reactive power, worsening the voltage performance.

A number of reactive power assumptions have been made, and are set out in table 3.1. For each element, the assumed operational power factor (pf) range is provided.

Table 3.1: Reactive power assumptions

Technology	Reactive power capability
Existing onshore wind	As per present day operation
New onshore wind- transmission connected	Voltage control 0.95 pf to -0.95 pf
New onshore wind- cluster connected	Unity power factor
New onshore wind- distribution connected	-0.98 power factor
Offshore wind	Voltage control 0.95 pf to -0.95 pf
PV -small scale and micro	-0.98 power factor
Biomass	-0.98 power factor
New thermal generator	0.8 pf to -0.95 pf
Marine	Voltage control 0.95 pf to -0.95 pf
Electric vehicle	-0.98 power factor
Heat pump	-0.98 power factor

To highlight the voltage performance of the transmission network, it has been assumed that reactive power support is available, in ±100 Mvar blocks, at the following sites: Coleraine, Coolkeeragh, Kells, Omagh and Tamnamore.

For each hour assessed, where voltages are outside normal limits for both intact network and post contingency conditions, reactive power support is available from the listed locations. The number of hours such support is required for all scenarios and study years is reported. Where results are also presented in graphs, it should be noted the absolute value of reactive power support required is displayed.

In some cases, reactive power support is not sufficient in resolving voltage issues. This is a result of extreme loading of 110 kV circuits following contingency events, ultimately resulting in voltage collapse. The number of hours such a scenario occurs is also reported.

3.6. Generation dispatch down

The level of renewable generation dispatch down related to oversupply and curtailment was assessed in TESNI for each scenario and study year. An estimated level of renewable generation constraint has been provided in this report- this is additional dispatch down required to prevent network overloading following a contingency event. This is included to allow an estimate of the overall levels of generation dispatch down in each scenario to be provided. The quantities assigned to each category- in particular constraint and curtailment- will ultimately differ from what is presented here, as they will be influenced by both the renewable generation availability and the state of the transmission network across the year.


4. 2025

4. 2025

4.1. Scenarios summary

Table 4.1 details renewable generation capacity added in each scenario compared to 2020.

Table 4.1: New renewable generation capacity by 2025 in the scenarios

Renewable generation type	Modest Progress	Addressing Climate Change	Accelerated Ambition
Onshore wind - large scale (MW)	141	315	359
Onshore wind - small scale (MW)	26	45	59
Offshore wind (MW)	0	0	0
PV - large scale (MW)	45	128	343
PV - small scale and micro (MW)	8	39	91
Biomass (MW)	0	4	6
Hydro (MW)	0	0	0
Marine (MW)	0	0	0

Table 4.2 details new electric heat and transport added in each scenario compared to 2020.

Table 4.2: New electric heat and transport by 2025 in the scenarios

Electric heat and transport	Modest Progress	Addressing Climate Change	Accelerated Ambition
Electric vehicles (1,000's)	35	64	158
Heat pumps (1,000's)	16	42	100

Table 4.3 lists some demand data for each scenario.

Table 4.3: 2025 demand in the scenarios

Demand information	Modest Progress	Addressing Climate Change	Accelerated Ambition
TER (TWh)	8.5	9.3	10.2
Peak demand (MW)	1,609	1,735	1,909

Table 4.4 details some operational constraints for 2025. Full details are in TESNI 2020.

Table 4.4: 2025 operational constraints

Operational constraint	Modest Progress	Addressing Climate Change	Accelerated Ambition
SNSP upper limit (%)	75	80	85
Minimum thermal units in NI	2	2	2

Modest Progress 2025

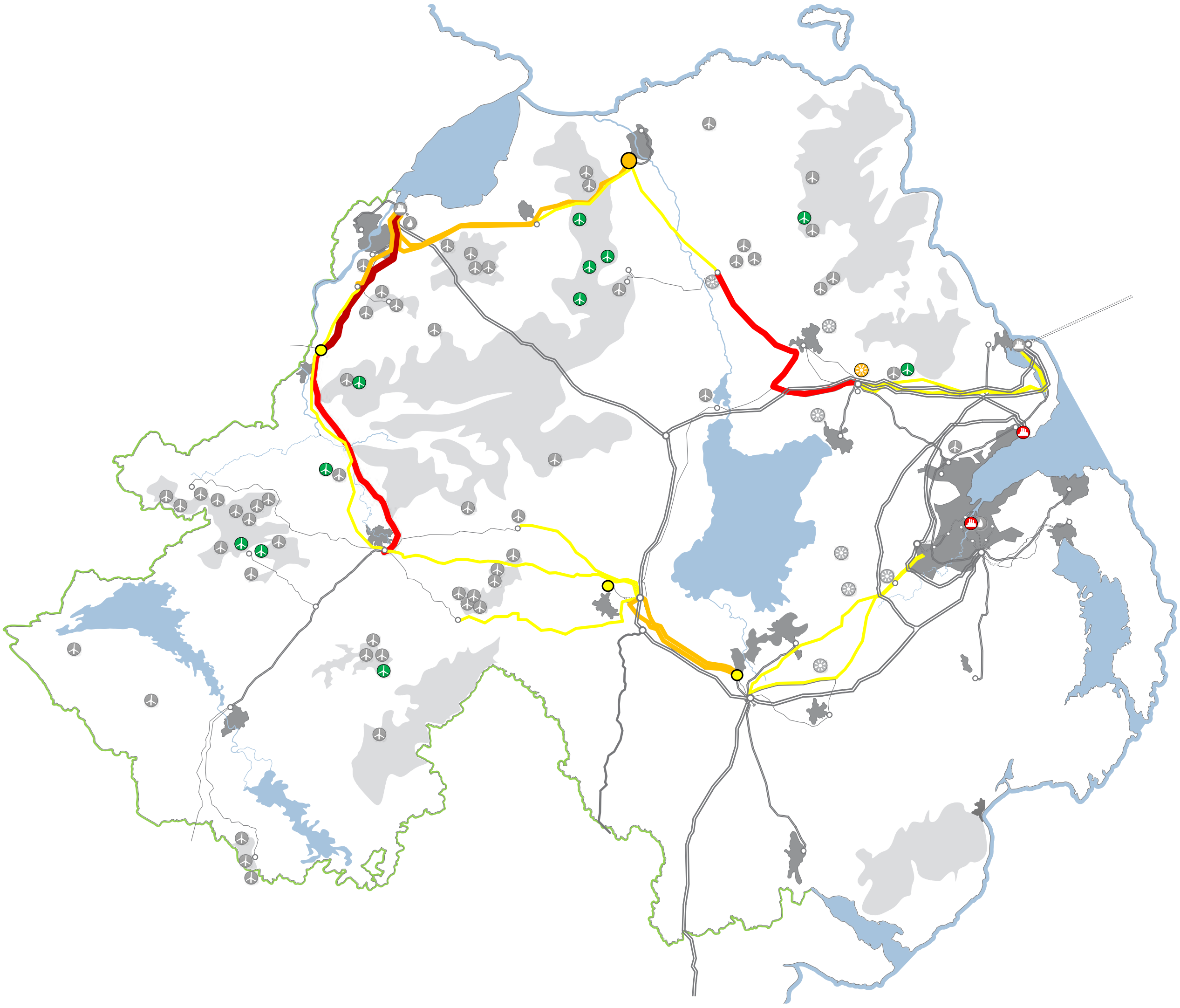


Figure 4.1: Modest Progress 2025

In **Modest Progress** there is limited additional renewable generation connected by 2025 compared to today. However, given the large quantity of renewable generation already connected in the north-west area, a risk of significant overloading is observed on the Kells to Rasharkin circuit, and the corridor between Coolkeeragh and Omagh.

With little growth in electric heat and transport in **Modest Progress**, very few bulk supply points are at risk of exceeding their firm capacity. Coleraine shows a higher risk of overloading; this issue is present today, and is related to the connection of renewable generation. The issue is currently managed with a special protection scheme.

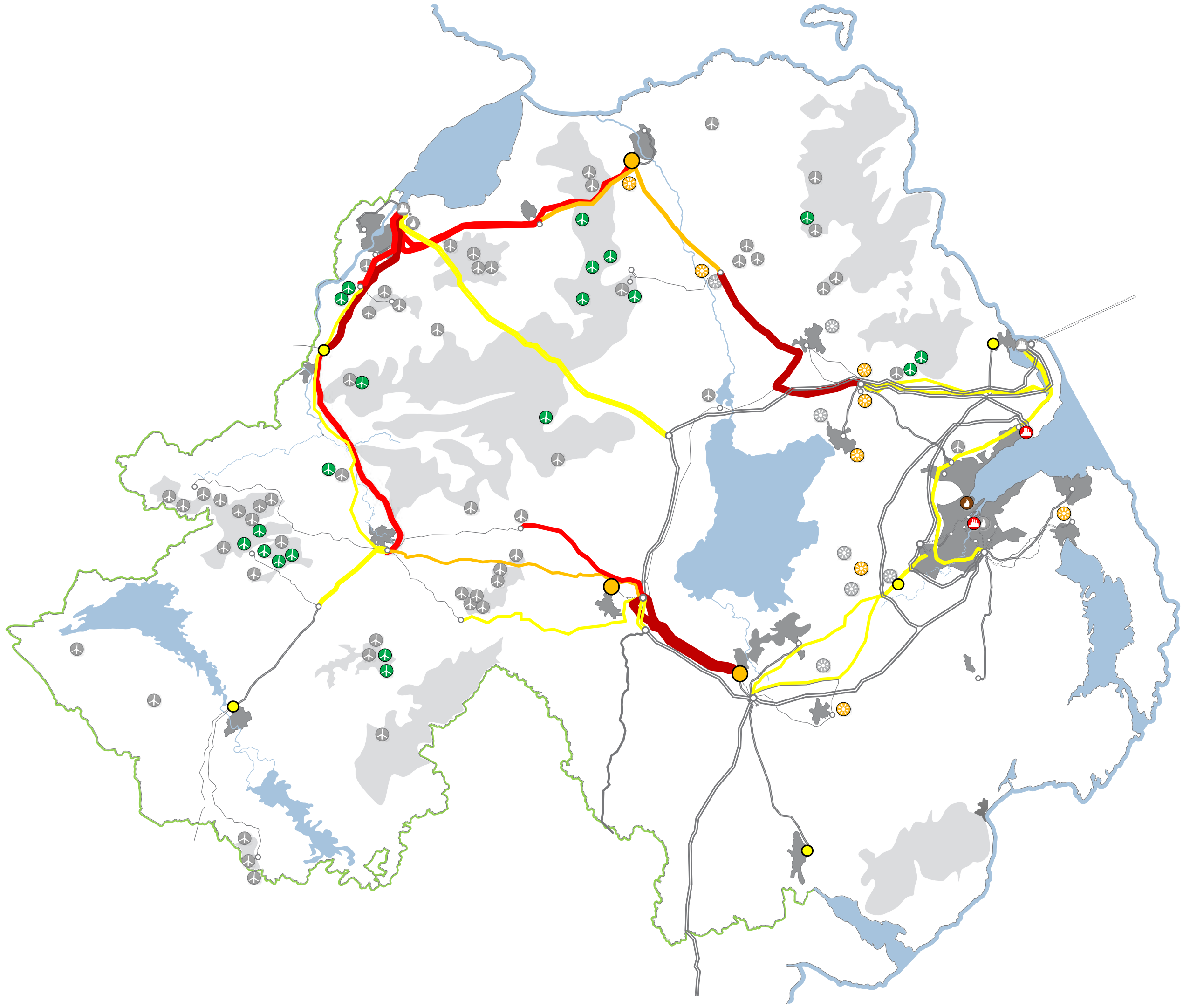


Figure 4.2: Addressing Climate Change 2025

To ultimately meet a 70% RES-E target by 2030, **Addressing Climate Change** sees a large increase in installed renewable generation by 2025. Given the short time horizon, this generation is all located onshore. With much of the additional wind generation connected in northern and western areas, the 110 kV network in these areas is at risk of significant overloading.

With an increased uptake in PV generation in the east of the country, more 110 kV circuits are shown to be at risk of overloading in this area compared to **Modest Progress**. However, the risk to these circuits is marginal when compared to circuits in the north-west area.

With the slower initial uptake of electric heating in **Addressing Climate Change**, bulk supply points in general do not come under significant pressure. A faster uptake in electric vehicles in this scenario does see some bulk supply points near larger towns at a very occasional risk of exceeding their firm capacity by 2025.

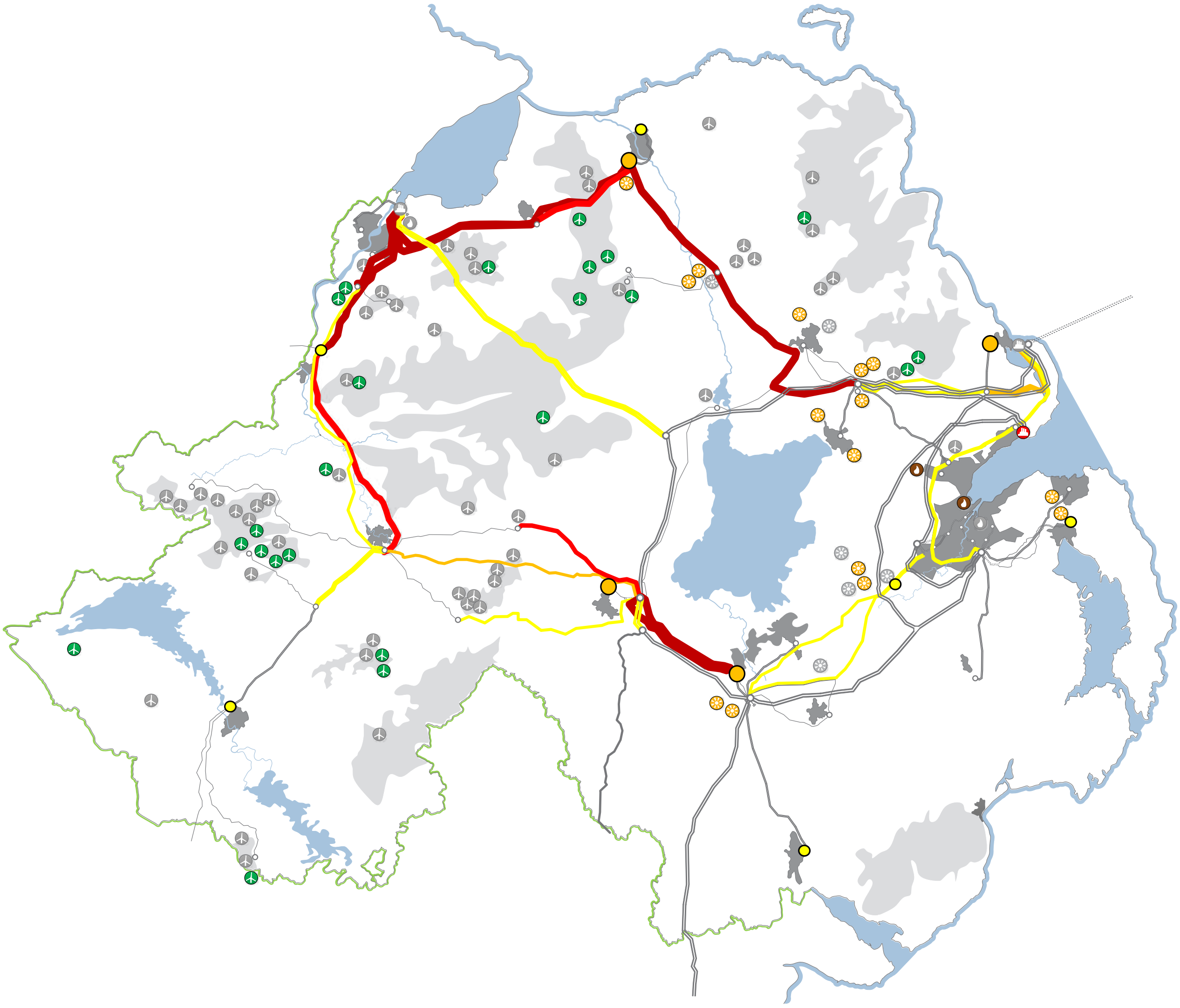


Figure 4.3: Accelerated Ambition 2025

With a need to meet a very ambitious 80% RES-E target by 2030, a large increase in renewable generation is anticipated by 2025 in **Accelerated Ambition**. As a result, circuits in northern and western areas at significant risk of overloading. With increased small-scale renewable generation, and increased electrical demand from heat and transport, more bulk supply points show overloading issues compared to **Modest Progress** and **Addressing Climate Change**.

4.2. Circuit overloads - northern area

A number of circuits are overloaded in this area in all scenarios in 2025. Figure 4.4 highlights corridors where circuits are at risk of overloading.

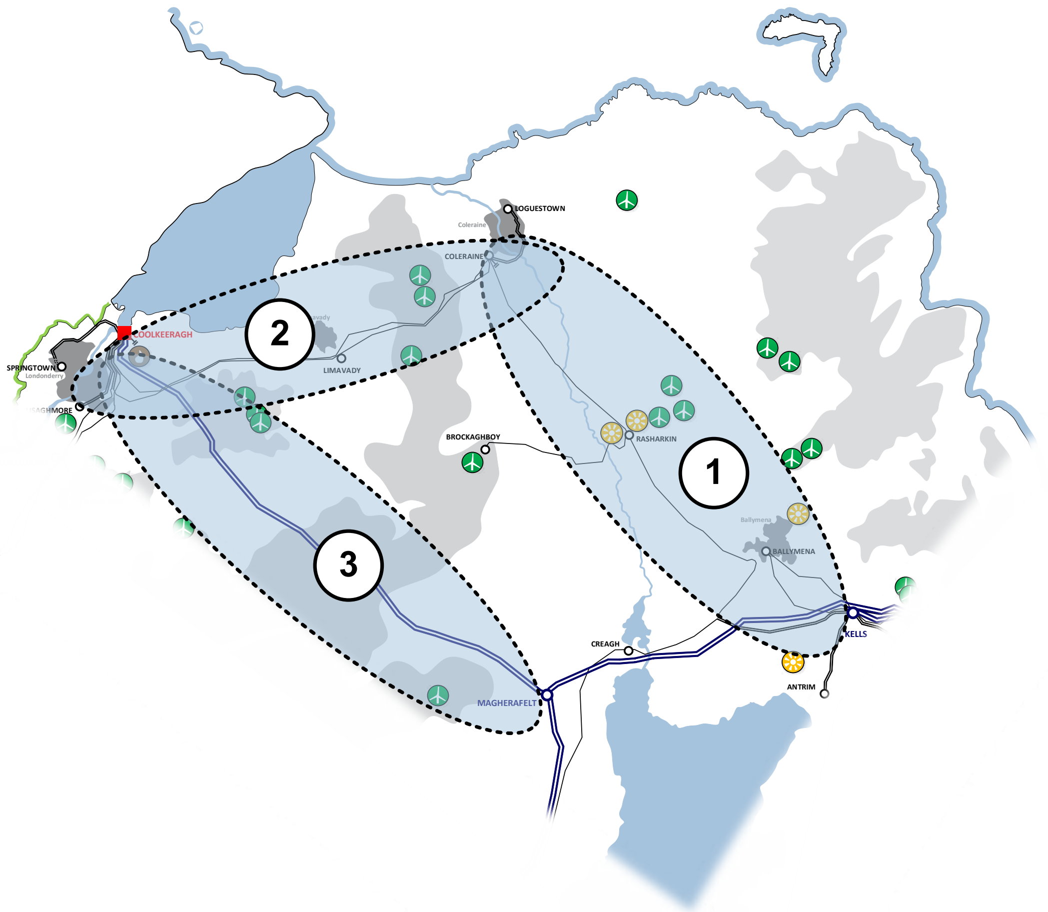


Figure 4.4: Overloaded corridors in the northern area in 2025

The Coleraine to Kells corridor (1) is at significant risk of overloading in all scenarios. Both the Kells to Rasharkin and the Coleraine to Rasharkin 110 kV circuits have a large risk of overloading following the Coolkeeragh to Magherafelt 275 kV double circuit contingency. Outages of either 110 kV circuit can also cause overloads of the other at times of high generation output at Rasharkin, Brockaghboy and Agivey.

The circuit with the highest risk of overloading in this corridor is the Kells to Rasharkin circuit. Figure 4.5 shows the load curves for the three scenarios for 2025.

With the largest increase in installed renewable generation capacity, **Accelerated Ambition** sees the largest risk of overloading across the year. Several hours in this scenario see excessive loading beyond twice the circuit rating, a result of heavily loaded circuits absorbing significant quantities of reactive power, and resulting in voltage collapse.

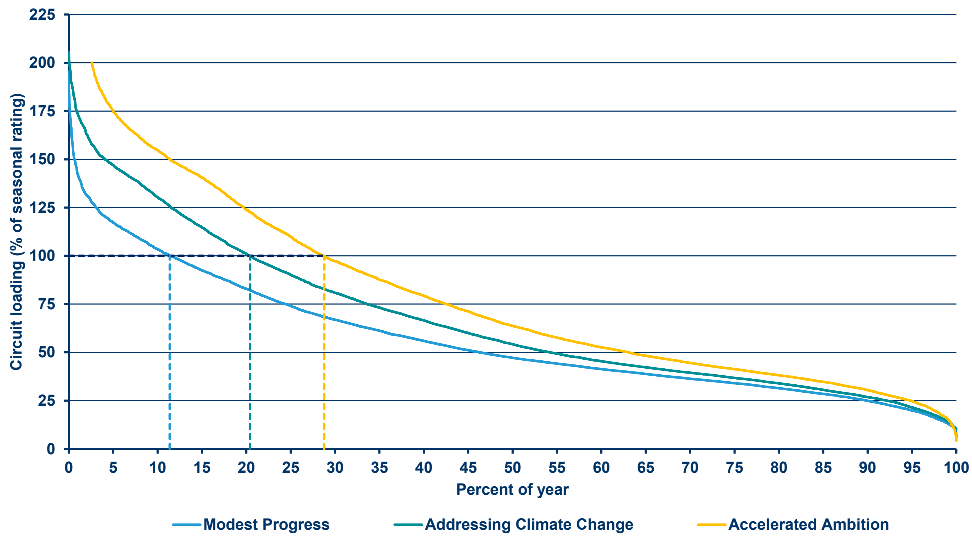


Figure 4.5: N-1 loading on the Kells to Rasharkin 110 kV circuit in 2025

The Coleraine to Coolkeeragh corridor (2) is at significant risk of overloading in all scenarios. All three 110 kV circuits see overloading under local 110 kV contingencies and for the loss of the Coolkeeragh to Magherafelt 275 kV double circuit. The most impacted circuit in all scenarios is the Coleraine to Coolkeeragh 110 kV circuit. The contingency load curves for this circuit are shown in figure 4.6. The risk of overloading this circuit in **Accelerated Ambition** is very high. Similar to the Coleraine to Kells corridor, a number of hours see voltage collapse issues, driven by extreme circuit overloading.

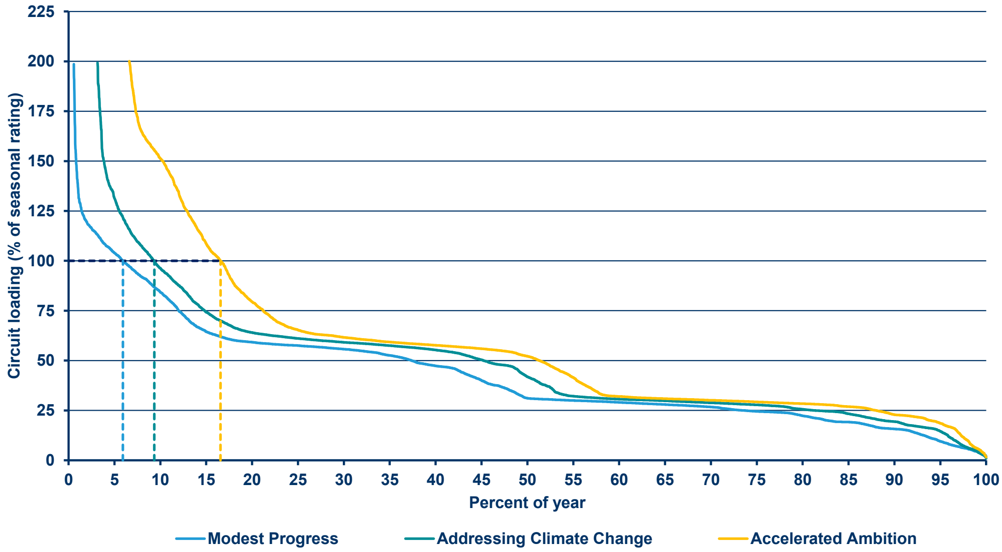


Figure 4.6: N-1 loading on the Coleraine to Coolkeeragh 110 kV circuit in 2025

At times of high generation output in the north-west area, there is a small risk of overload on either of the Coolkeeragh to Magherafelt 275 kV circuits (3) in the event of the loss of the other 275 kV circuit. In all scenarios, the risk is restricted to a small number of hours in the year.

4.3. Circuit overloads - western area

A number of circuits are overloaded in this area in all scenarios in 2025. Figure 4.7 highlights corridors where circuits are at risk of overloading.

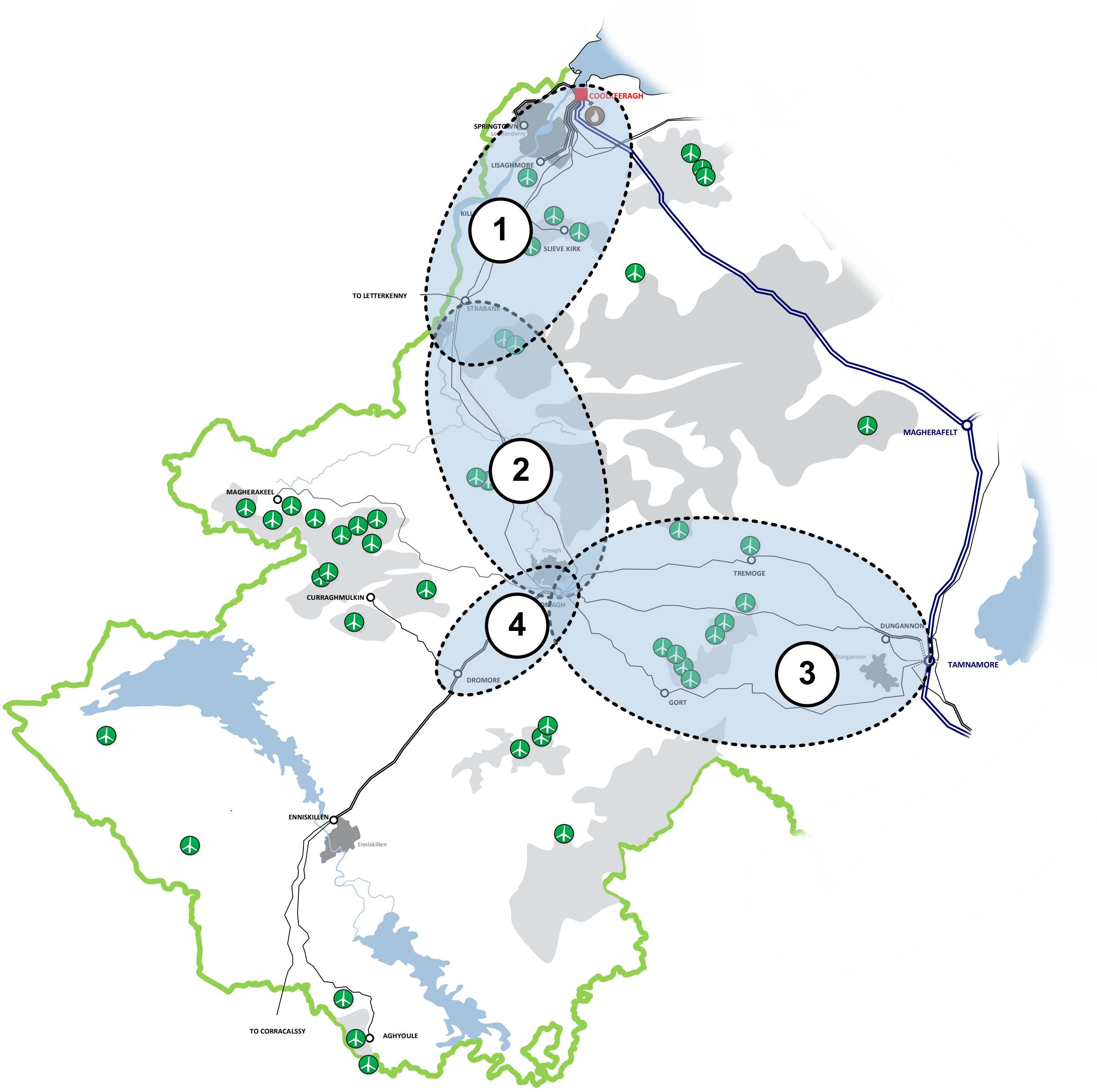


Figure 4.7: Overloaded corridors in the western area in 2025

The Coolkeeragh to Strabane corridor (1) is at significant risk of overloading in all scenarios. The most heavily loaded circuit in the corridor is the Coolkeeragh to Strabane 110 kV circuit, and the contingency load curves for this circuit are shown in figure 4.8. In all scenarios, the overload risk is present for over a third of the year. **Addressing Climate Change** and **Accelerated Ambition** both see the circuit at risk of overloading for almost half of the year, given the larger renewable generation capacity in the area in these scenarios.

The Omagh to Strabane corridor (2) is at risk of overloading in all scenarios If one Omagh to Strabane 110 kV circuit is lost, the remaining circuit is at risk of overloading. As the Omagh to Strabane 'B' circuit has a lower rating than the 'A' circuit, the risk to this circuit is greater, and the N-1 loading on the 'B' circuit is shown in figure 4.9. The risk of overloading the 'A' circuit is marginal, and is typically present for less than 2% of the year.

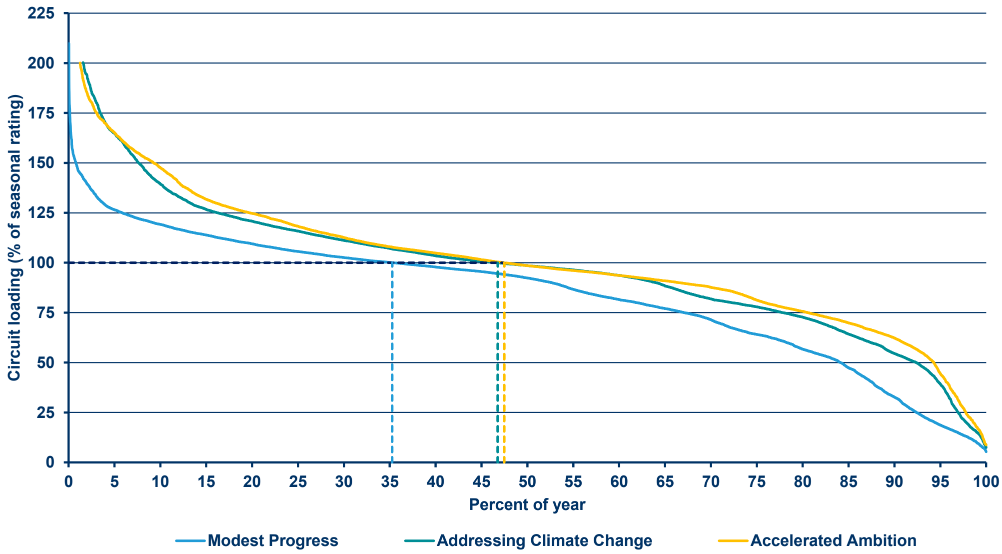


Figure 4.8: N-1 Loading on the Coolkeeragh to Strabane 110 kV circuit in 2025

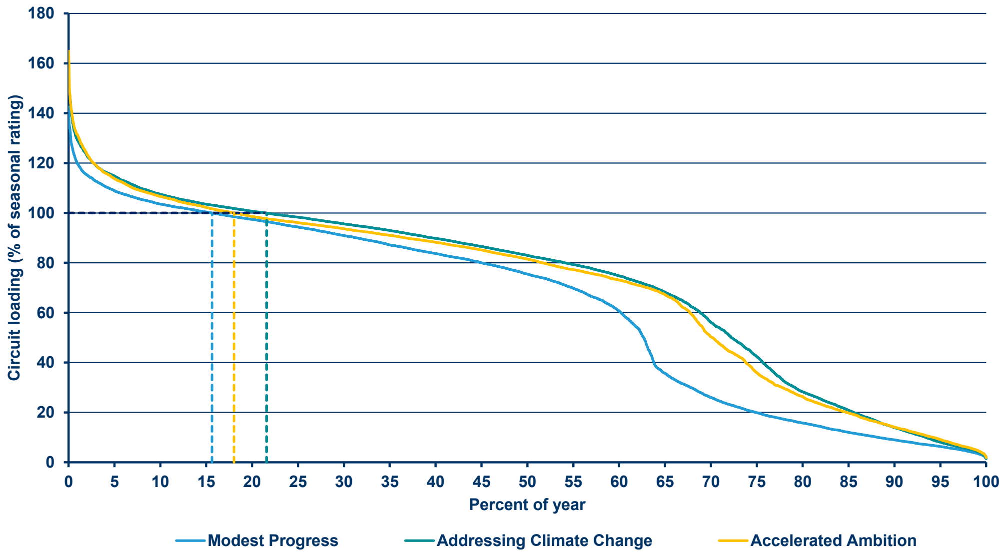


Figure 4.9: N-1 Loading on the Omagh to Strabane 110 kV 'B' circuit in 2025

The three 110 kV circuits in the Omagh to Tamnamore corridor (3) are all at risk of overloading in all scenarios. With two of the three circuits having renewable generation clusters located along them, the sections between the clusters and Tamnamore tend to see the heaviest loadings- however, a combination of the higher rating of the Gort to Tamnamore circuit and more assumed generation connected at Tremoge mean that the most heavily overloaded circuit is the section between Tamnamore and Tremoge. The N-1 loading on this circuit is shown in figure 4.10.

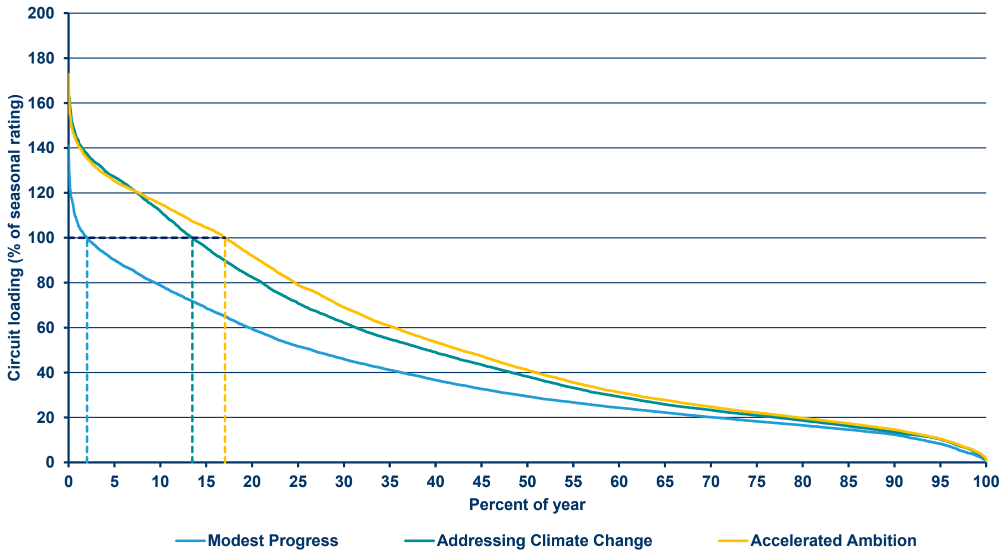


Figure 4.10: N-1 Loading on the Tamnamore to Tremoge 110 kV circuit in 2025

The risk is marginal in **Modest Progress** however, with additional renewable generation connected in the area, including at Tamnamore cluster in both **Addressing Climate Change** and **Accelerated Ambition**, a greater risk of overloading is observed in these scenarios.

The connection of Curraghmulkin cluster along the Enniskillen to Omagh 110 kV double circuit at Dromore presented a significant overload risk to the section of the double circuit between Dromore and Omagh (4). This section is planned to be uprated with higher capacity conductor. In spite of this, a small overload risk remains in both **Addressing Climate Change** and **Accelerated Ambition** in 2025, resulting from further renewable generation assumed to connect in the area. The N-1 loading is shown in figure 4.11.

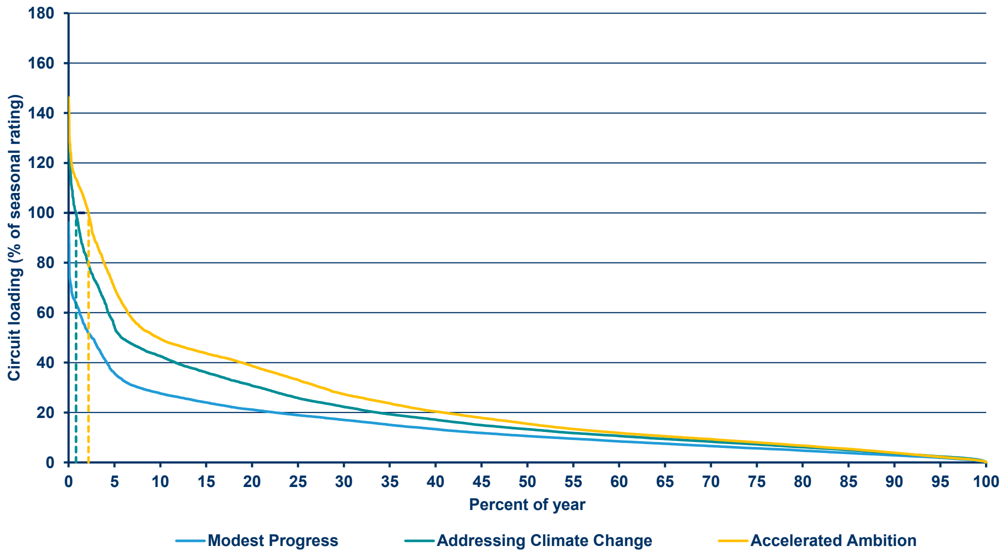


Figure 4.11: N-1 Loading on the Dromore to Omagh 110 kV 'A' circuit in 2025

4.4. Circuit overloads - eastern area

A number of circuits are overloaded in this area in all scenarios in 2025. Figure 4.12 highlights corridors where circuits are at risk of overloading. In general, the degree and extent of overloading in this area is much lower than in the northern and western areas.

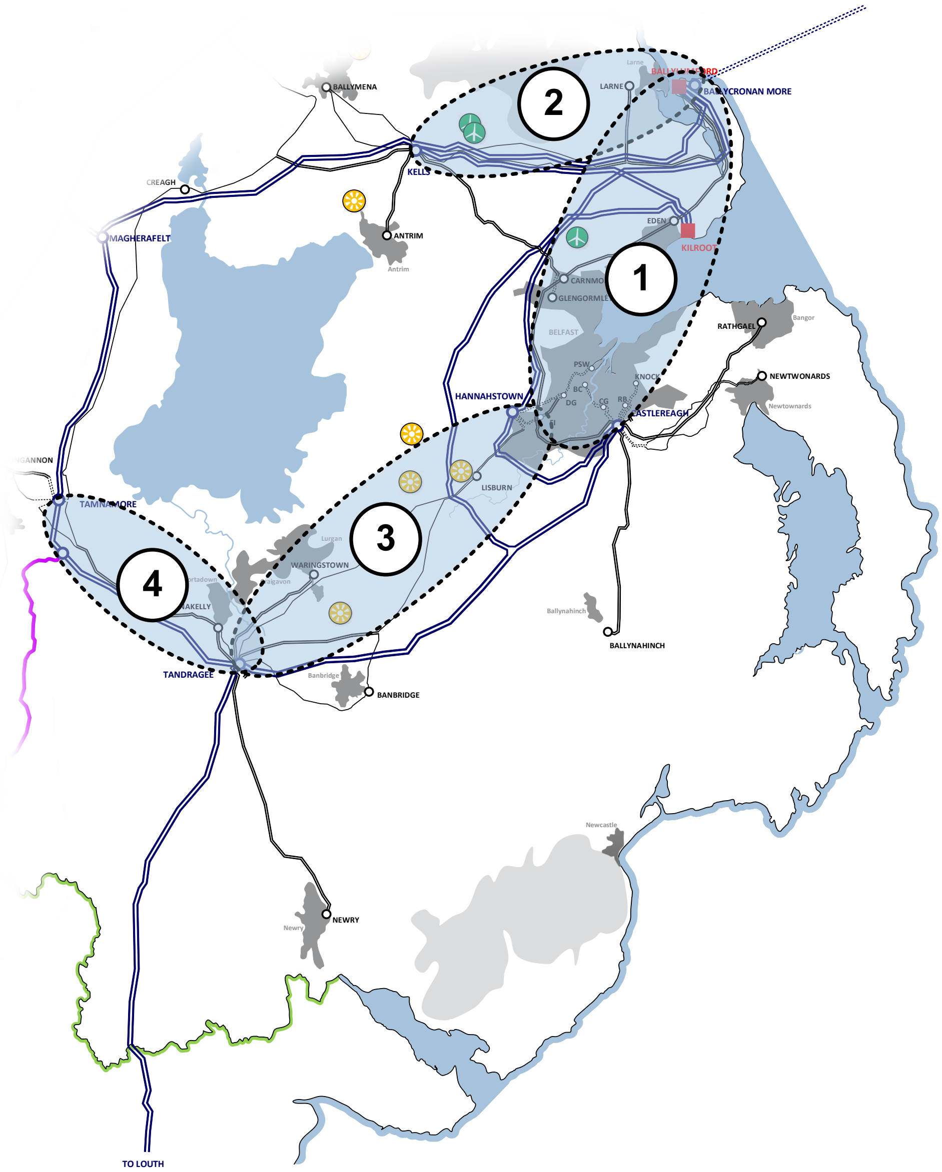


Figure 4.12: Overloaded corridors in the eastern area in 2025

The 110 kV circuits exiting the Islandmagee area are at risk of overloading in all scenarios in 2025. The risk to both the Ballylumford to Castlereagh (1) and Ballylumford to Kells (2) corridors is limited, affecting a small number of hours in the year. As an example, figure 4.13 shows the N-1 loading on the Ballylumford to Ballyvallagh 110 kV 'A' circuit.

The 110 kV circuits between Hannahstown and Tandragee (3) are at very marginal risk of overloading. Double circuit contingencies on the 275 kV network between Tandragee and Castlereagh can result in heavy power flows on the underlying 110 kV network. Coupled with high PV generation output at Lisburn, the 110 kV circuits can be overloaded. With the highest installed capacity of PV generation, the risk is greatest in Accelerated Ambition; however, it is still limited to less than 1% of the year.

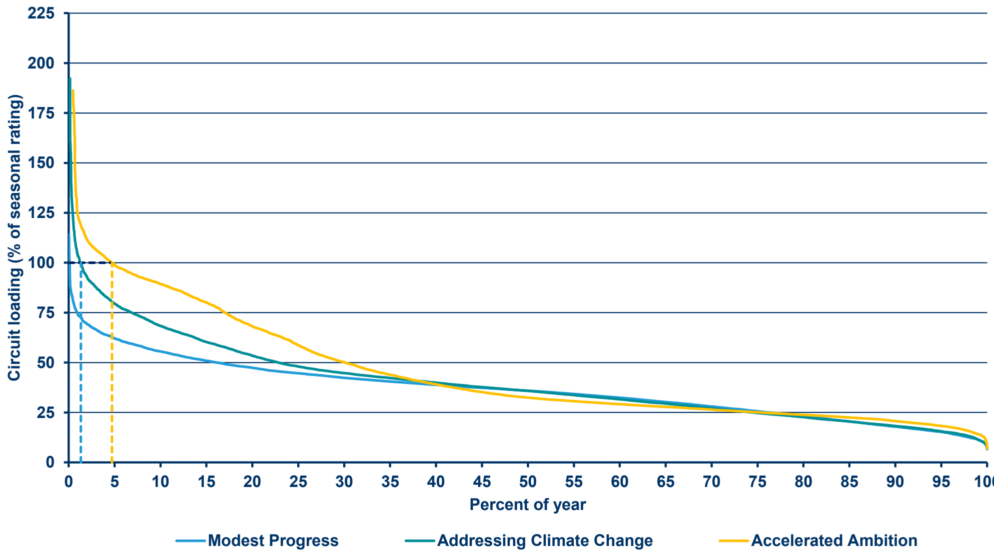


Figure 4.13: N-1 Loading on the Ballylumford to Ballyvallagh 110 kV 'A' circuit in 2025

The corridor between Drumnakelly and Tamnamore (4) is at significant risk of overloading across the year. The 110 kV circuits between Drumnakelly and Tamnamore can become very heavily overloaded at times of high renewable generation output following the loss of the Coolkeeragh to Magherafelt 275 kV double circuit. This is particularly true in both **Addressing Climate Change** and **Accelerated Ambition**, with the large increases in installed renewable generation capacities in these scenarios. Figure 4.14 shows the N-1 loading on the Drumnakelly to Tamnamore 110 kV 'A' circuit.

This issue can be mitigated by operating with the Drumnakelly and Tamnamore 110 kV circuits open, but this then presents a risk to both the interbus transformers at Tamnamore and the 275 kV double circuit between Tamnamore and the proposed 275/400 kV substation at Turleenan.

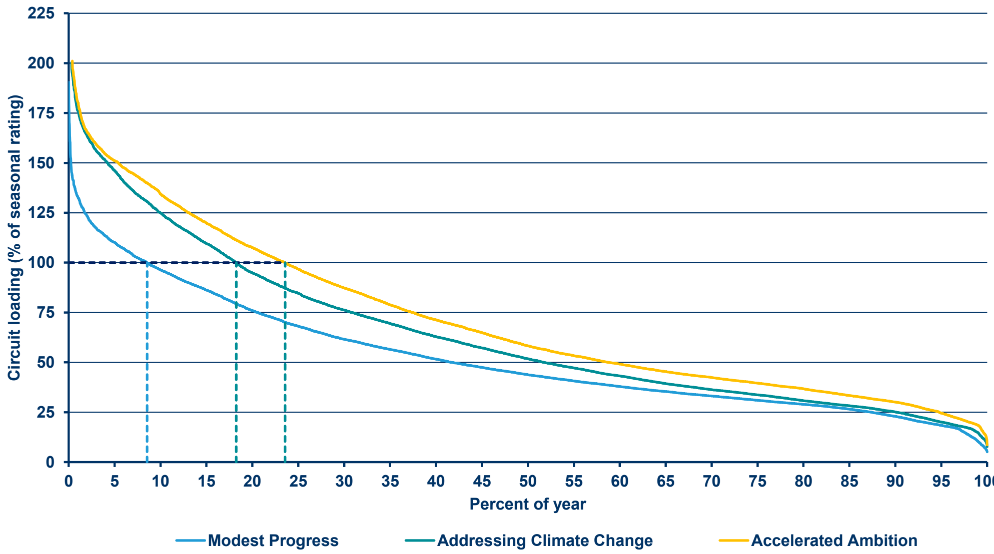


Figure 4.14: N-1 Loading on the Drumnakelly to Tamnamore 110 kV 'A' circuit in 2025

4.5. Phase Angle

Figure 4.15 shows the voltage phase angle difference between Coolkeeragh and Magherafelt for the loss of the 275 kV double circuit across the year. A difference of greater than 20° occurs a significant number of times in all scenarios, more so in both Addressing Climate Change and Accelerated Ambition, given the larger renewable generation portfolio in the north-west area in these scenarios.

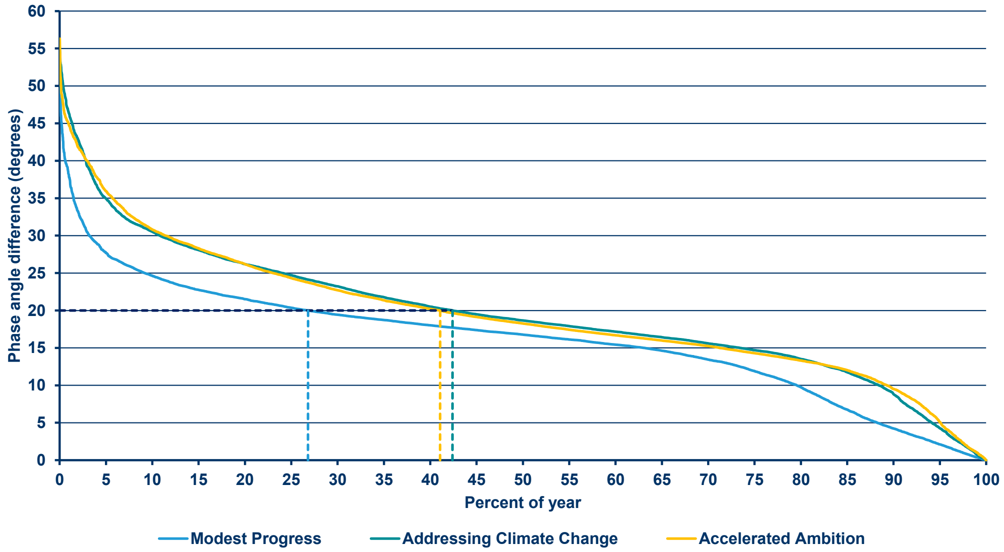


Figure 4.15: Coolkeeragh to Magherafelt phase angle difference

4.6. Bulk supply points

Very few capacity issues are noted at bulk supply points in all scenarios in 2025. Typically, the more rapid uptake of electric heat and transport in **Accelerated Ambition** sees a number of BSPs at risk of exceeding firm capacity for a handful of hours in the year. Table 4.5 presents the maximum loading (% load) at each bulk supply point and the percentage of the year (% year) the firm capacity is exceeded, for each scenario.

Table 4.5: N-1 Bulk Supply Point assessment 2025

Bulk Supply Point	Modest Progress		Addressing Climate Change		Accelerated Ambition		Driver
	% load	% year	% load	% year	% load	% year	
Airport Road	35	0	38	0	41	0	Electric heat and transport
Antrim	48	0	51	0	58	0	
Ballymena Rural	72	0	74	0	75	0	
Ballymena Town	47	0	50	0	54	0	
Ballynahinch	61	0	66	0	73	0	
Banbridge	66	0	72	0	83	0	
Belfast Central	58	0	62	0	67	0	
Belfast North Main	45	0	44	0	54	0	
Carnmoney	22	0	21	0	31	0	
Coleraine	148	7.8	151	10.4	147	7.4	Small scale generation
Coolkeeragh	22	0	21	0	20	0	
Creagh	40	0	42	0	46	0	
Cregagh	82	0	89	0	96	0	
Donegall N	50	0	53	0	58	0	
Donegall S	66	0	71	0	78	0	
Drumnakelly	116	3.3	122	7.2	146	17.1	Electric heat and transport
Dungannon	114	0.9	124	3.4	141	10.4	Electric heat and transport
Eden	75	0	80	0	85	0	
Enniskillen	87	0	96	0	103	0.1	Electric heat and transport
Finaghy	69	0	75	0	82	0	
Knock	61	0	66	0	72	0	
Larne	99	0	106	0.2	160	8.1	Renewable generation
Limavady	74	0	74	0	72	0	
Lisaghmore	73	0	79	0	88	0	
Lisburn	82	0	91	0	105	0.2	PV generation
Loguestown	86	0	93	0	105	0.1	Electric heat and transport
Newry	89	0	98	0	111	0.2	Electric heat and transport
Newtownards	79	0	87	0	101	0.1	PV generation
Omagh	84	0	82	0	79	0	
Rathgael	64	0	70	0	80	0	
Rosebank	22	0	26	0	29	0	
Springtown	51	0	55	0	60	0	
Strabane	100	0.1	105	0.1	0	0.4	Renewable generation
Waringstown	72	0	79	0	89	0	

4.7. Voltage performance

With the increased levels of renewable generation in the scenarios, coupled with a reduction in the minimum number of thermal generation units required to be dispatched, at times, low voltage issues are noted on the transmission network. Typically, these issues arise at times of high renewable generation output in the north-west following the Coolkeeragh to Magherafelt 275 kV double circuit contingency. With all generation in the area having to make use of the 110 kV network to transfer power, the heavily loaded 110 kV circuits consume a significant quantity of reactive power, resulting in widespread low voltages across the north-west area.

Figure 4.16 shows the amount of reactive compensation required in the scenarios, and percent of the year it was required. With little growth in renewable generation compared to today, **Modest Progress** sees little requirement for reactive compensation. With higher SNSP limits, **Addressing Climate Change** and **Accelerated Ambition** both see a greater need for reactive compensation.

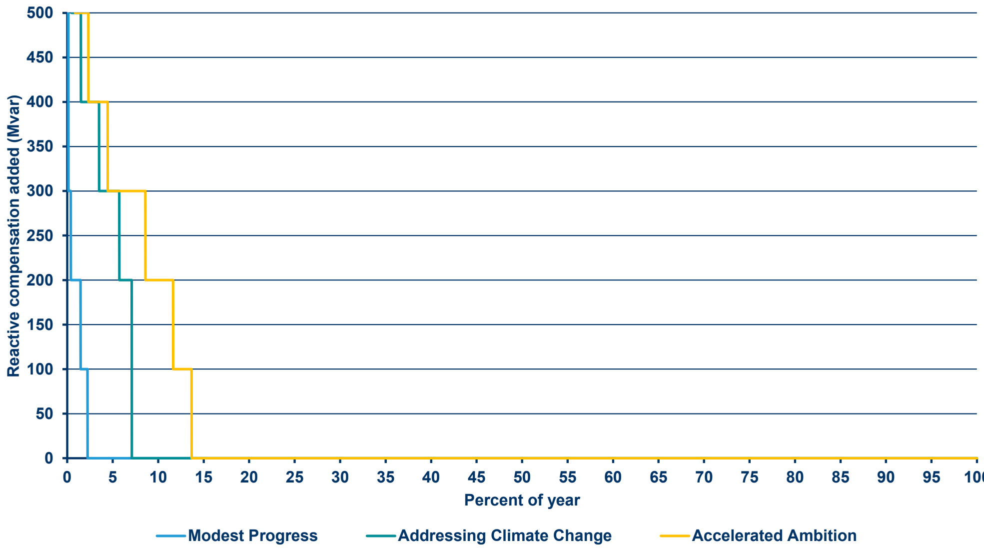


Figure 4.16: Reactive compensation added in 2025

In some cases, it is still not possible to solve the network, due to extreme loading of 110 kV circuits resulting in voltage collapse. This was observed in approximately 0.5% of hours across the year in **Addressing Climate Change** and 1% of hours in **Accelerated Ambition**.

4.8. Generation dispatch down

Table 4.6 shows the estimated level of renewable generation dispatch down in the scenarios for 2025. Dispatch down related to oversupply and curtailment was previously calculated as part of the dispatch modelling in the TESNI 2020. Constraints have been estimated as part of the network analysis performed for the SNA.

With a higher assumed value of SNSP, **Addressing Climate Change** sees less curtailment than **Modest Progress**. However, the resulting power flows on the present network from these levels of renewable generation result in higher network constraints. With the largest renewable generation portfolio, **Accelerated Ambition** sees significant dispatch down in all categories.

Table 4.6: Renewable generation dispatch down in 2025 in the scenarios

Dispatch down	Modest Progress	Addressing Climate Change	Accelerated Ambition
Curtailment + Oversupply (GWh)	268	190	418
Constraint (GWh)	134	229	440
Total (GWh)	**402**	**419**	**858**

5. 2030

5. 2030

5.1. Scenarios summary

Table 5.1 details renewable generation capacity added in each scenario compared to 2020.

Table 5.1: New renewable generation capacity in MW by 2030 in the scenarios

Bulk Supply Point	Modest Progress	Addressing Climate Change	Accelerated Ambition
Onshore wind - large scale	440	487	550
Onshore wind - small scale	50	101	59
Offshore wind	0	350	500
PV - large scale	169	300	754
PV - small scale and micro	21	86	184
Biomass	4	23	43
Hydro	0	0	0
Marine	0	0	100

Table 5.2 details new electric heat and transport added in each scenario compared to 2020.

Table 5.2: New electric heat and transport by 2030 in the scenarios

Electric heat and transport	Modest Progress	Addressing Climate Change	Accelerated Ambition
Electric vehicles (1,000's)	158	273	372
Heat pumps (1,000's)	26	167	159

Table 5.3 lists some demand data for each scenario.

Table 5.3: 2030 demand in the scenarios

Demand information	Modest Progress	Addressing Climate Change	Accelerated Ambition
TER (TWh)	8.6	9.9	11.7
Peak demand (MW)	1,629	1,851	2,115

Table 5.4 details some operational constraints for 2030. Full details are in TESNI 2020.

Table 5.4: 2030 operational constraints

Operational constraint	Modest Progress	Addressing Climate Change	Accelerated Ambition
SNSP upper limit (%)	85	95	95
Minimum thermal units in NI	2	2	1

Modest Progress 2030

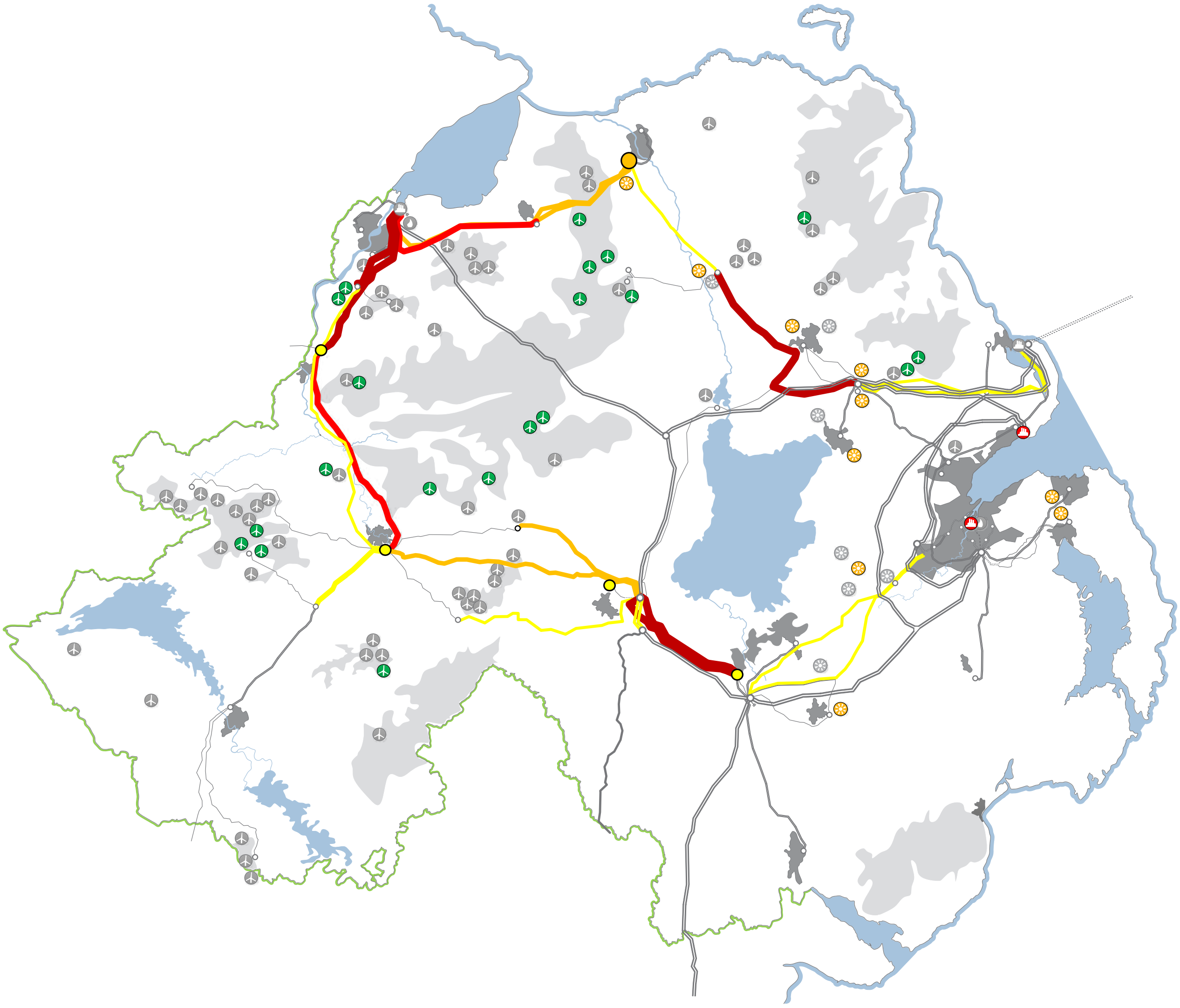


Figure 5.1: Modest Progress 2030

Modest Progress delivers 60% RES-E by 2030, which is entirely facilitated by onshore renewable generation. The majority of this new capacity is wind generation located in northern and western areas. Combined with lower growth in demand, the 110 kV network in the north-west comes under increased pressure, with a number of circuits in the area at risk of significant overloading.

In the east of the country, a number of 110 kV overloads are observed, relates to a growth in PV generation. The risk of overloading circuits in this area is marginal compared to those observed in the north-west.

Low demand growth, and slow uptake of electric heating in **Modest Progress** sees the majority of bulk supply points continue to have sufficient firm capacity, with only a handful experiencing a marginal overload risk across the year.

Addressing Climate Change 2030

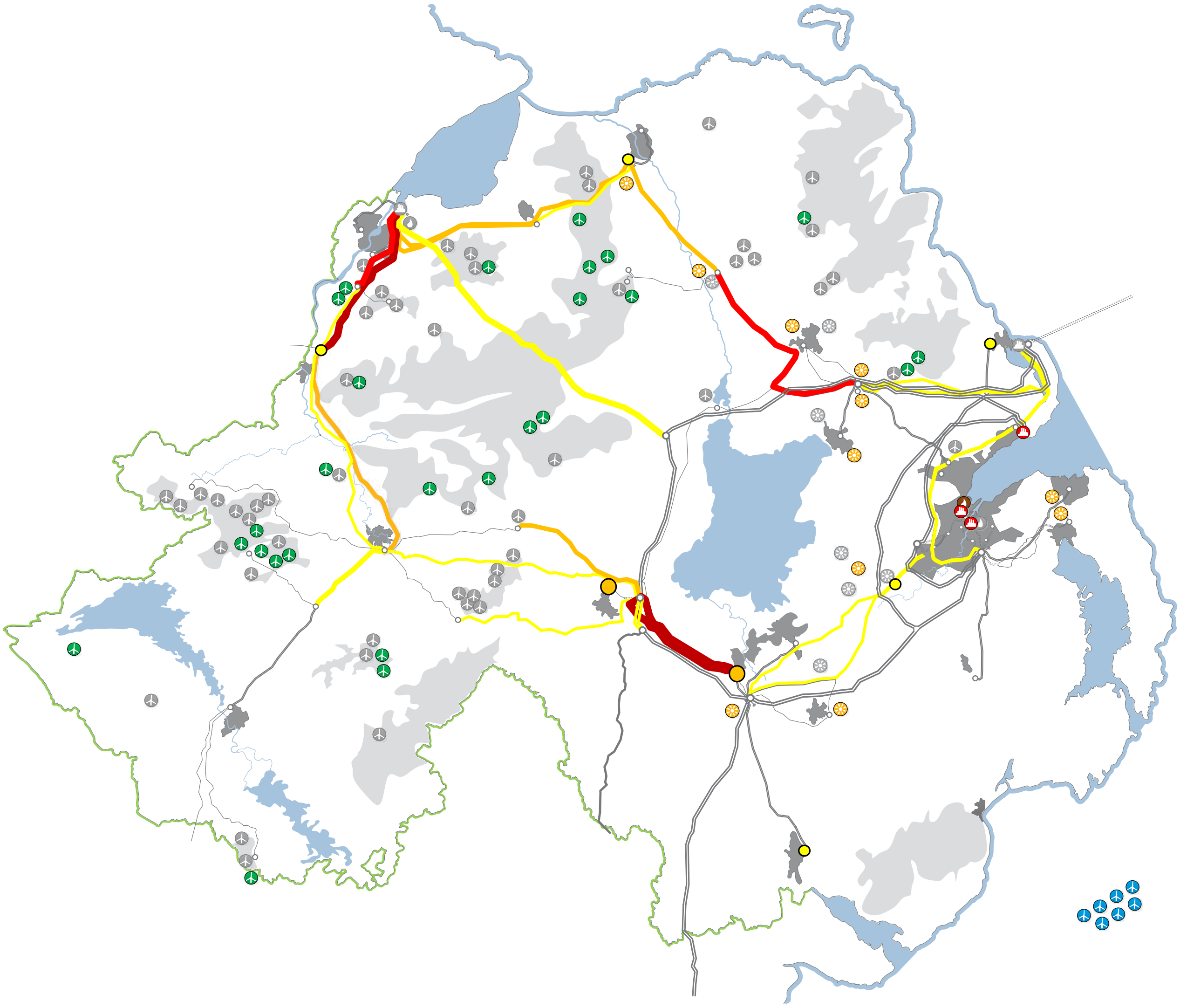


Figure 5.2: Addressing Climate Change 2030

Addressing Climate Change delivers 70% RES-E by 2030. This is primarily facilitated by the development of offshore renewable generation to the east of the country in this scenario. Combined with relaxed operational constraints compared to 2025, and an increase in electric heat and transport, overload risks to many circuits in the north-west area actually reduce when compared to 2025.

By 2030, **Addressing Climate Change** highlights the benefits of the development of offshore renewable generation. The stronger transmission network towards the east of the country is capable of connecting the large offshore wind farm. Less onshore renewable generation capacity is required as a result to meet the 70% RES-E target. The severity and extent of overloading in the north-west observed in **Addressing Climate Change** 2030 is less than in **Modest Progress**, in spite of the lower RES-E target of 60% in **Modest Progress**.

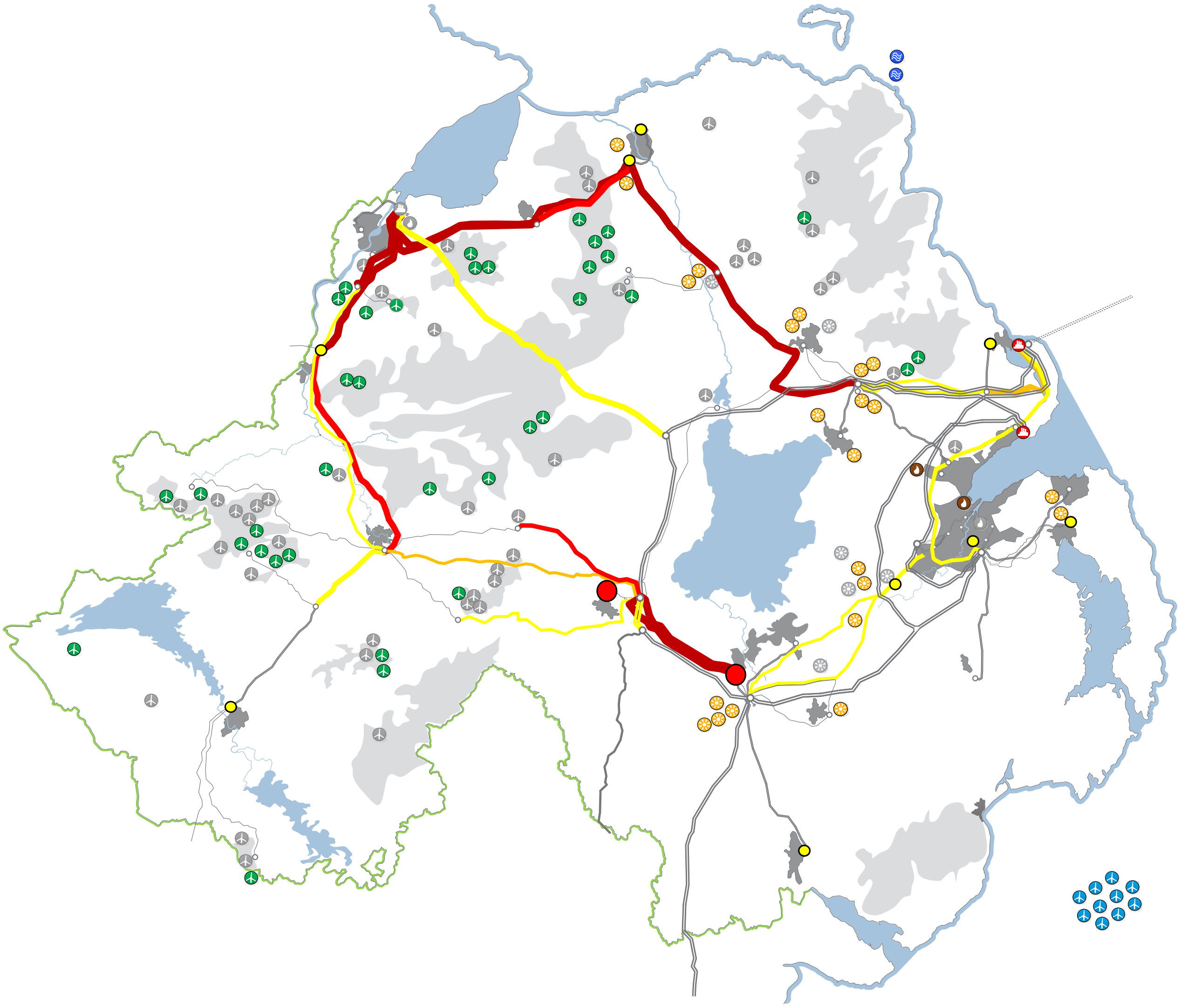


Figure 5.3: Accelerated Ambition 2030

Delivering an 80% RES-E target for 2030 sees significant overloading of the transmission network across the north-west in **Accelerated Ambition**. In spite of the connection of a larger offshore wind farm in **Accelerated Ambition** than in **Addressing Climate Change**, and the development of marine generation, the amount of onshore renewable generation still required to meet a 80% target results in the heaviest overloading of the network observed in all three scenarios in 2030.

An increase in economic growth towards 2030, combined with a faster uptake of both electric heat and transport, sees more bulk supply points at risk of exceeding their firm capacity during the year; in some cases, this risk is significant.

5.2. Circuit overloads - northern area

A number of circuits are overloaded in this area in all scenarios in 2030. Figure 5.4 highlights corridors where circuits are at risk of overloading.

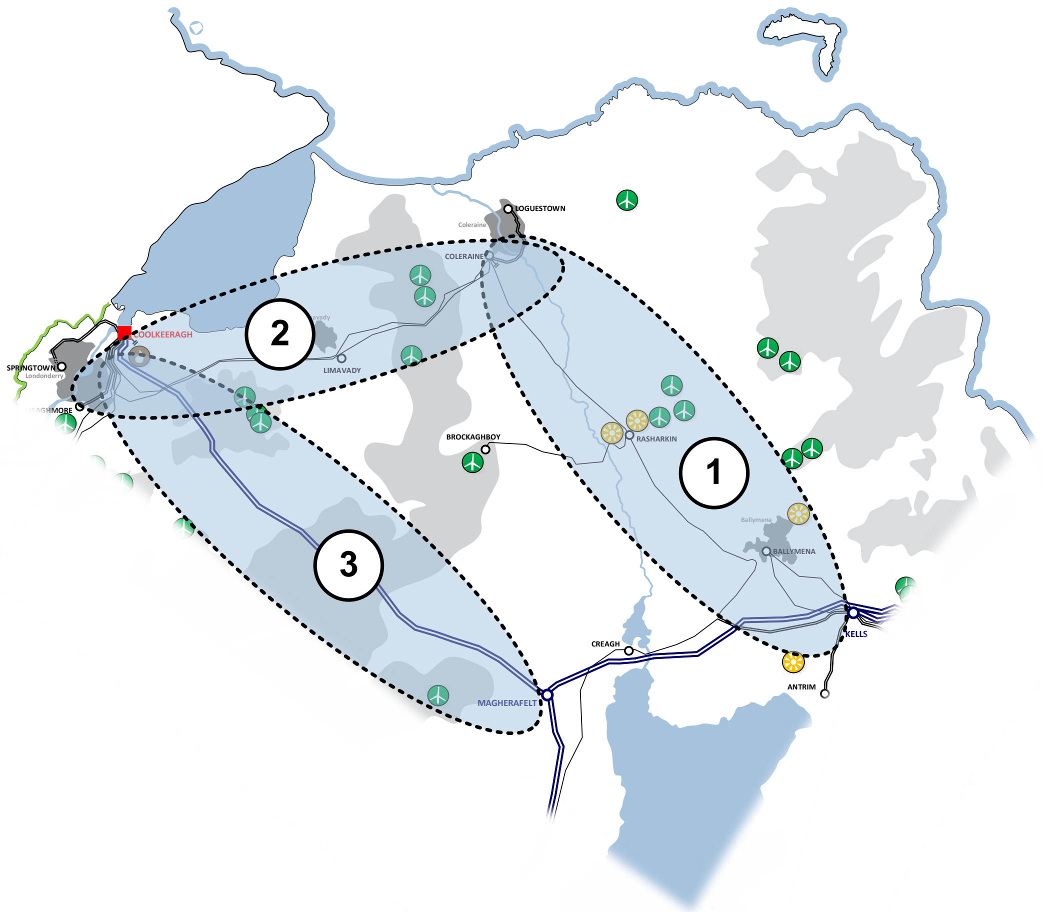


Figure 5.4: Overloaded corridors in the northern area in 2030

With further increases in renewable generation in all scenarios by 2030, the Coleraine to Kells corridor (1) is again at significant risk of overloading in all scenarios. The circuit with the highest risk of overloading in this corridor is the Kells to Rasharkin circuit. Figure 5.5 shows the load curves for the three scenarios for 2030.

In general, the degree of overloading in 2030 is similar to 2025. Of note is that **Addressing Climate Change** now sees the lowest risk of overloading. The majority of additional renewable generation capacity in this scenario is located to the east of the country, in the form of offshore wind and PV. Combined with additional demand growth in the form of electric heat and transport, the degree and extent of overloading in both northern and western areas of the transmission network tend to be similar, or sometimes reduced, compared to 2025 in **Addressing Climate Change**.

In spite of offshore generation also being progressed in **Accelerated Ambition**, similar trends in results are not observed, due to the large increase in onshore renewable generation also required to ultimately deliver an 80% RES-E target.

The Coleraine to Rasharkin circuit sees a reduced risk of overloading in both **Modest Progress** and **Addressing Climate Change**, due to an increase in demand in the north-west area from electric heat and transport. **Accelerated Ambition** continues to see a larger risk of overloading across the year, due to the large increase in renewable generation in the scenario.

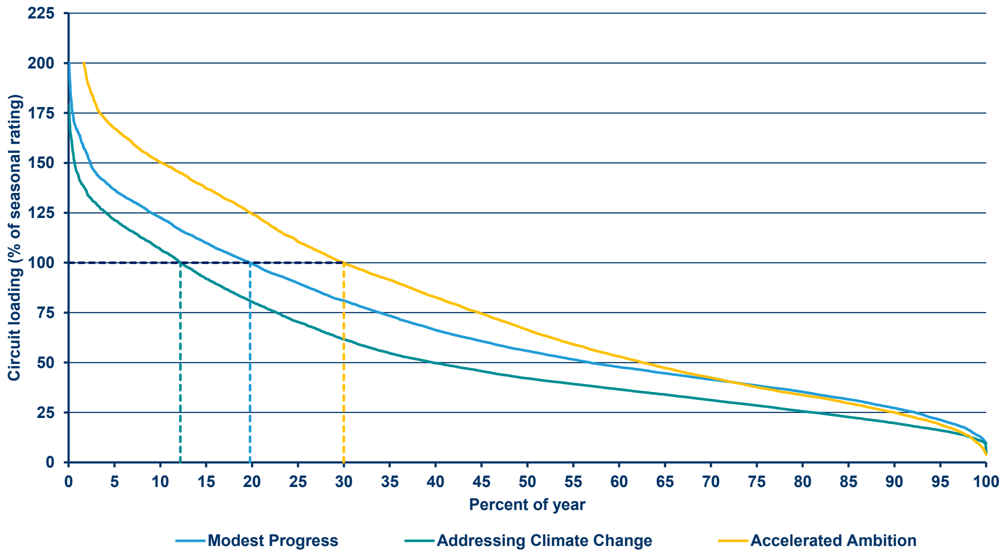


Figure 5.5: N-1 loading on the Kells to Rasharkin 110 kV circuit in 2030

The Coleraine to Coolkeeragh corridor (2) is at significant risk of overloading in all scenarios, with most impacted circuit again being the Coleraine to Coolkeeragh 110 kV circuit. The contingency load curves for this circuit are shown in figure 5.6. **Addressing Climate Change** sees a reduced risk compared to 2025. The risk of overloading this circuit in **Accelerated Ambition** is very high, with extreme loading causing voltage collapse in almost 10% of hours across the year.

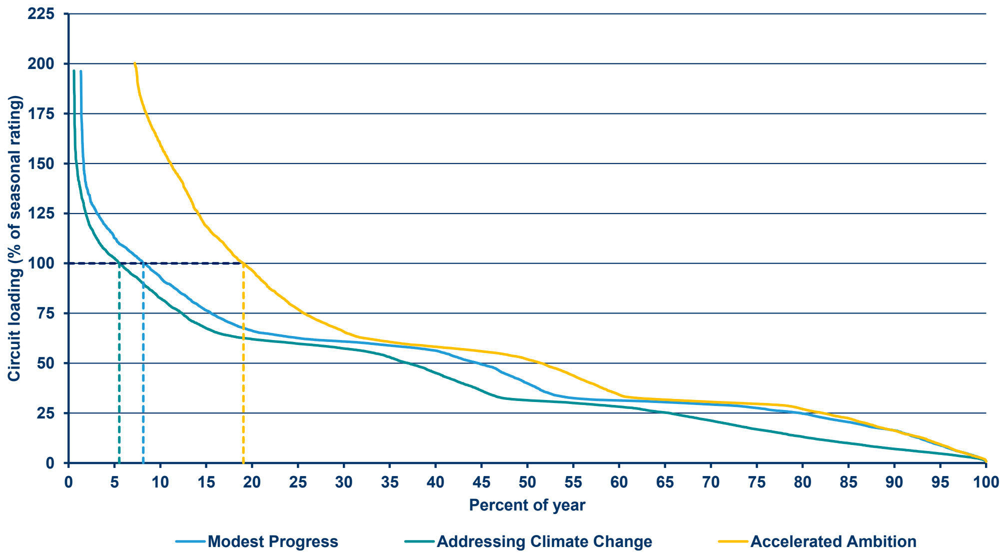


Figure 5.6: N-1 loading on the Coleraine to Coolkeeragh 110 kV circuit in 2030

At times of high generation output in the north-west area, there is a small risk of overload on of the Coolkeeragh to Magherafelt 275 kV circuits (3) in the event of the loss of the other 275 kV circuit.

5.3. Circuit overloads - western area

A number of circuits are overloaded in this area in all scenarios in 2030. Figure 5.7 highlights corridors where circuits are at risk of overloading.

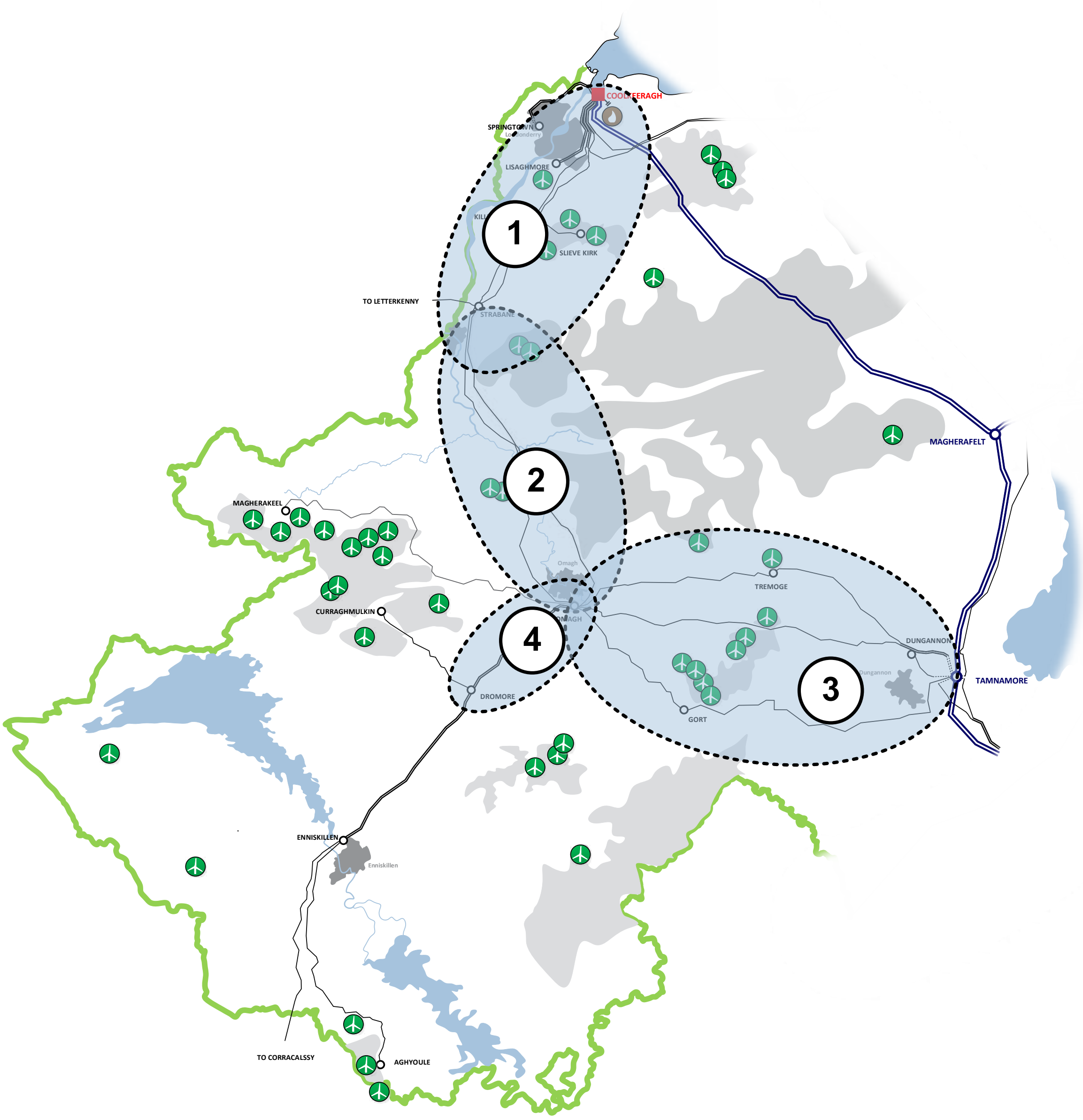


Figure 5.7: Overloaded corridors in the western area in 2030

The Coolkeeragh to Strabane corridor (1) is at significant risk of overloading in all scenarios. The most heavily loaded circuit in the corridor is again the Coolkeeragh to Strabane 110 kV circuit, and the contingency load curves for this circuit are shown in figure 5.8. In all scenarios, the overload risk is present for over a third of the year. **Modest Progress** now sees the highest occurrences of overloads, as a result of a continued focus on onshore renewable generation development and lower demand growth.

The Coolkeeragh to Killymallaght 110 kV circuit sees a similar degree and extent of overloading, whilst the risk is lower on the Killymallaght to Strabane 110 kV circuit due to the network configuration in the area.

The Omagh to Strabane corridor (2) is at risk of overloading in all scenarios, however, the extent of overloading reduces compared to 2025. The risk is now highest in **Modest Progress** due to a combination of onshore renewable generation growth and lower demand growth in this scenario. In **Addressing Climate Change**, the risk has reduced to the extent that it is marginal, a result of the development of renewable generation capacity towards the east of the country and demand growth from electric heat and transport.

The N-1 loading on the Omagh to Strabane 110 kV 'B' circuit is shown in figure 5.9.

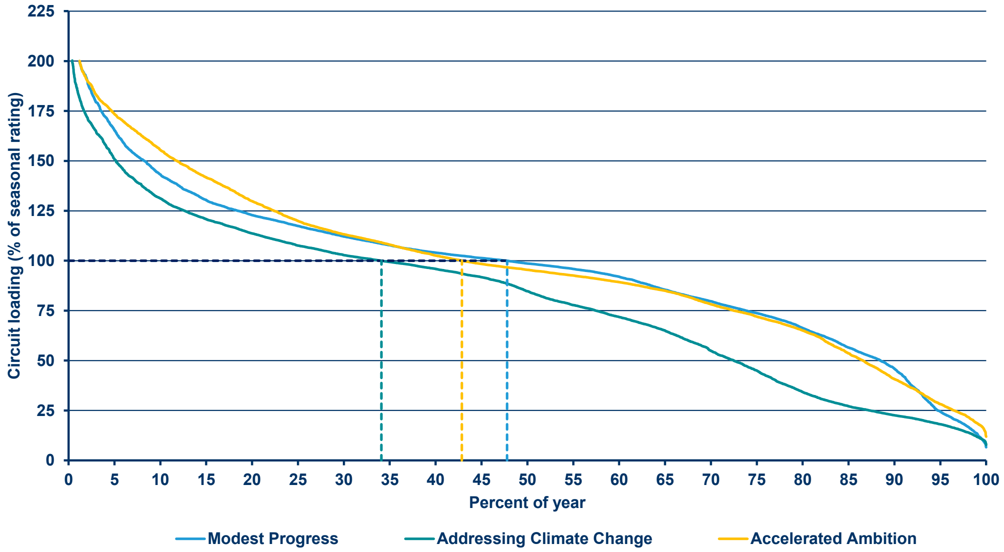


Figure 5.8: N-1 loading on the Coolkeeragh to Strabane 110 kV circuit in 2030

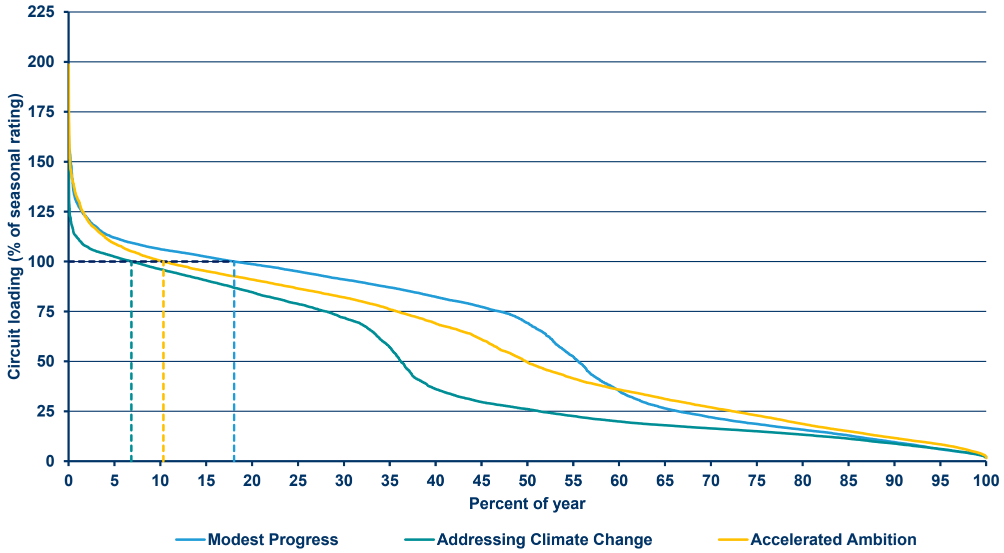


Figure 5.9: N-1 loading on the Omagh to Strabane 110 kV 'B' circuit in 2030

The Omagh to Tamnamore corridor (3) continues to be at risk of overloading in 2030. In **Addressing Climate Change** the risk has reduced from 2025. With the continued focus on developing onshore renewable generation, the risk in **Modest Progress** increases considerable from 2025. Given the large increase in renewable generation capacity required to meet an 80% RES-E target, the risk remains highest in **Accelerated Ambition**.

With little additional renewable generation capacity assumed in all scenarios in the Fermanagh area, the risk to the Enniskillen to Omagh corridor remains low in 2030. Figure 5.11 shows the N-1 loading for the section between Dromore and Omagh. In all scenarios, the risk of overloading is for less than 2% of the year. With some demand growth at Enniskillen from electric heat and transport, the risk in both **Addressing Climate Change** and **Accelerated Ambition** is actually reduced from 2025.

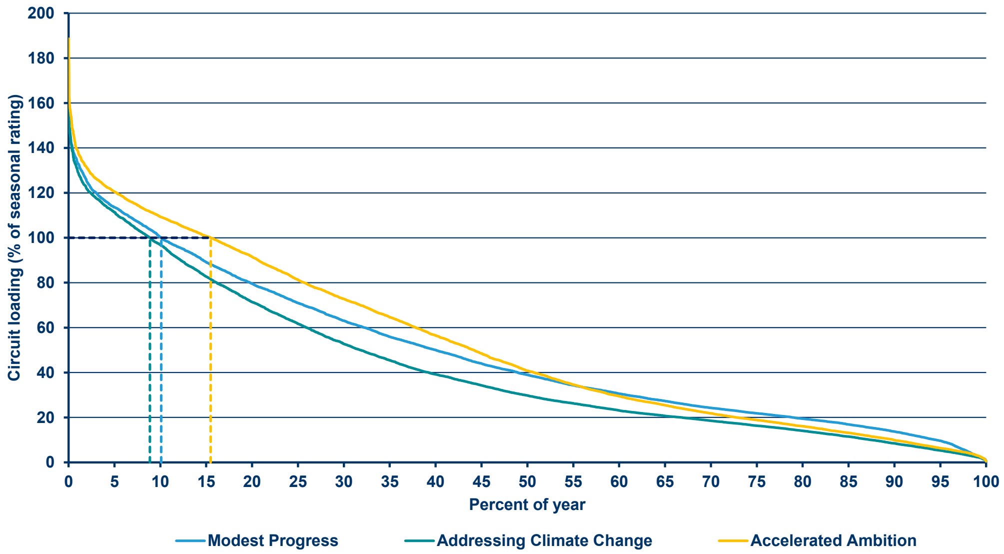


Figure 5.10: N-1 loading on the Tamnamore to Tremoge 110 kV circuit in 2030

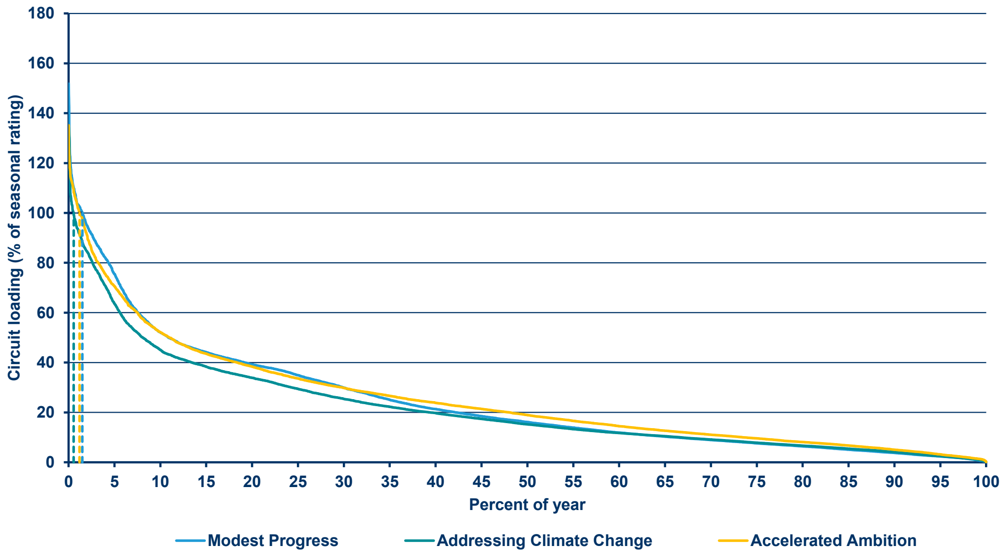


Figure 5.11: N-1 loading on the Dromore to Omagh 110 kV ‘A’ circuit in 2030

5.4. Circuit overloads - eastern area

A number of circuits are overloaded in this area in all scenarios in 2030. Figure 5.12 highlights corridors where circuits are at risk of overloading. Again, the degree and extent of overloading in this area is much lower than in the northern and western areas.

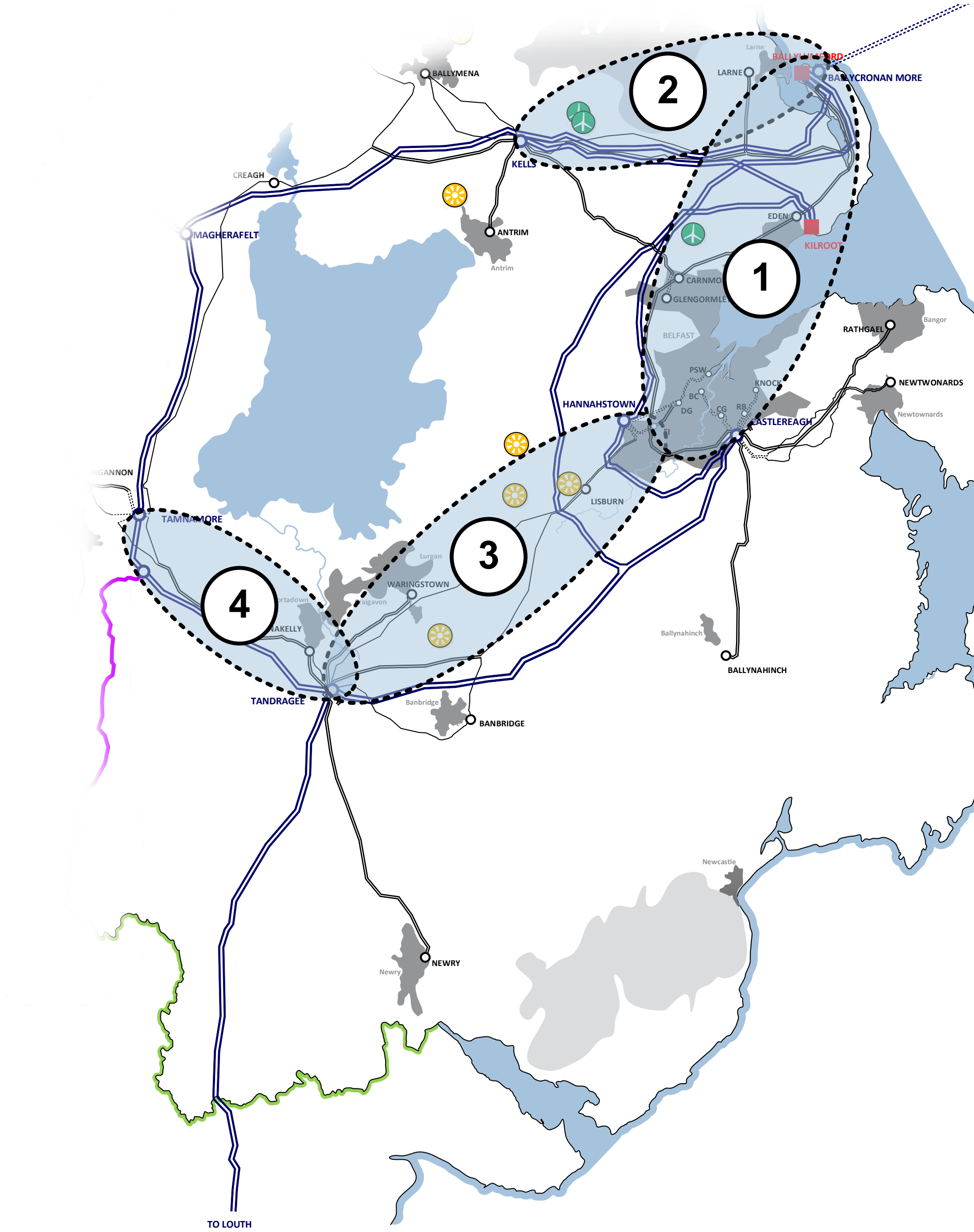


Figure 5.12: Overloaded corridors in the eastern area in 2030

The 110 kV circuits exiting the Islandmagee area are at risk of overloading in all scenarios in 2030. The risk to both the Ballylumford to Castlereagh (1) and Ballylumford to Kells (2) corridors is limited, affecting a small number of hours in the year. Similarly, the 110 kV circuits between Hannahstown and Tandragee (3) are at very marginal risk of overloading.

The Tamnamore to Tandragee corridor (4), on the other hand, sees considerable risk of overloading in all scenarios. The 110 kV circuits between Drumnakelly and Tamnamore are again the most impacted. Figure 5.13 shows the N-1 loading on the Drumnakelly to Tamnamore 110 kV 'A' circuit.

Mitigating the issue by operating with the Drumnakelly and Tamnamore 110 kV circuits open again presents a risk to both the interbus transformers at Tamnamore and the 275 kV double circuit between Tamnamore and the proposed 275/400 kV substation at Turleenan. This risk continues to be marginal, being present for about 1% of the year.

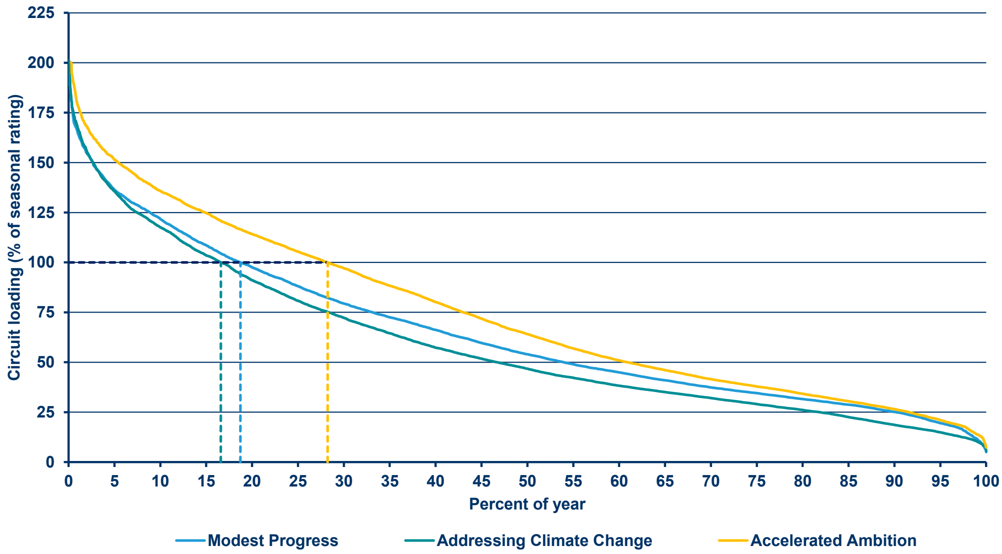


Figure 5.13: N-1 loading on the Drumnakelly to Tamnamore 110 kV 'A' circuit in 2030

5.5. Phase Angle

Figure 5.14 shows the voltage phase angle difference between Coolkeeragh and Magherafelt for the loss of the 275 kV double circuit across the year. An assumed relaxation of operational constraints by 2030 sees a reduction in the number of hours the 20° difference is exceeded in both **Addressing Climate Change** and **Accelerated Ambition**. **Modest Progress**, meanwhile, sees the greatest risk across the year with its continued focus on onshore renewable generation development, particularly in the north-west area.

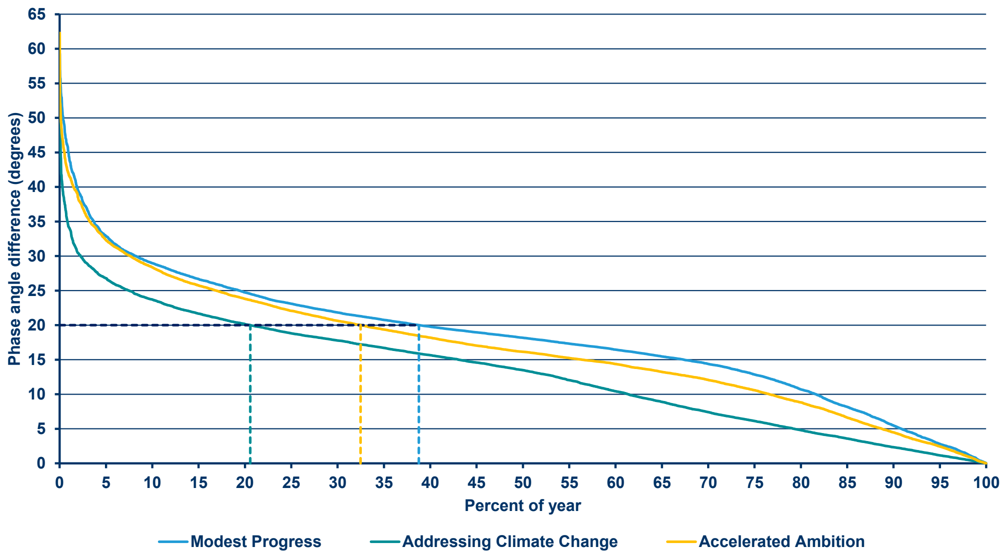


Figure 5.14: Coolkeeragh to Magherafelt phase angle difference

5.6. Bulk supply points

Very few capacity issues continue to be noted at bulk supply points in **Modest Progress** and **Addressing Climate Change** by 2030. Rapid development of electric heat and transport in **Accelerated Ambition** sees significant capacity issues at both Drumnakelly and Dungannon. Table 5.5 presents the maximum loading (% load) at each bulk supply point and the percentage of the year (% year) the firm capacity is exceeded, for each scenario.

5.7. Voltage performance

As in the 2025 analysis, reactive compensation was added at up to five sites in 100 Mvar blocks when required. Again, in some cases, it is still not possible to solve the network, due to extreme loading of 110 kV circuits resulting in voltage collapse.

Figure 5.15 shows the amount of reactive compensation required in the scenarios, and percent of the year it was required. The voltage performance in **Addressing Climate Change** improves compared to 2025, with approximately 5% of the year requiring some amount of reactive compensation. With growth in renewables, particularly in the north-west area, **Modest Progress** sees more hours requiring reactive compensation, to a similar extent as observed in **Addressing Climate Change**. **Accelerated Ambition** continues to show a greater need for reactive compensation, and again sees a number of hours where the load flow cannot be solved due to the extreme loading on the 110 kV transmission network.

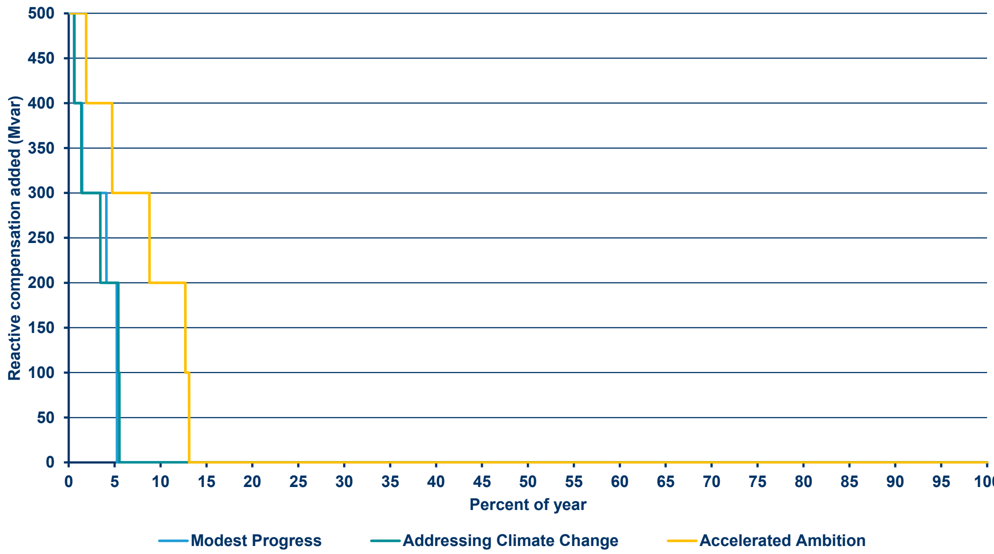


Figure 5.15: Reactive power compensation added in 2030

Table 4.5: N-1 Bulk Supply Point assessment 2025

Bulk Supply Point	Modest Progress		Addressing Climate Change		Accelerated Ambition		Driver
	% load	% year	% load	% year	% load	% year	
Airport Road	35	0	38	0	41	0	
Antrim	49	0	55	0	63	0	
Ballymena Rural	73	0	83	0	97	0	
Ballymena Town	45	0	50	0	56	0	
Ballynahinch	61	0	68	0	78	0	
Banbridge	69	0	79	0	91	0	
Belfast Central	56	0	63	0	71	0	
Belfast North Main	39	0	41	0	53	0	
Carnmoney	22	0	21	0	35	0	
Coleraine	153	9.5	142	4.1	135	1.3	Small scale generation
Coolkeeragh	22	0	19	0	23	0	
Creagh	38	0	43	0	49	0	
Cregagh	81	0	91	0	105	0.3	Electric heat and transport
Donegall N	49	0	55	0	64	0	
Donegall S	65	0	74	0	87	0	
Drumnakelly	117	4.0	131	14.8	148	33.5	Electric heat and transport
Dungannon	116	1.8	133	7.2	151	21.9	Electric heat and transport
Eden	71	0	81	0	90	0	
Enniskillen	86	0	97	0	110	0.3	Electric heat and transport
Finaghy	70	0	81	0	96	0	
Knock	60	0	68	0	79	0	Electric heat and transport
Larne	94	0	106	0.1	152	3.4	Renewable generation
Limavady	76	0	68	0	79	0	
Lisaghmore	73	0	83	0	96	0	
Lisburn	91	0	109	0.4	128	4.6	PV generation
Loguestown	87	0	99	0	112	1.4	Electric heat and transport
Newry	94	0	109	0.7	122	2.0	Electric heat and transport
Newtownards	84	0	96	0	113	2.2	PV generation
Omagh	120	0.8	85	0	84	0	Renewable generation
Rathgael	67	0	76	0	88	0	PV generation
Rosebank	26	0	40	0	38	0	
Springtown	51	0	57	0	65	0	
Strabane	104	0.1	102	0.1	130	2.1	Renewable generation
Waringstown	74	0	84	0	97	0	

5.8. Generation dispatch down

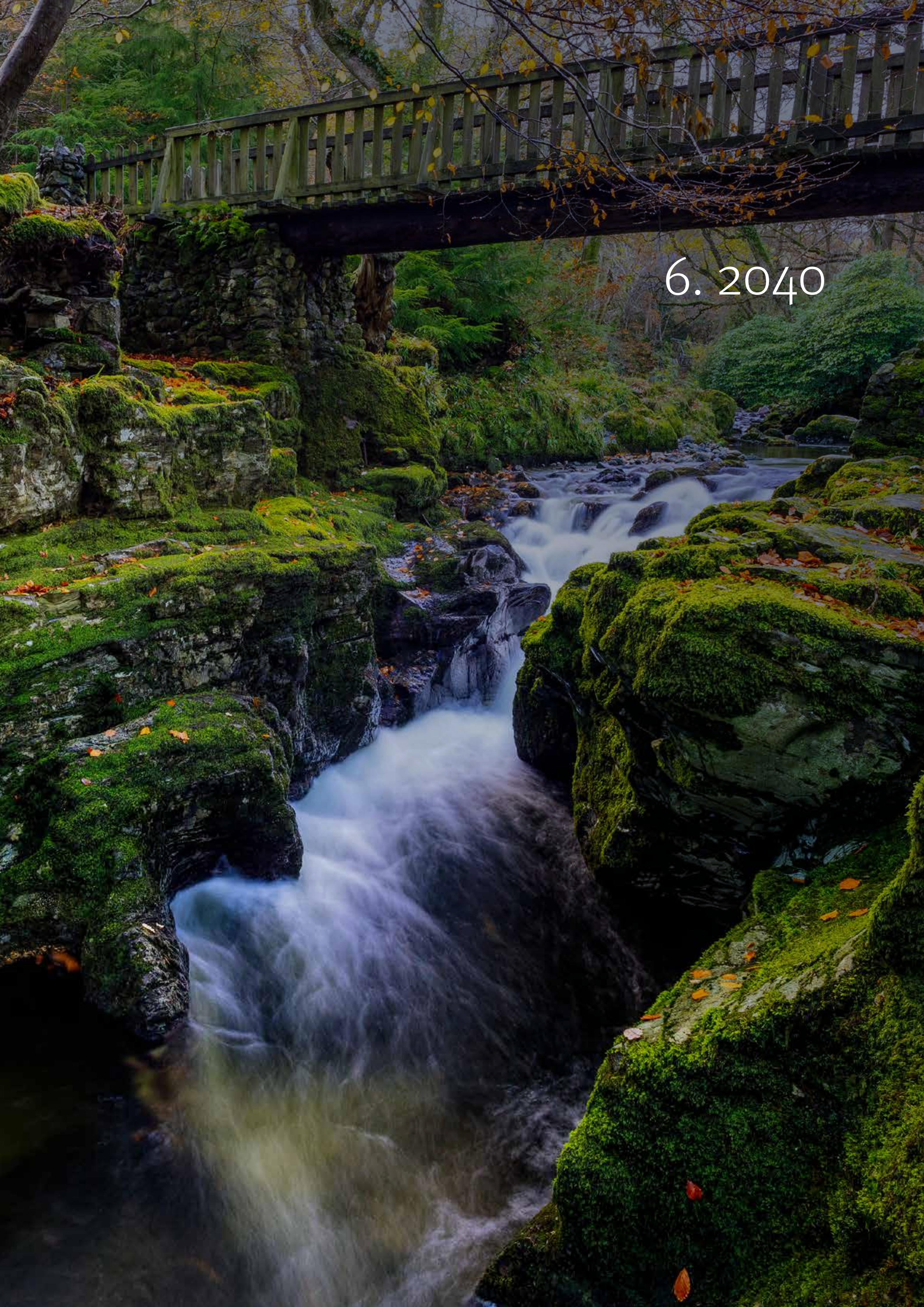
Table 5.6 shows the estimated level of renewable generation dispatch down in the scenarios for 2030. Dispatch down related to oversupply and curtailment was previously calculated as part of the dispatch modelling in the TESNI 2020. Constraints have been estimated as part of the network analysis performed for the SNA.

As observed on the circuit loadings, the level of risk to the transmission network in the north-west area in particular, has reduced by 2030 in **Addressing Climate Change**. As a result, the level of constrained generation has reduced when compared to 2025. The significant levels of dispatch down relating to curtailment and oversupply in both **Addressing Climate Change** and **Accelerated Ambition** help reduce the level of generation ultimately required to be constrained; however, the large quantity of renewable generation in **Accelerated Ambition** still sees a considerable amount of generation constraint required.

Table 5.6: Renewable generation dispatch down in 2030 in the scenarios

Dispatch down	Modest Progress	Addressing Climate Change	Accelerated Ambition
Curtailment + Oversupply (GWh)	391	775	1,232
Constraint (GWh)	112	132	581
Total (GWh)	**503**	**907**	**1,813**

6. 2040



6. 2040

6.1. Scenarios summary

Table 6.1 details renewable generation capacity added in each scenario compared to 2020.

Table 6.1: New renewable generation capacity by 2040 in the scenarios

Bulk Supply Point	Modest Progress	Addressing Climate Change	Accelerated Ambition
Onshore wind - large scale	791	1,012	1,026
Onshore wind - small scale	50	102	59
Offshore wind	0	500	850
PV - large scale	390	703	1,124
PV - small scale and micro	81	251	422
Biomass	8	46	67
Hydro	0	0	0
Marine	0	0	200

Table 6.2 details new electric heat and transport added in each scenario compared to 2020.

Table 6.2: New electric heat and transport by 2040 in the scenarios

Electric heat and transport	Modest Progress	Addressing Climate Change	Accelerated Ambition
Electric vehicles (1,000's)	625	940	1,181
Heat pumps (1,000's)	147	329	452

Table 6.3 lists some demand data for each scenario.

Table 6.3: 2040 demand in the scenarios

Demand information	Modest Progress	Addressing Climate Change	Accelerated Ambition
TER (TWh)	10.0	12.4	14.8
Peak demand (MW)	2,000	2,326	2,801

By 2040, as set out in TESNI 2020, it is assumed that all operational constraints are relaxed.

Modest Progress 2040

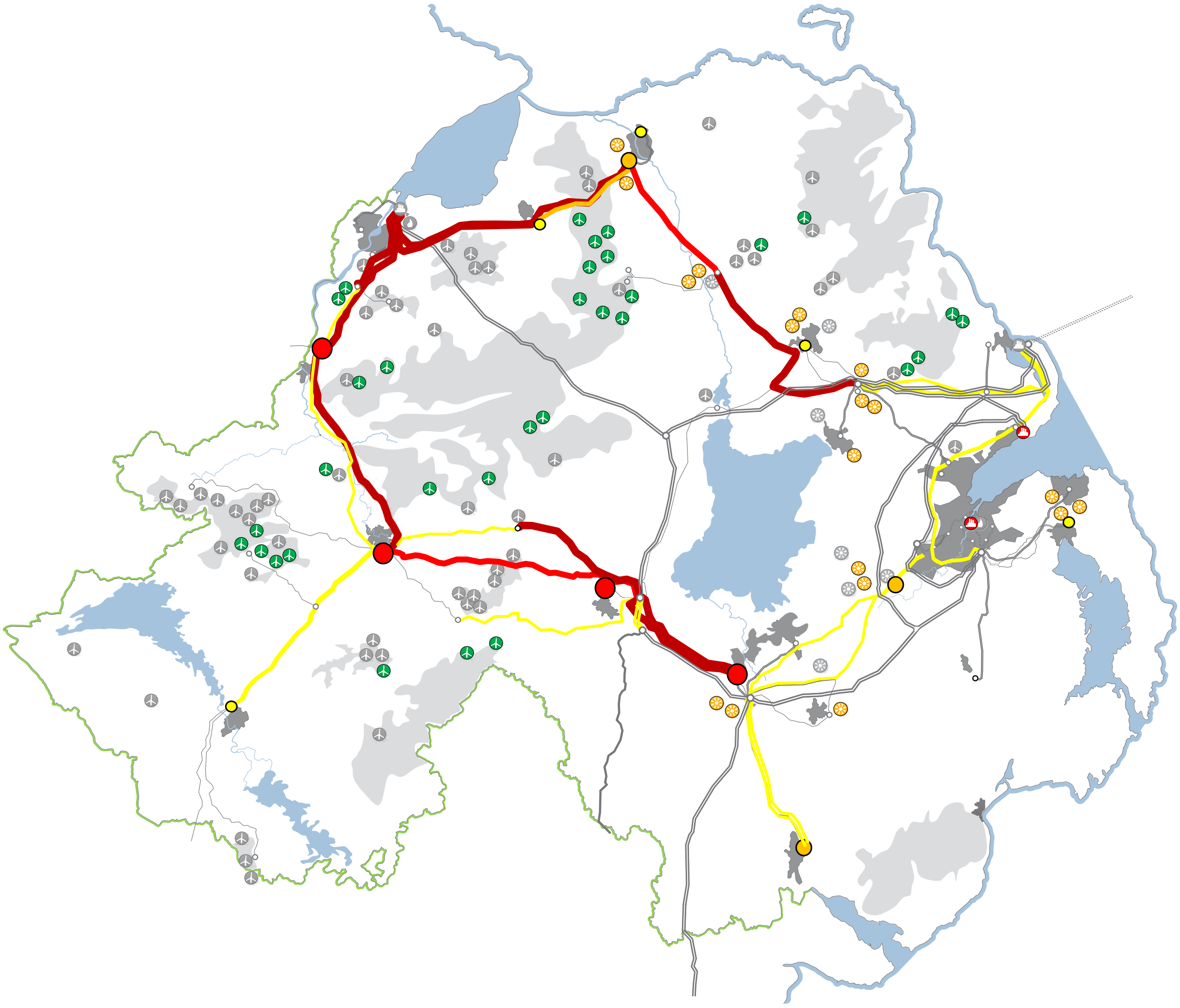


Figure 6.1: Modest Progress 2040

Continued development of onshore renewable generation only in **Modest Progress** sees much of the 110 kV transmission network at risk of overloading. Once again, the north-west area is the most impacted, with most circuits here at risk of considerable overloading for a significant portion of the year.

Further development of PV generation to the east of the country sees more 110 kV circuits here at risk of overloading, although the risk continues to be low compared to that observed in the north-west area.

A faster transition to electric heat and transport in **Modest Progress** by 2040 sees more bulk supply points at risk of exceeding their firm capacity.

Addressing Climate Change 2040

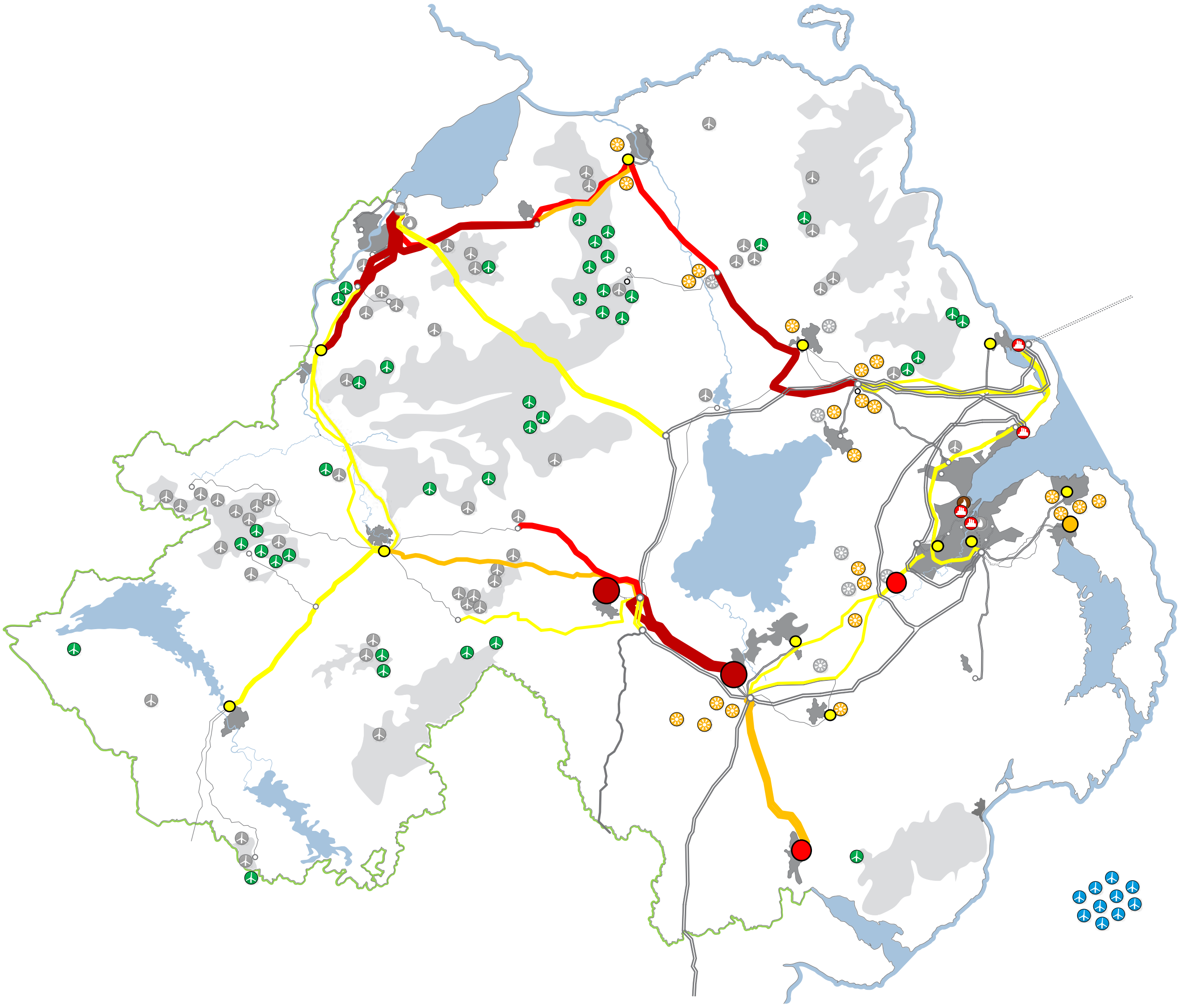


Figure 6.2: Addressing Climate Change 2040

Through the continued development of offshore renewable generation to the east of Northern Ireland, **Addressing Climate Change** continues to shows a lower degree of overloading across the transmission network that **Modest Progress**. This is in spite of **Addressing Climate Change** facilitating 79% RES-E by 2040, compared to 68% in **Modest Progress**.

The north-west area is significantly overloaded, particularly on 110 kV circuits from Coolkeeragh and Coleraine.

The continued transition to electric heat and transport sees an increase in bulk supply points exceeding their firm capacity in **Addressing Climate Change**. The larger towns supplied via Newry, Dungannon and Drumnakelly drive significant overload risks at these bulk supply points. A larger uptake in micro PV, particularly in the greater Belfast area, sees the effects of the transition to electric heat and vehicles moderated.

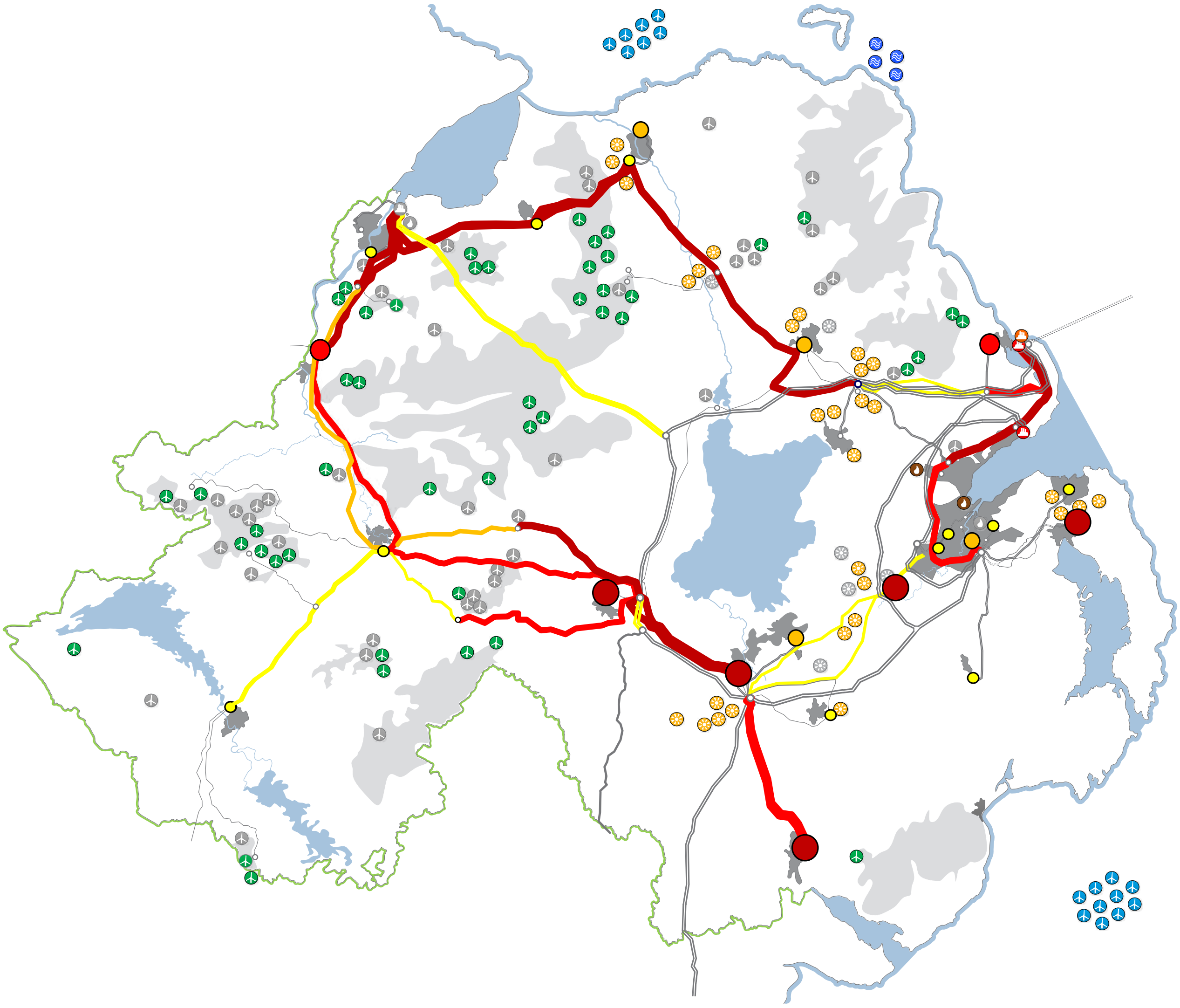


Figure 6.3: Accelerated Ambition 2040

Accelerated Ambition delivers 88% RES-E by 2040. The amount of renewable generation capacity required to deliver such a figure drives large overloads across most of the 110 kV transmission network. The north-west area sees extreme risks of overloading, driven in part by the development of offshore generation in the area.

Accelerated Ambition delivers a net-zero power system by 2040. This is partly facilitated with the assumed development of a carbon capture and storage CCGT at Ballylumford; this development helps drive a higher risk of overloading 110 kV circuits to the east of the country than observed in the other scenarios and study years.

With the fastest transition to electric heat and transport, **Accelerated Ambition** sees the greatest number of bulk supply points at risk of exceeding their firm capacity, and this risk is severe at number of sites. A very high capacity of both large-scale and small-scale PV drives overload risks at Lisburn and Newtownards.

6.2. Circuit overloads

By 2040, many 110 kV circuits across Northern Ireland are at risk of significant and extensive overloading in all scenarios. This is unsurprising as the large renewable generation portfolios in all scenarios overwhelm the network at times of high output under contingency conditions.

In all scenarios, further renewable generation connections in the north-west area results in increased risks to the 110 kV transmission network. The assumed development of offshore wind generation in waters off the north coast in **Accelerated Ambition** sees the 110 kV network in the north-west area saturated for much of the year. Figure 6.4 shows the load curves for the three scenarios for the Kells to Rasharkin 110 kV circuit in 2040. Figure 6.5 shows the same for the Coleraine to Coolkeeragh 110 kV circuit.

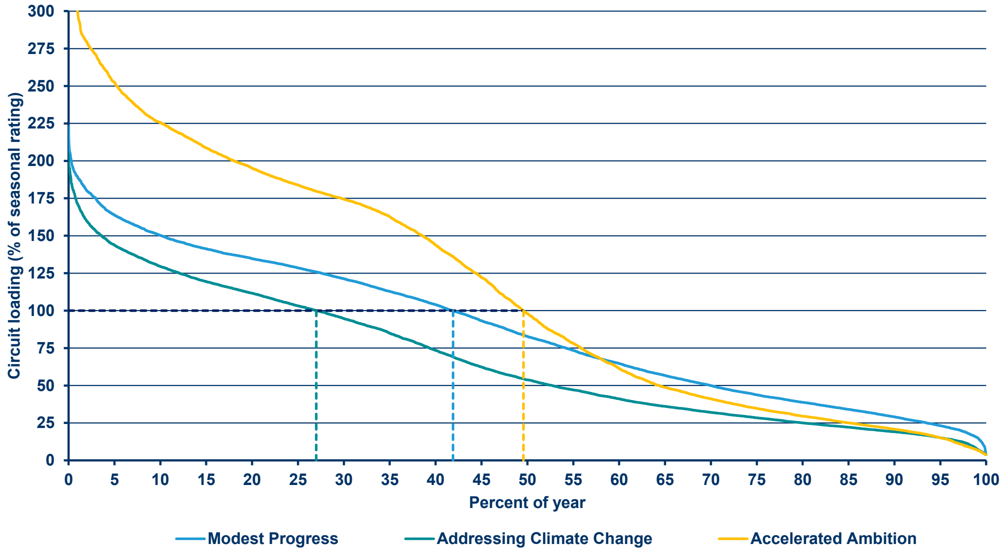


Figure 6.4: N-1 loading on the Kells to Rasharkin 110 kV circuit in 2040

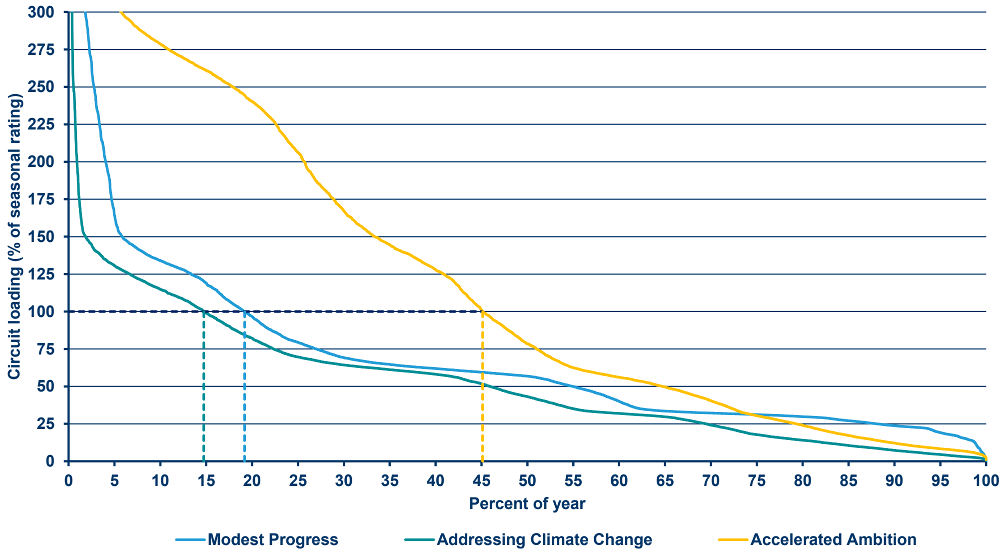


Figure 6.5: N-1 loading on the Coleraine to Coolkeeragh 110 kV circuit in 2040

The results for **Accelerated Ambition** demonstrate the impact of the connection of offshore wind off the north coast of Northern Ireland into the existing transmission network. 110 kV circuits are at risk of overloading for almost half of the year, with hugely excessive circuit loadings observed. **Modest Progress** again sees more of a risk of overloading than **Addressing Climate Change** due to the reliance on onshore renewable generation only.

The increased risk of overloading the110 kV network in the east of the country in **Accelerated Ambition**, as the result of an assumed CCS CCGT connection, is clearly shown on the loadings for the Carnmoney to Eden 110 kV 'A' circuit in figure 6.6 and the Ballylumford to Ballyvallagh 110 kV 'A' circuit in figure 6.7.

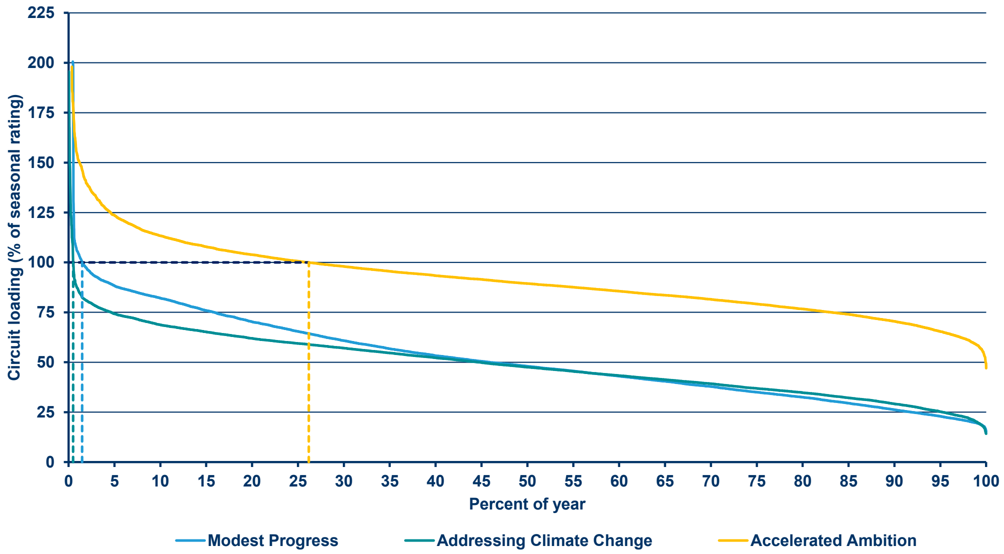


Figure 6.6: N-1 loading on the Carnmoney to Eden 110 kV 'A' circuit in 2040

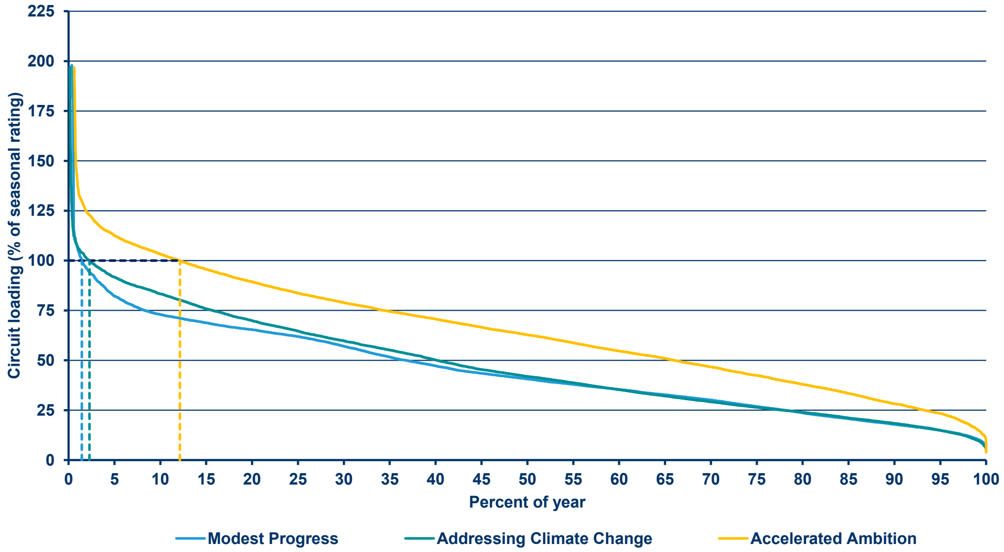


Figure 6.7: N-1 loading on the Ballylumford to Ballyvallagh 110 kV 'A' circuit in 2040

The results highlight that, as we move towards 2050, accommodating the levels of renewable generation required to enable Northern Ireland to meet decarbonisation targets will require significant development of the transmission network. The results for **Addressing Climate Change** show that there are benefits to developing renewable generation capacity towards the east of Northern Ireland, where the transmission network is stronger and the demand is larger.

6.3. Phase Angle

Figure 6.8 shows the voltage phase angle difference between Coolkeeragh and Magherafelt for the loss of the 275 kV double circuit across the year. With the majority of new renewable generation connections developed towards the east if Northern Ireland, **Addressing Climate Change** sees a similar number of hours where a 20⁰ phase angle difference is exceeded as in 2030. **Modest Progress** and **Accelerated Ambition**, as a result of significant growth in renewable generation capacity in the north-west area, both see a significant increase in the proportion of the year the 20⁰ phase angle difference is exceeded. In the case of **Modest Progress**, this risk is present in nearly 60% of the year.

The results again highlight that significant development of the transmission network will be required to accommodate the high levels of renewable generation required to achieve a net-zero power system. Reducing the large phase angle differences observed would require such developments as new transmission network capacity, storage capacity within the north-west area and increased demand in the north-west area.

The results for **Addressing Climate Change** also show that there are benefits to developing new renewable generation capacity towards the east of Northern Ireland, as opposed to within the north-west area.

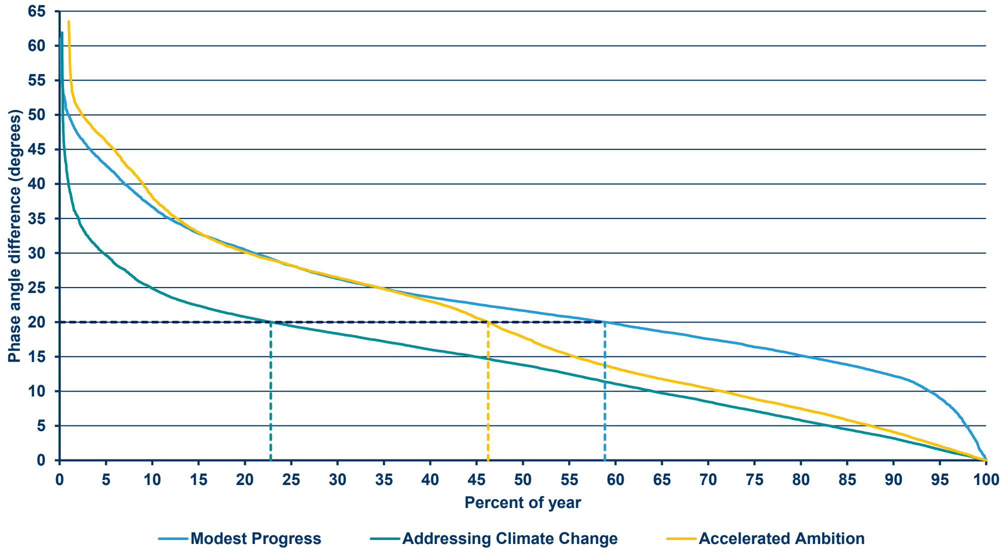


Figure 6.8: Coolkeeragh to Magherafelt phase angle difference in 2040

6.4. Bulk supply points

With significant growth in electric heat and transport in all scenarios by 2040, and large growth in micro PV in both **Addressing Climate Change** and **Accelerated Ambition**, it is not surprising to see many bulk supply points come under increased pressure by 2040. Table 6.4 presents the results of the analysis for the three scenarios, showing the maximum loading (% load) at each bulk supply point and the percentage of the year (% year) the firm capacity is exceeded.

Being a radially fed bulk supply point, the high degree of overload risk at Newry is also observed on the 110 kV circuits connecting the substation to Tandragee. Figure 6.9 shows the N-1 loading for the Newry to Tandragee 110 kV 'A' circuit.

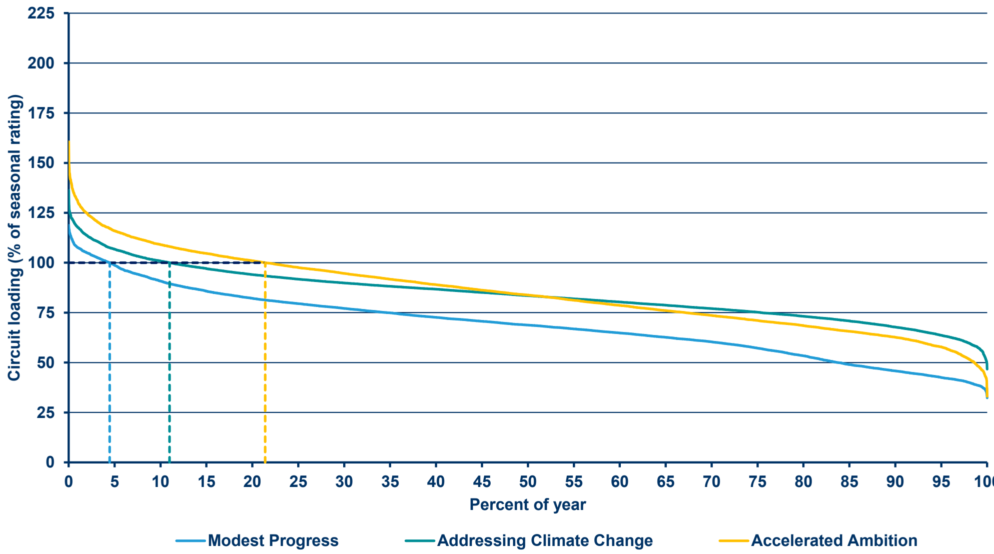


Figure 6.9: N-1 loading on the Newry to Tandragee 110 kV 'A' circuit in 2040

Table 6.4: N-1 Bulk Supply Point assessment 2040

Bulk Supply Point	Modest Progress		Addressing Climate Change		Accelerated Ambition		Driver
	% load	% year	% load	% year	% load	% year	
Airport Road	32	0	40	0	46	0	
Antrim	64	0	74	0	90	0	
Ballymena Rural	106	0.1	124	0.5	156	4.7	PV generation
Ballymena Town	43	0	52	0	61	0	
Ballynahinch	74	0	86	0	101	0.1	Electric heat and transport
Banbridge	96	0	109	0.1	132	4.6	Electric heat and transport
Belfast Central	56	0	68	0	80	0	
Belfast North Main	25	0	27	0	69	0	
Carnmoney	46	0	53	0	65	0	
Coleraine	145	8.7	133	4.3	132	1.6	Small scale generation
Coolkeeragh	21	0	54	0	47	0	
Creagh	44	0	52	0	61	0	
Cregagh	89	0	107	0.3	133	10.1	Electric heat and transport
Donegall N	56	0	65	0	81	0	
Donegall S	75	0	92	0	118	1.6	Electric heat and transport
Drumnakelly	138	14.9	165	42.8	193	64.9	Electric heat and transport
Dungannon	157	12.0	182	31.8	217	64.6	Electric heat and transport
Eden	69	0	84	0	97	0	
Enniskillen	105	0.1	119	0.6	140	3.1	Electric heat and transport
Finaghy	88	0	105	0.1	137	8.1	Electric heat and transport
Knock	69	0	82	0	103	0.1	Electric heat and transport
Larne	89	0	110	0.3	165	15.1	Renewable generation
Limavady	116	0.2	96	0	117	0.2	Renewable generation
Lisaghmore	94	0	110	0.1	136	2.4	Electric heat and transport
Lisburn	143	7.3	154	19.3	186	56.1	PV generation
Loguestown	113	0.3	132	3.5	158	17.1	Electric heat and transport
Newry	136	7.0	156	20.3	184	26.0	Electric heat and transport
Newtownards	120	1.0	139	7.0	171	31.9	PV generation
Omagh	173	17.9	143	3.1	113	0.2	Renewable generation
Rathgael	90	0	105	0.1	128	4.0	PV generation
Rosebank	33	0	44	0	55	0	
Springtown	61	0	71	0	87	0	
Strabane	162	20.3	167	15.2	163	18.2	Renewable generation
Waringstown	98	0	114	0.5	138	7.6	Electric heat and transport

6.5. Voltage performance

Given the continued increase in both renewable generation and electric heat and transport in all scenarios, combined with an assumed removal of all operational constraints, it is unsurprising to see a significant increase in voltage issues compared to 2030. Figure 6.10 shows the amount of reactive compensation required in the scenarios in 2040, and the extent of the year it was required.

A lack of reactive power support from thermal generation and very heavily loaded circuits sees **Modest Progress** and **Addressing Climate Change** require reactive power compensation for up to a quarter of the year, with approximately 3% of hours still showing voltage collapse. **Accelerated Ambition** meanwhile has significant issues, with over a third of the year requiring reactive power compensation. Even with this, voltage collapse is noted across 15% of the year.

Such high levels of renewable generation and relaxed operational constraints are beyond what the current transmission network is capable of delivering, and, the results demonstrate the significant challenges that will likely arise in the delivery of a net-zero energy system.

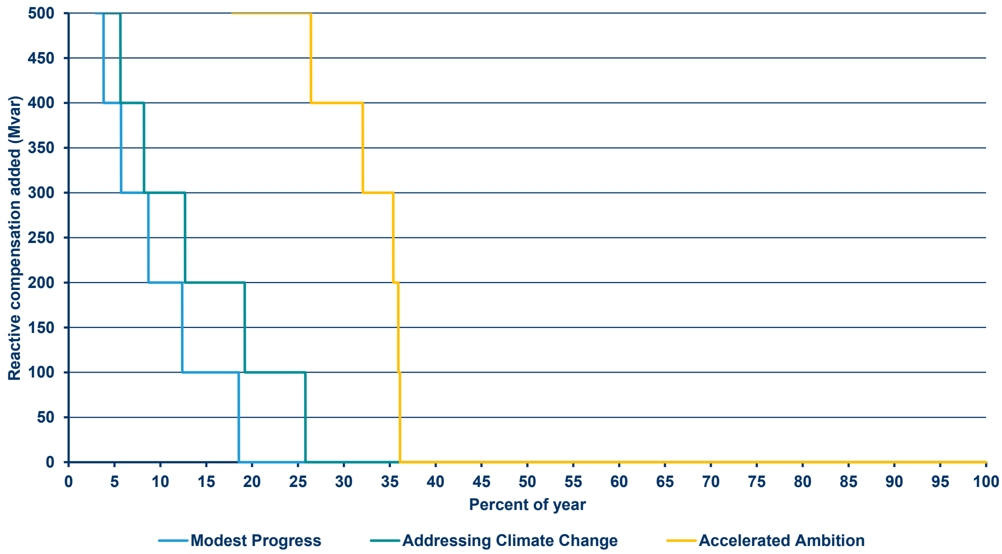


Figure 6.10: Reactive power compensation added in 2040

6.6. Generation dispatch down

Table 6.5 shows the estimated level of renewable generation dispatch down in the scenarios for 2040. Renewable generation dispatch down as a result of network constraints has increased significantly in all scenarios- in particular in **Accelerated Ambition** as a result of the development of offshore renewable generation off the north coast. With its focus on new renewable generation capacity in the east of Northern Ireland, **Addressing Climate Change** sees similar levels of constraints as **Modest Progress**, despite delivering a higher RES-E figure in 2040.

The results again highlight the need for significant investment in the transmission system in order to deliver a net-zero power system. New additional transmission capacity, and the development of technologies such as demand management, storage, power to gas and additional interconnection can all play a role in reducing generation dispatch down.

Table 6.5: Renewable generation dispatch down in 2040 in the scenarios

Dispatch down	Modest Progress	Addressing Climate Change	Accelerated Ambition
Curtailment + Oversupply (GWh)	807	859	1,390
Constraint (GWh)	311	332	1,606
Total (GWh)	**1,118**	**1,191**	**2,996**

7. Analysis with TDPNI projects included

7. Analysis with TDPNI projects included

The results for 2030 and 2040 have highlighted that all scenarios have a significant impact on the Northern Ireland transmission network.

A number of network reinforcement projects are listed in the TDPNI that are not included in the original analysis. Many of these projects are at an early stage of the grid development framework. Network analysis for the years 2030 and 2040 has been performed again, this time with many of these projects included. Table 7.1 lists the additional projects that were included.

Table 7.1: Additional TDPNI projects included in the 2030 analysis

TDPNI projects included in analysis
Carnmoney to Eden 110 kV uprate/reconfiguration
Carnmoney to Castlereagh 110 kV uprate/reconfiguration
Coolkeeragh to Killymallaght 110 kV uprate
Coolkeeragh to Strabane 110 kV uprate
Coolkeeragh reactive compensation
Drumnakelly and Armagh reinforcement
Kells to Rasharkin second 110 kV circuit
Killymallaght to Strabane 110 kV circuit uprate
North West of NI 110 kV reinforcement
Omagh to Dromore third circuit
Omagh to Strabane 110 kV uprate
Tamnamore to Drumnakelly 110 kV uprate
Tamnamore to Turleenan 275 kV uprate

As these projects are at an early stage of the grid development process, it must be stressed than any reinforcements shown on the diagrams in this section are for indicative purposes only, and do not represent any final project design. As SONI is committed to early, meaningful and transparent engagement in relation to our proposed grid investments, a project solution will only be determined following consultation with a range of key stakeholder groups, including the public, communities and landowners.

Modest Progress 2030

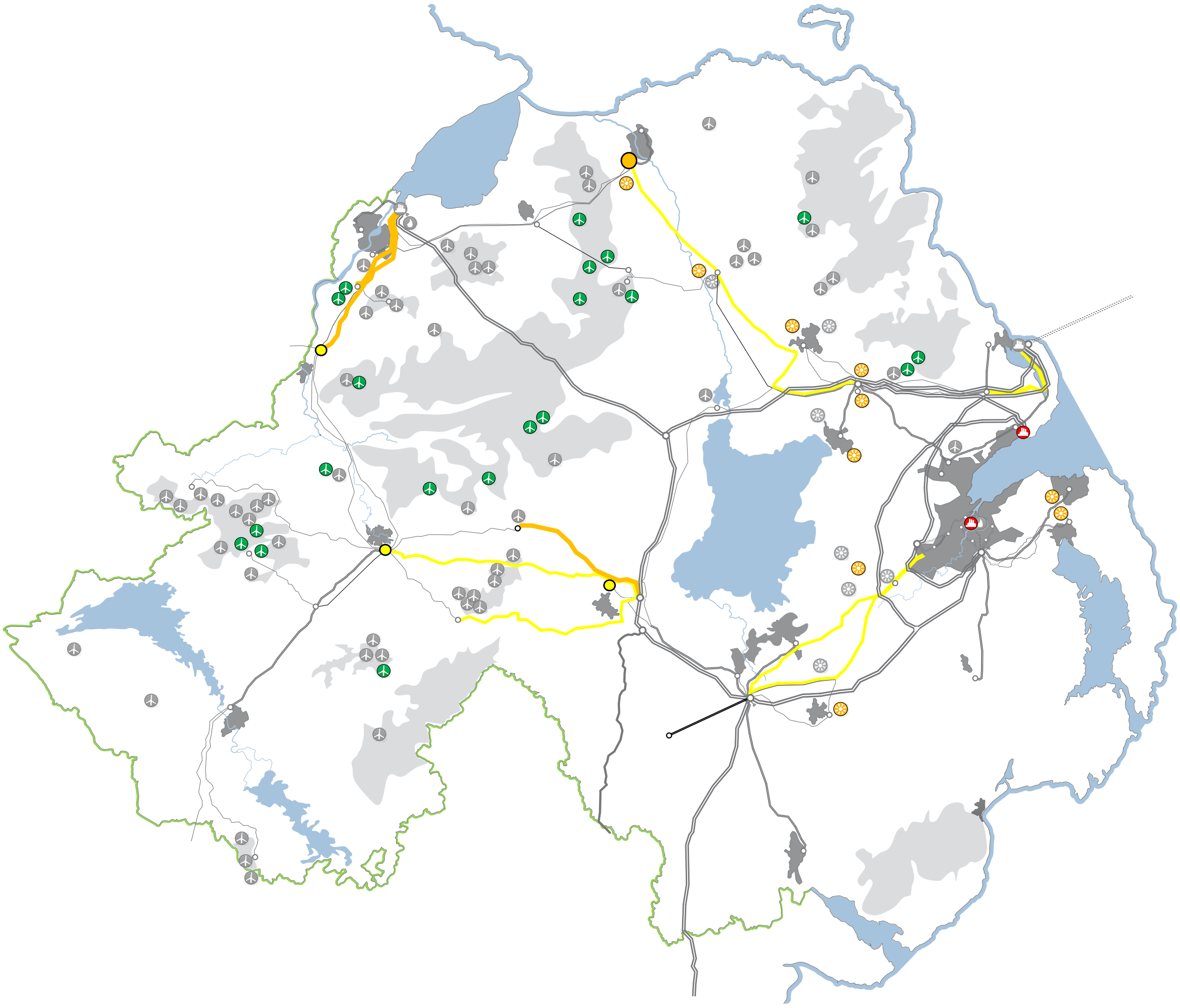


Figure 7.1: Modest Progress 2030 with TDPNI projects

Delivery of TDPNI projects means that achieving a 60% RES-E target in **Modest Progress** results in a much lower risk of significant overloading of the transmission network. Given that renewable generation is entirely comprised of onshore technology in **Modest Progress**, with the majority of this located in northern and western areas, overload risks still remain on parts of the transmission network. However, the extent and severity is much lower than when the TDPNI projects are not present, as shown in the results highlighted in figure 5.1 in **section 5**.

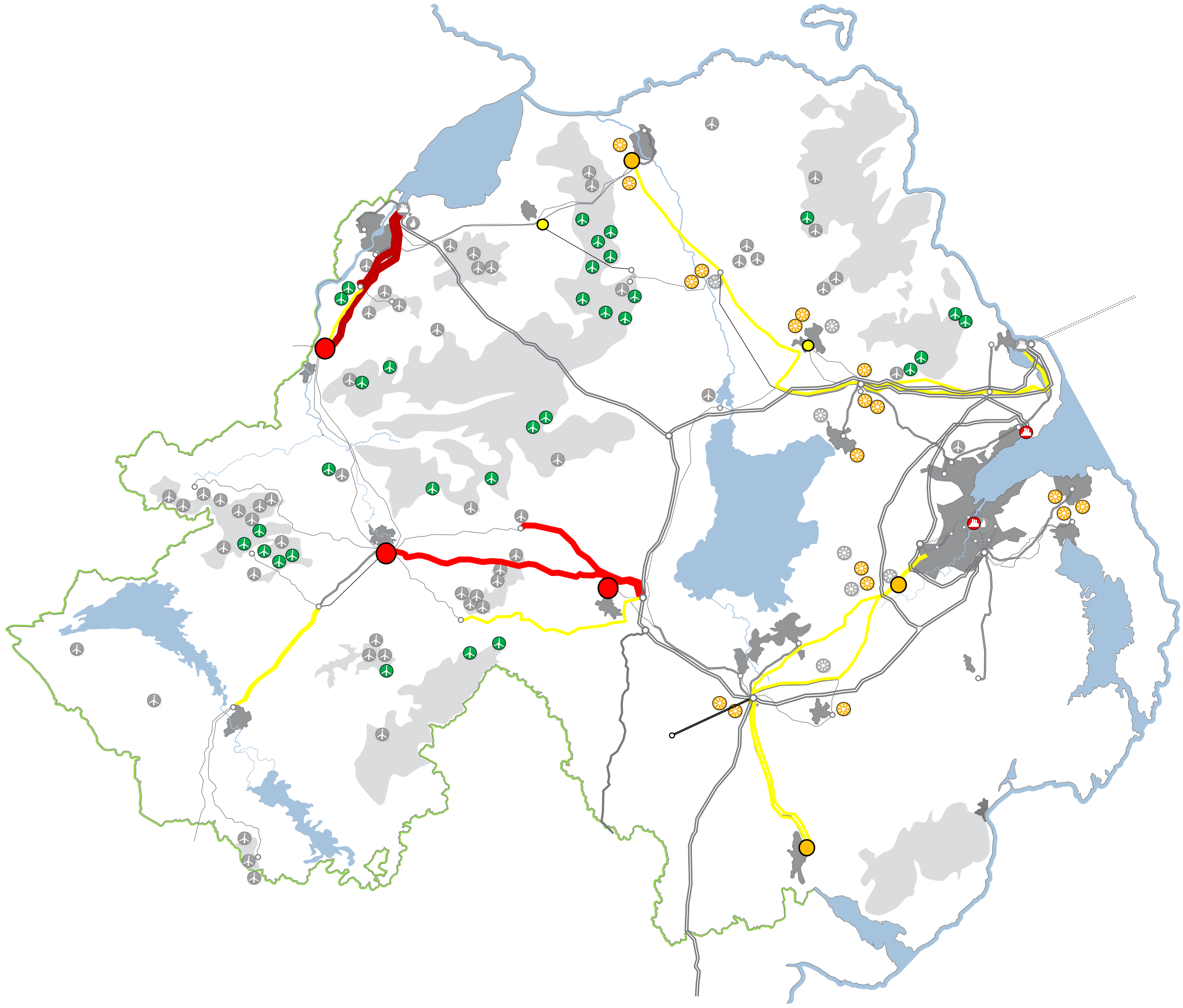


Figure 7.2: Modest Progress 2040 with TDPNI projects

With continued delivery of onshore renewable generation only in **Modest Progress**, parts of the transmission network in the north-west area come under significant pressure once again by 2040, in spite of the increased capacity delivered by projects from the TDPNI. The number of circuits affected is much reduced compared to the results indicated in figure 6.1 in in **section 6**.

Addressing Climate Change 2030

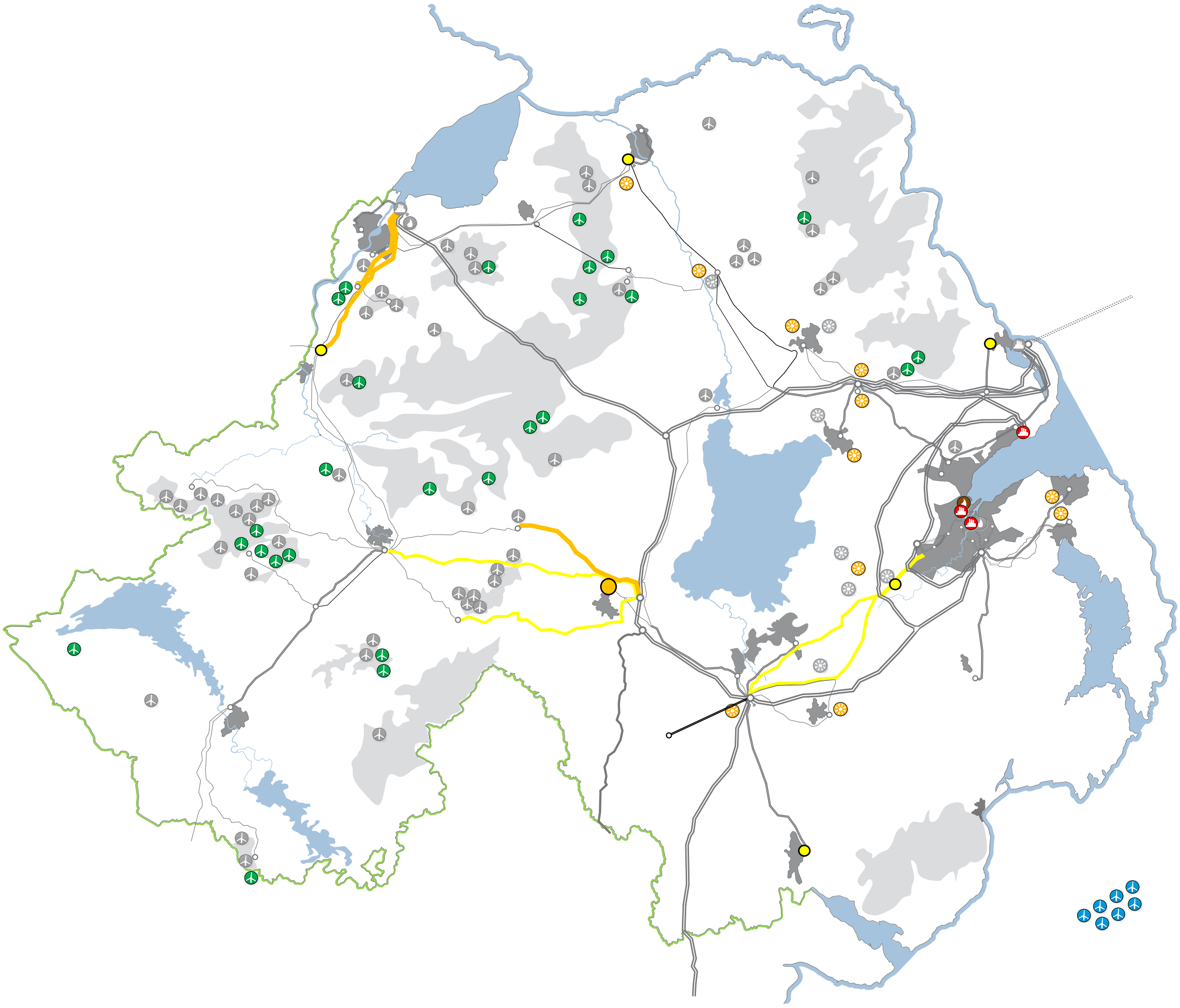


Figure 7.3: Addressing Climate Change 2030 with TDPNI projects

The inclusion of projects from the TDPNI, combined with the development of offshore renewable generation to the east of the country, sees a large reduction in the risk of overloading circuits across the transmission network in **Addressing Climate Change**.

Addressing Climate Change delivers a 70% RES-E target by 2030, and this is facilitated with a greatly reduced risk to the transmission network than without the TDPNI projects included; once again, the risk to the network is lower than in **Modest Progress**, in spite of the lower 2030 RES-E target of 60% in that scenario. The performance is even superior to that of **Modest Progress** in 2040, which delivers 69% RES-E but at greater risk to the transmission network.

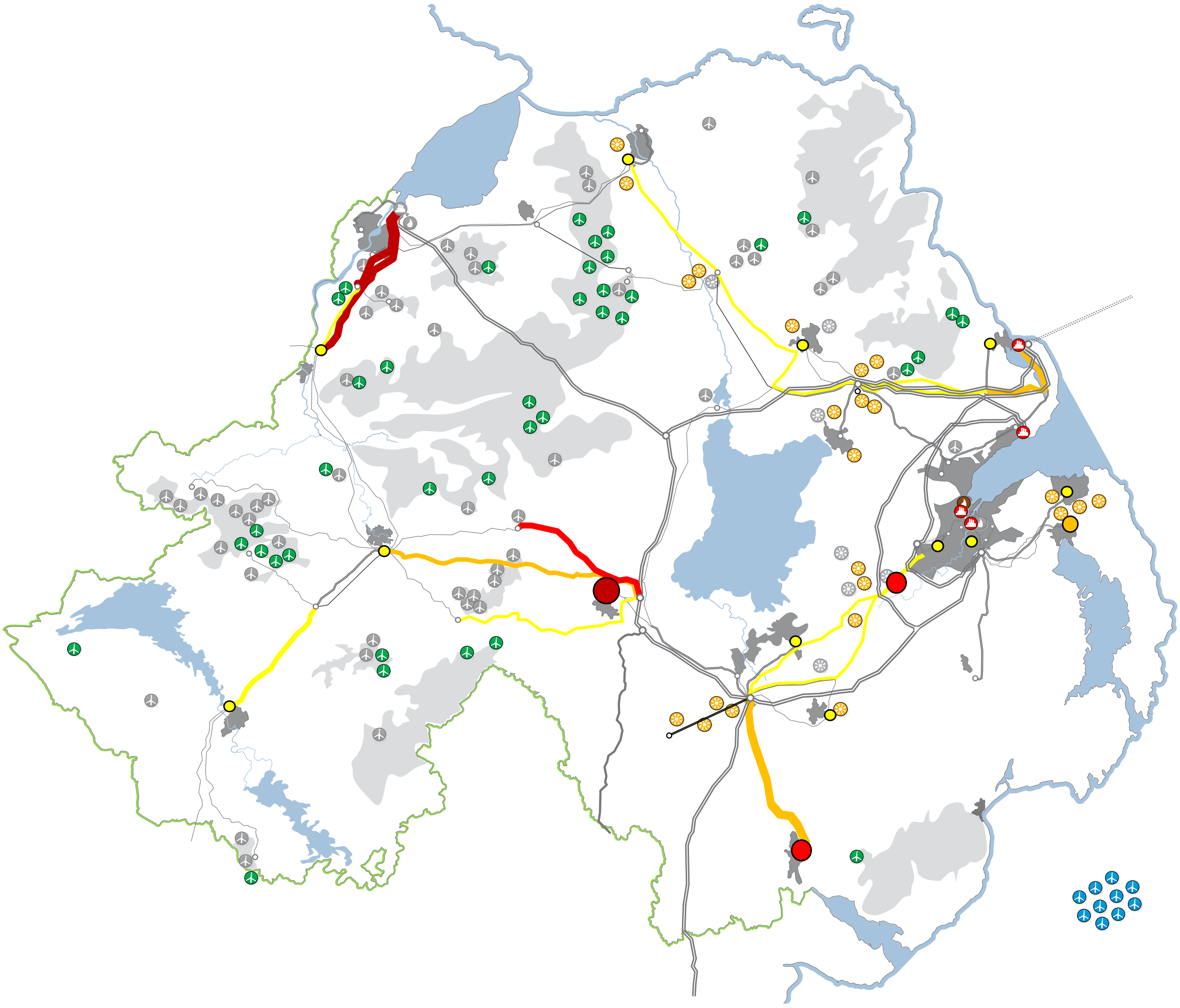


Figure 7.4: Addressing Climate Change 2040 with TDPNI projects

Further development of renewable generation capacity sees parts of the transmission network in the north-west area come under significant pressure once again by 2040, in spite of the increased capacity delivered by projects from the TDPNI. Given that **Addressing Climate Change** facilitates 79% RES-E by 2040, the number of circuits at risk of severe or sustained overloading is relatively small, and much reduced compared to the analysis highlighted in figure 6.2 in **section 6**.

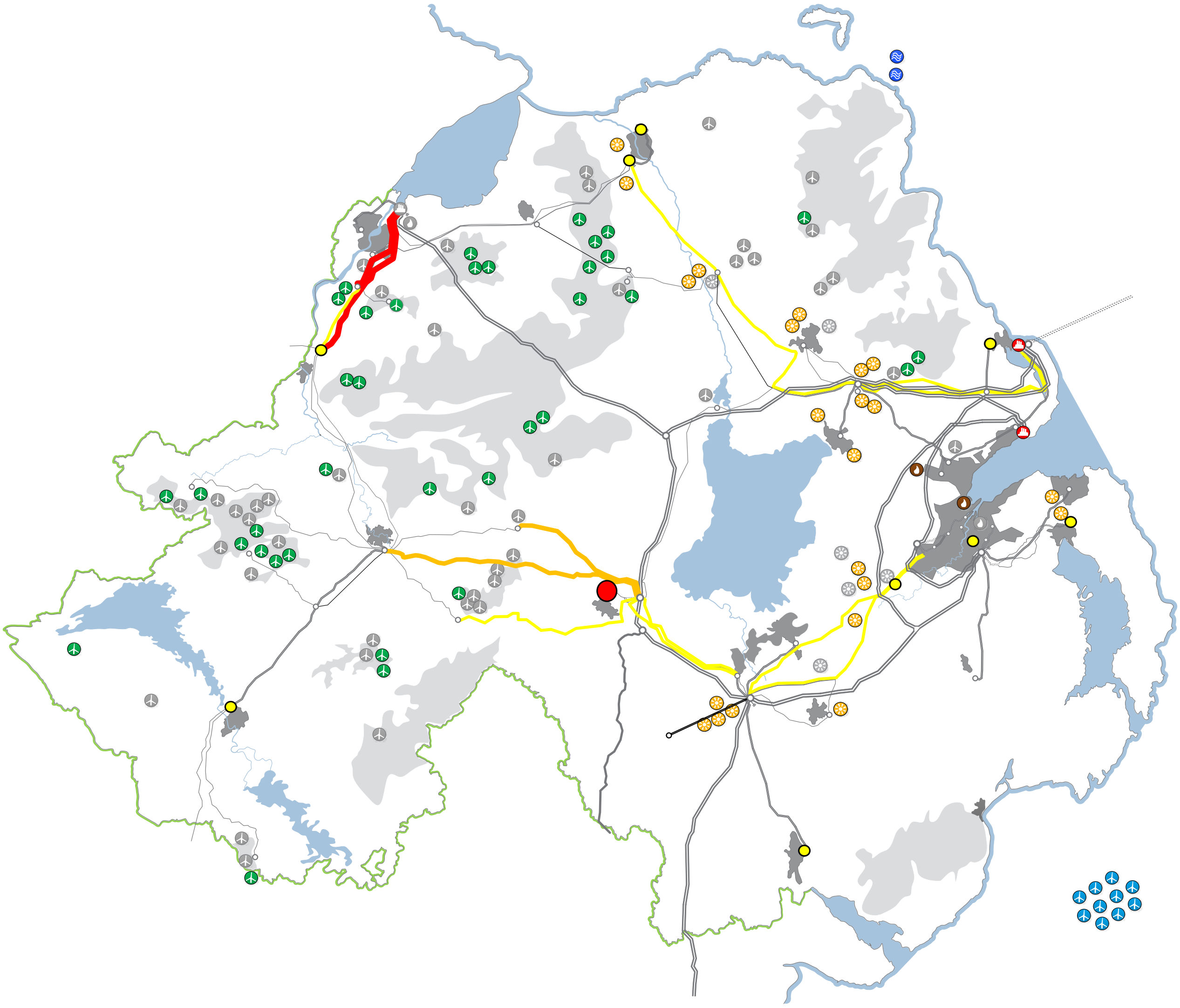


Figure 7.5: Accelerated Ambition 2030 with TDPNI projects

Without the inclusion the projects from the TDPNI listed in table 7.1, delivering the 80% RES-E target for 2030 in **Accelerated Ambition** saw significant overloading of the transmission network across the north-west. Inclusion of the projects sees many of the risks reduced to marginal concerns, however significant issues are still observed on a couple of circuits in the north-west area.

Accelerated Ambition 2040

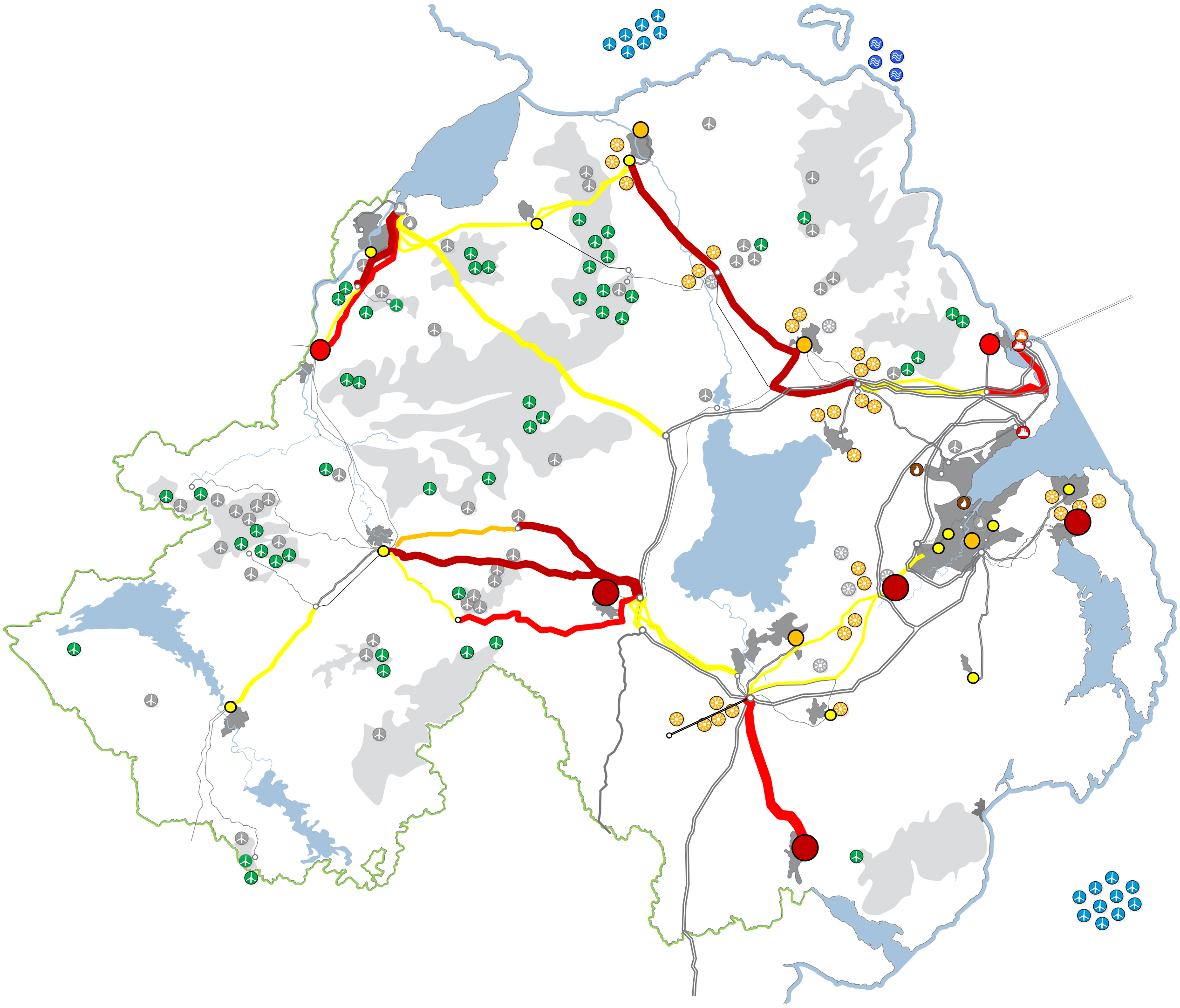


Figure 7.6: Accelerated Ambition 2040 with TDPNI projects

By 2040, the development of large scale offshore renewable generation to the north of Northern Ireland sees much of the transmission network in the north-west at significant risk of overloading in **Accelerated Ambition**, in spite of the inclusion of many reinforcement projects from the TDPNI.

Network reinforcement/reconfiguration projects towards the east of Northern Ireland sees a removal of some of the significant risks identified on the 110 kV network in the area, previously highlighted in figure 6.3 in **section 6**.

7.1. Notable changes

An additional 110 kV route from the north-west area is provided with a combination of a second circuit between Kells and Rasharkin circuit and the 'North West of NI 110 kV reinforcement' project. This development helps to reduce much of the significant overloading observed on 110 kV circuits in the north-west area. Figure 7.7 shows the previous 2030 analysis on the Kells to Rasharkin circuit, and figure 7.8 shows how the contingency loading has significantly reduced with the TDPNI projects included.

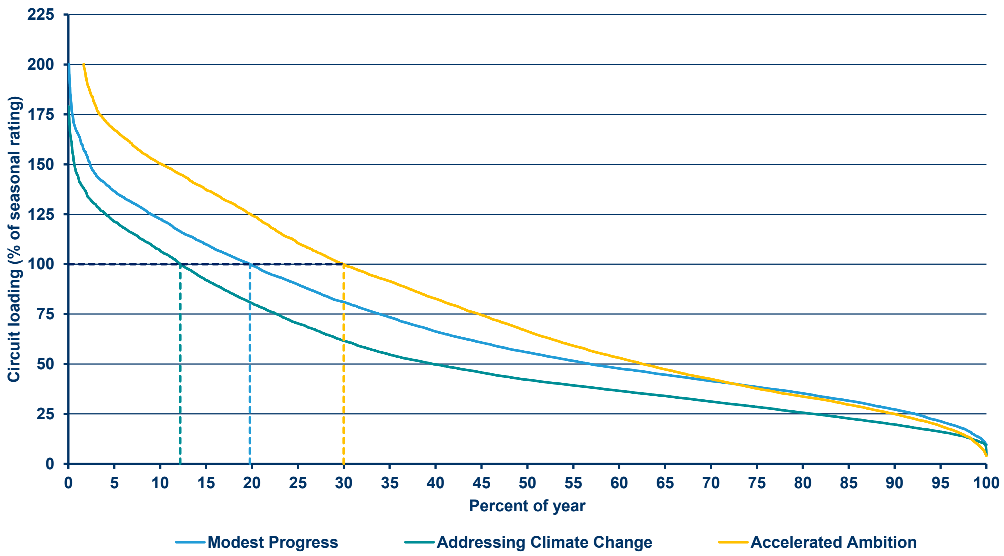


Figure 7.7: N-1 loading on the Kells to Rasharkin 110 kV circuit in 2030 with present network configuration

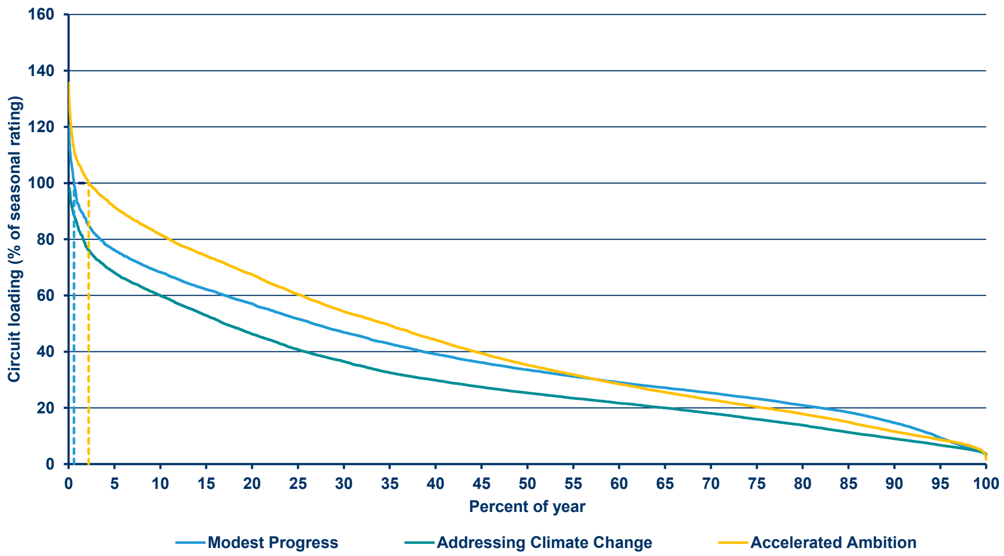


Figure 7.8: N-1 loading on the Kells to Rasharkin 110 kV circuit in 2030 with additional TDPNI projects included

By 2040, there continues to be a minimal risk of overloading this circuit in both **Modest Progress** and **Addressing Climate Change**. However, the development of offshore renewable generation off the north coast by 2040 sees the circuit once again come under significant pressure in **Accelerated Ambition**, as shown in figure 7.9.

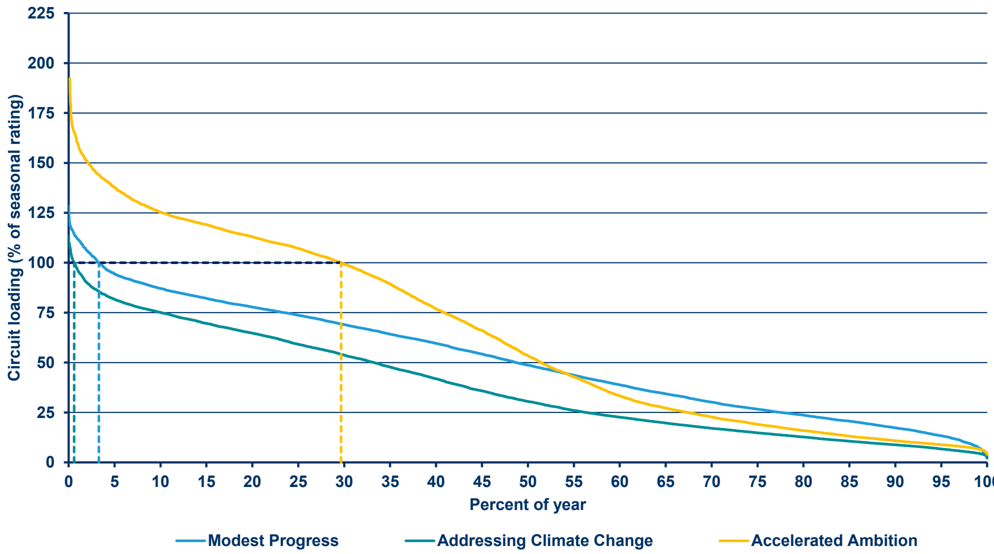


Figure 7.9: N-1 loading on the Kells to Rasharkin 110 kV circuit in 2040 with additional TDPNI projects included

110 kV circuit uprates within the north-west area also eliminates many of the risks observed on the Coolkeeragh to Coleraine and Omagh to Strabane corridors. The uprating of the Drumnakelly to Tamnamore 110 kV circuits effectively eliminates risks to these circuits, allowing them to be operated normally closed all year round. Figure 7.10 shows the contingency loading on these circuits without the uprate in place

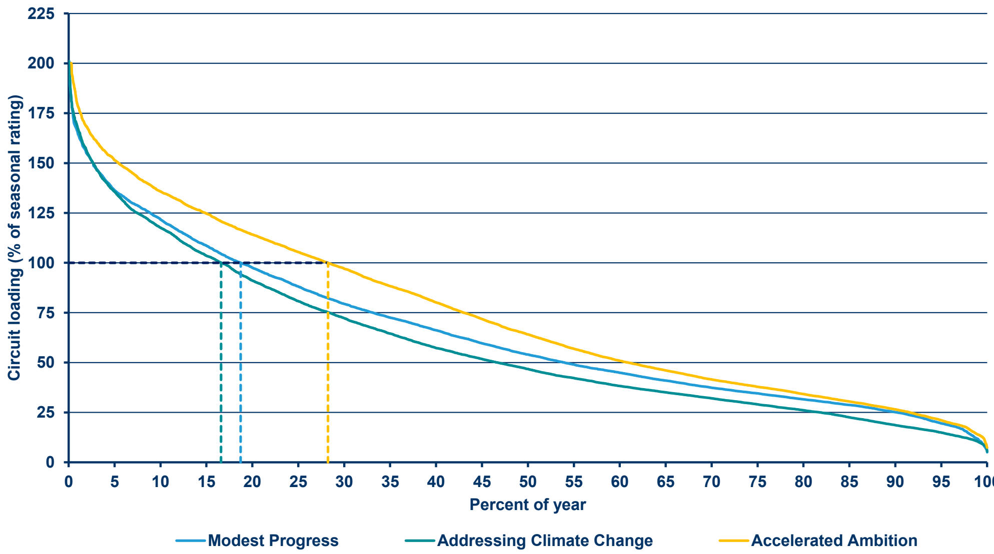


Figure 7.10: N-1 Loading on the Drumnakelly to Tamnamore 110 kV 'A' circuit in 2030 with present network configuration

Figures 7.11 and 7.12 show the contingency loading following the uprate in both 2030 and 2040 respectively. A very marginal risk of overloading remains in **Accelerated Ambition**, impacting several hours in the year only in 2030; by 2040, this risk has only increased to affect 2% of the hours in the year. No overloading is observed in both **Modest Progress** and **Addressing Climate Change** for either year.

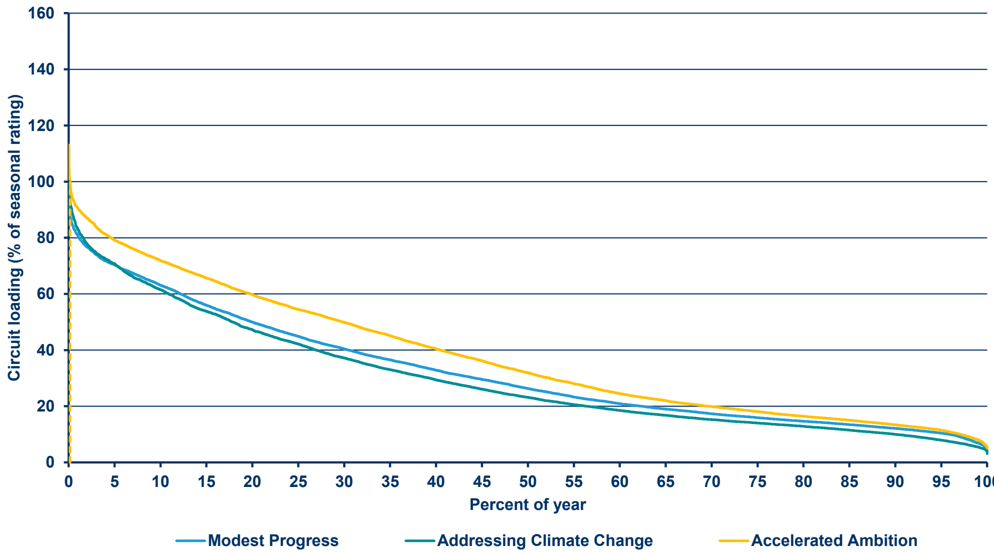


Figure 7.11: N-1 Loading on the Drumnakelly to Tamnamore 110 kV 'A' circuit in 2030 with additional TDPNI projects included

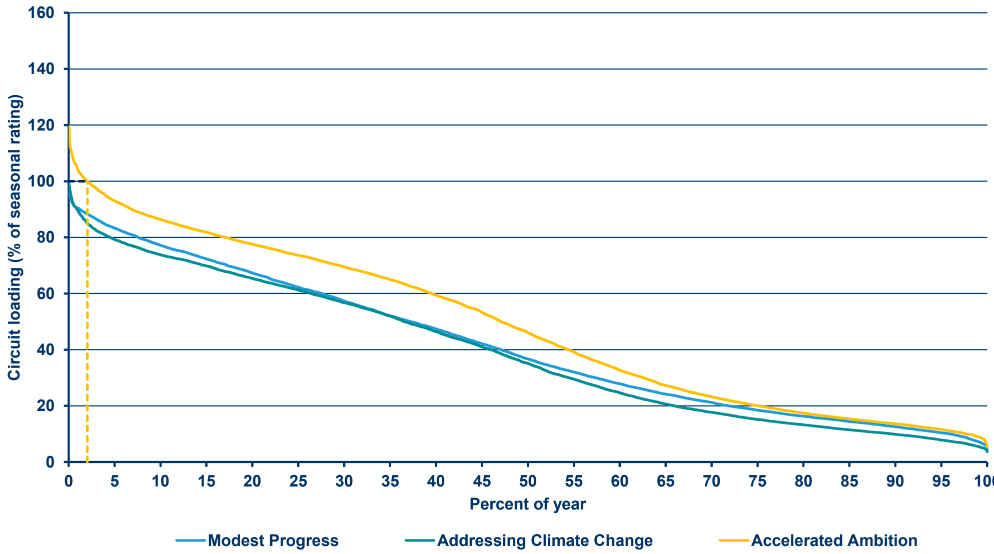


Figure 7.12: N-1 Loading on the Drumnakelly to Tamnamore 110 kV 'A' circuit in 2040 with additional TDPNI projects included

The provision of a third 110 kV circuit from Omagh to Dromore removes all overload risk to the two existing circuits on this route. Meanwhile, the Drumnakelly and Armagh reinforcement projects relieves the significant overloading observed at Drumnakelly bulk supply point, driven by demand growth from electric heat and vehicles in the area.

Towards the east of Northern Ireland, circuit uprates and reconfigurations on the Carnmoney to Eden and Carnmoney to Castlereagh 110 kV double circuits removes the overload risk on the Ballylumford to Castlereagh corridor, and reduces the risk to the Ballylumford to Kells corridor, where marginal overloading is observed. A small risk remains to the 110 kV circuits between Hannahstown and Lisburn, due to the increased levels of PV generation assumed in the Lisburn area.

With additional network capacity provided through both new circuit and uprated circuits, and the inclusion of reactive compensation at Coolkeeragh, there is a significant improvement to the voltage profile across the transmission network in all scenarios in 2030. This is demonstrated by a reduction in hours requiring additional reactive compensation in all scenarios. Figure 7.14 shows the reactive compensation requirements with the TDPNI projects included, compared to figure 7.13, which shows the results from **section 5.7**.

In both **Modest Progress** and **Addressing Climate Change**, a need for further reactive compensation appears in less than 1% of hours across the year. In **Accelerated Ambition** the need is observed in just under 3% of hours- a significant reduction compared to the results with the current network configuration. There still remains a small number of non-convergent hours in Accelerated Ambition.

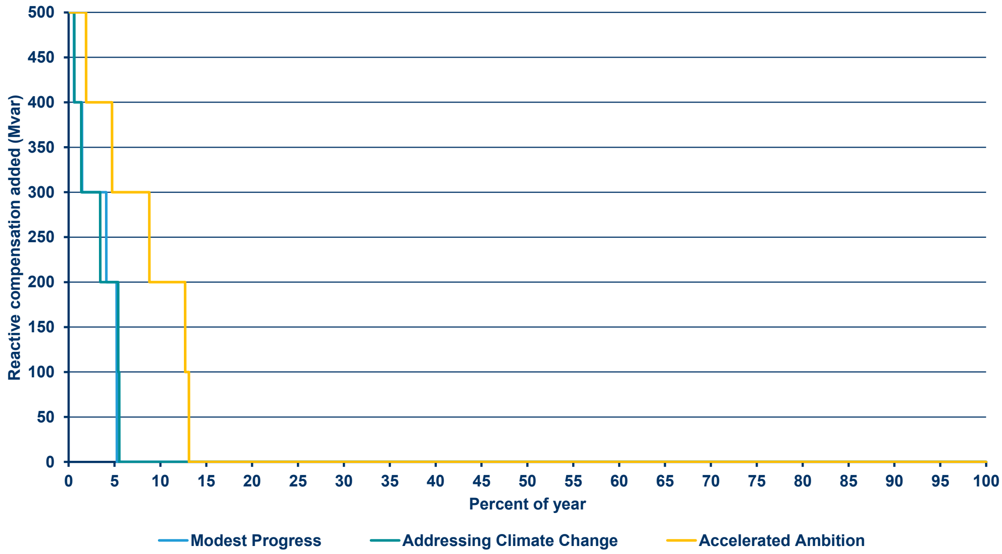


Figure 7.13: Reactive compensation added in 2030 with present network configuration

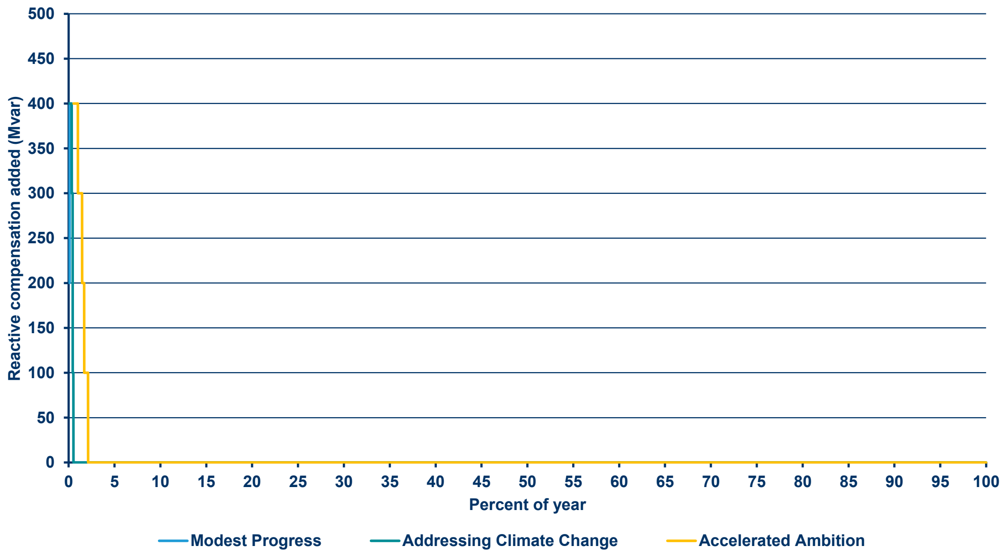


Figure 7.14: Reactive compensation added in 2030 with additional TDPNI projects included

By 2040, increases are noted in both the amount and extent of reactive power compensation required in all scenarios, as shown in figure 7.15. In both **Modest Progress** and **Addressing Climate Change**, the number of hours is significantly lower than those observed in figure 6.10 in **section 6.5**, without the TDPNI projects included. With a large increase in generation in the north-west area, **Accelerated Ambition** sees a requirement for reactive compensation for a quarter of the year, with a significant number of those hours being non convergent.

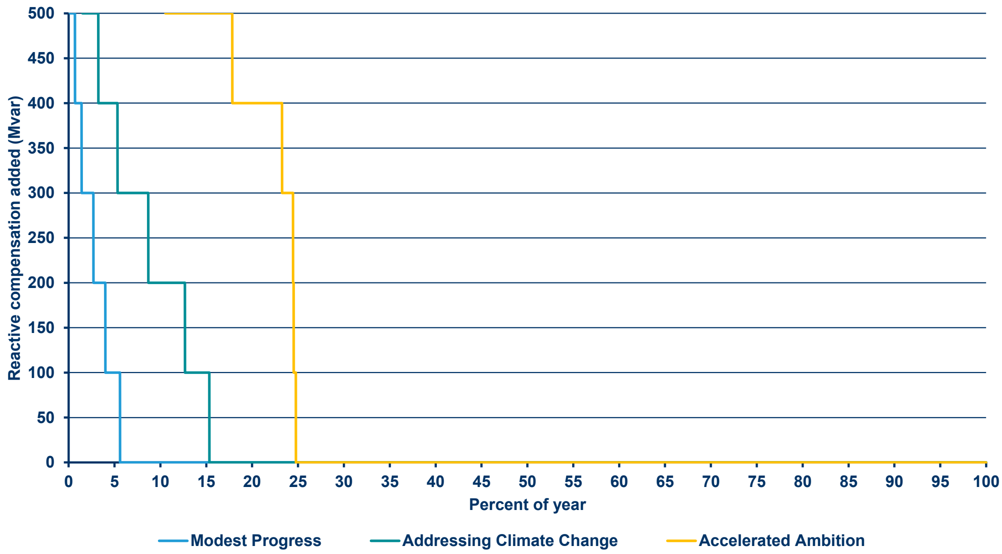


Figure 7.15: Reactive compensation added in 2040 with additional TDPNI projects included

The development of additional network capacity along the Coleraine to Kells corridor sees a significant reduction in the number of hours where a 20⁰ phase angle difference between Coolkeeragh and Magherafelt is exceeded, following the loss of the 275 kV double circuit, in all scenarios. Figure 7.16 shows the phase angle difference for the three scenarios with the present network configuration, and the improvement is clearly seen in figure 7.17, once the TDPNI projects are included.

Addressing Climate Change continues to be the scenario with the fewest issues., with an angle difference of greater than 20⁰ being a risk in less than 10% of hours across the year. With its focus on onshore renewable generation only, **Modest Progress** continues to see the largest risk.

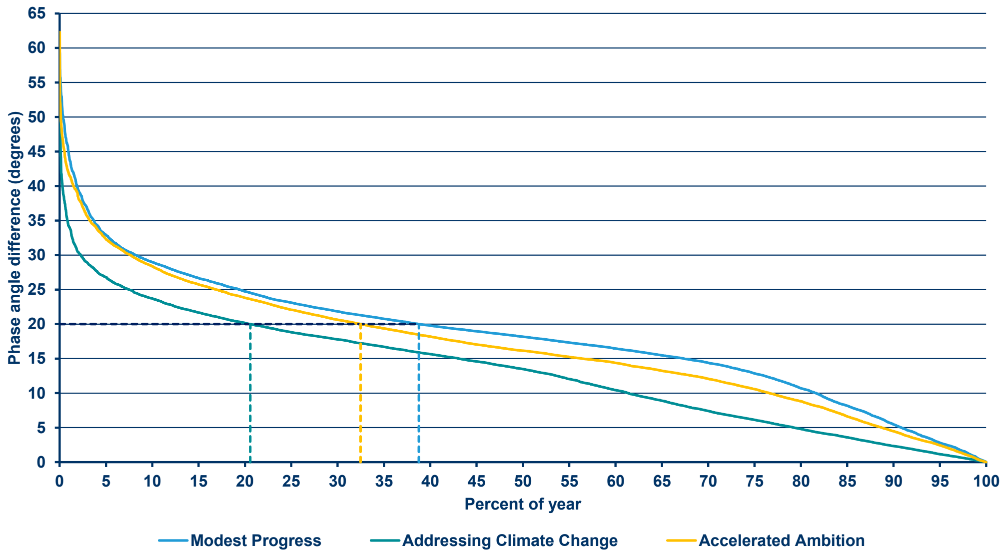


Figure 7.16: Coolkeeragh to Magherafelt phase angle difference in 2030 with present network configuration

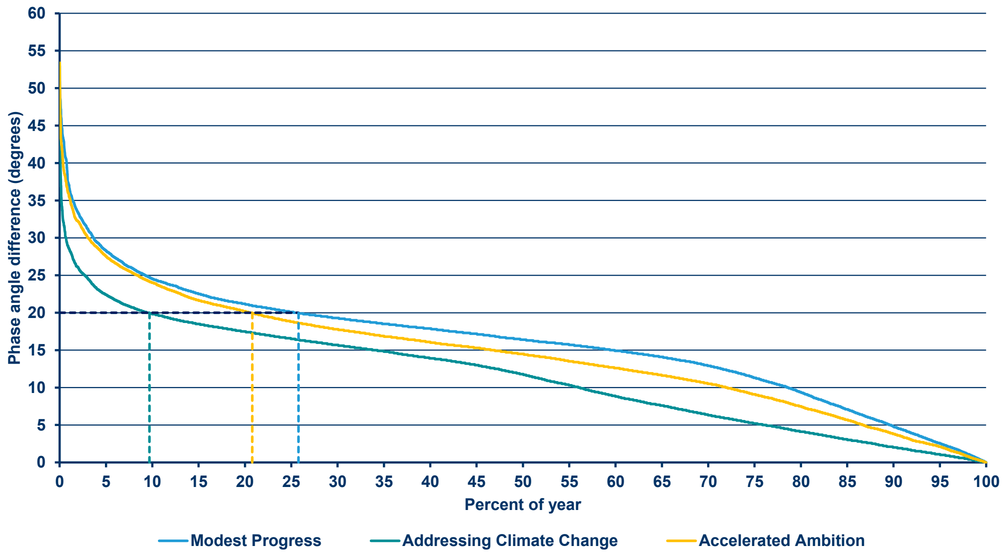


Figure 7.17: Coolkeeragh to Magherafelt phase angle difference in 2030 with additional TDPNI projects included

By 2040, a significant increase in the number of hours a 20° phase angle is exceeded is observed in both **Modest Progress** and **Accelerated Ambition**. **Addressing Climate Change** once again sees significantly fewer breaches across the year. Phase angle analysis results for 2040, with the TDPNI projects included, are shown in figure 7.18.

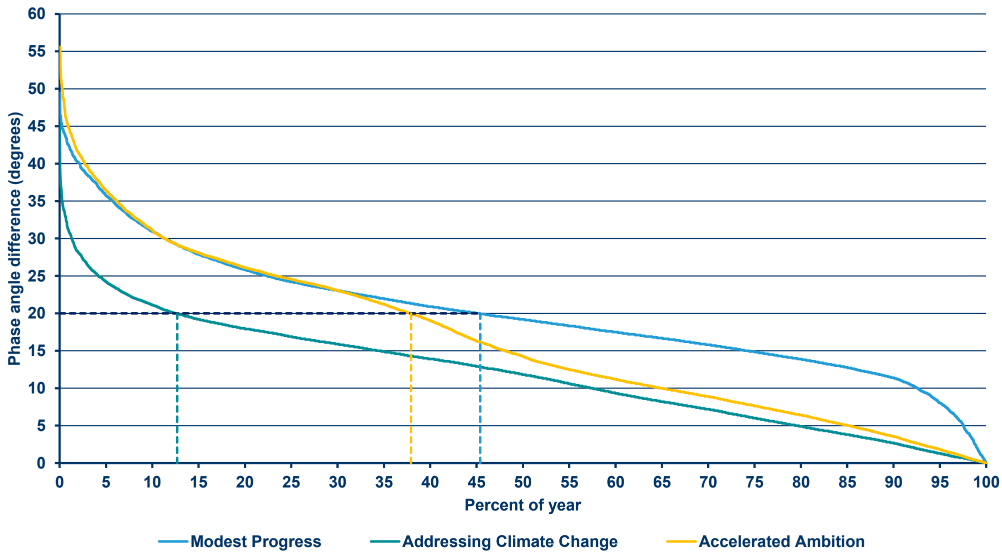
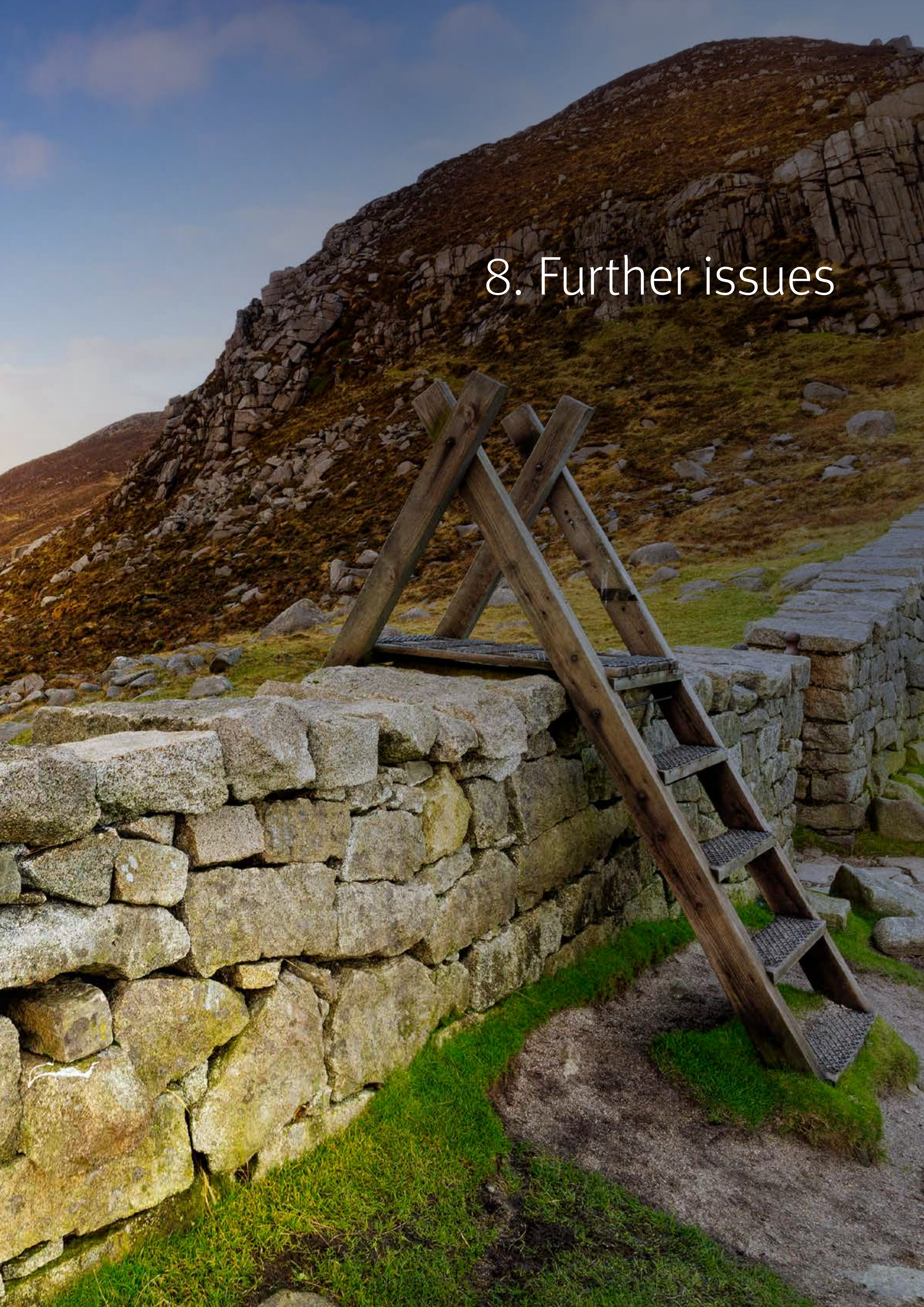


Figure 7.18: Coolkeeragh to Magherafelt phase angle difference in 2040 with additional TDPNI projects included

8. Further issues



8. Further issues

Following the analysis in 2030 and 2040 with a number of TDPNI projects assumed complete, presented in **section 7**, a number of needs still remain. These are indicated in figure 8.1.

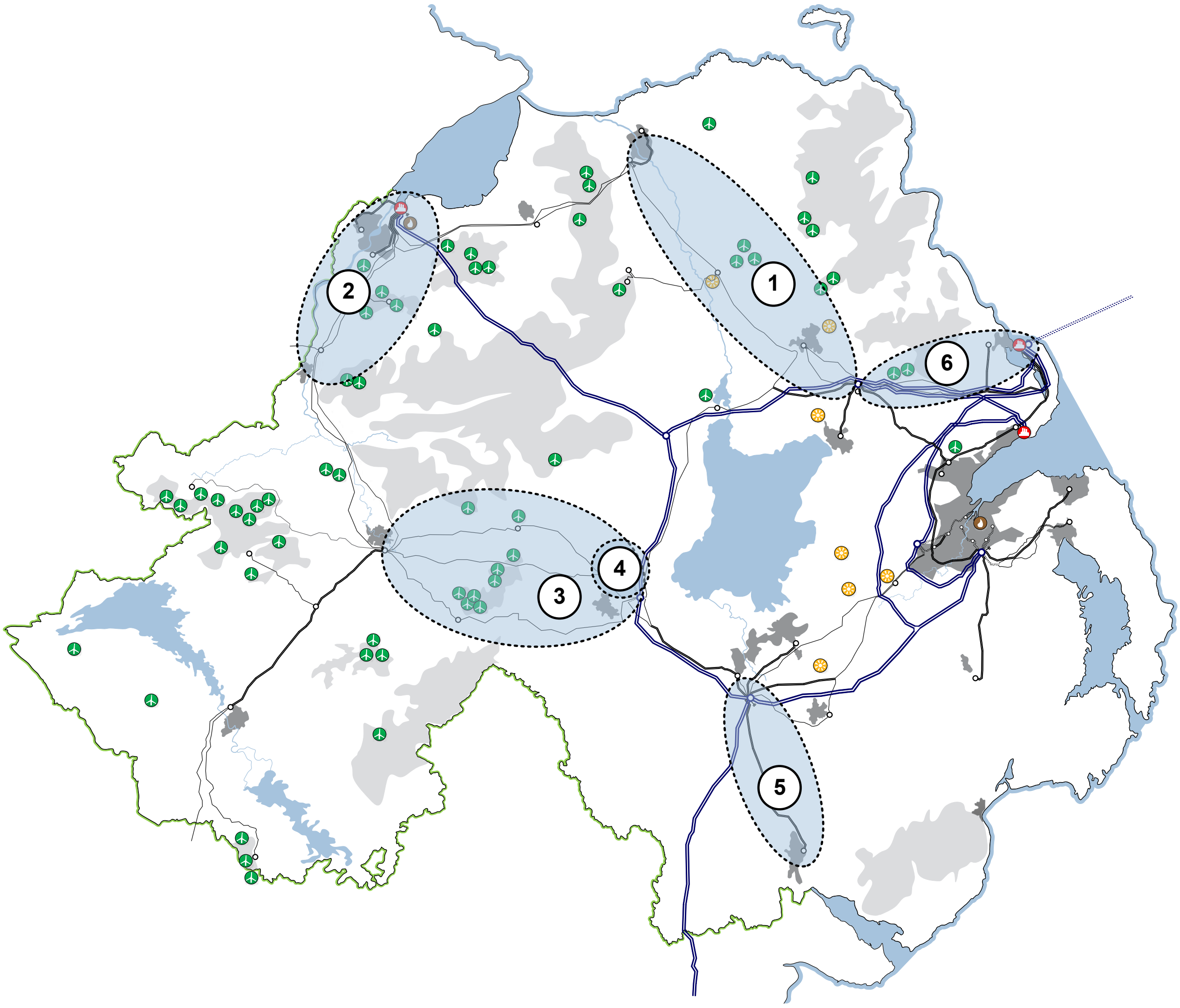


Figure 8.1: Remaining areas of need in Northern Ireland following inclusion of TDPNI projects

8.1. Coleraine to Kells

Driver: offshore renewable generation development

Depending on the scenario, the Coleraine to Kells corridor, area (1) in figure 8.1, can see significant overloading, in spite of the development of additional network capacity in this area from several TDPNI projects. Figure 8.2 shows the N-1 contingency loading on the Kells to Rasharkin 110 kV circuit in 2040 for all scenarios. Significant Offshore development off the north coast of Northern Ireland sees the Kells to Coleraine corridor at risk of significant overloading again in **Accelerated Ambition**.

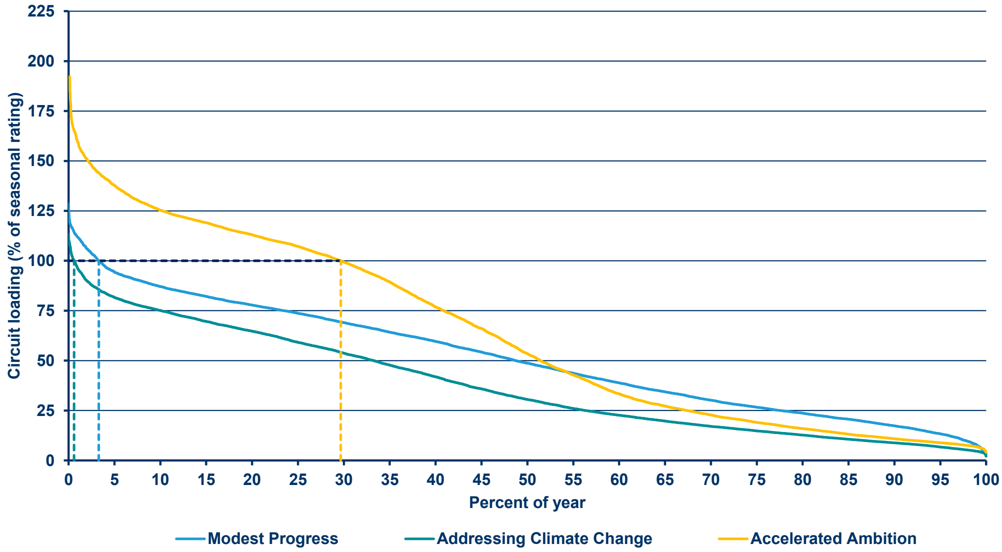


Figure 8.2: N-1 Loading on the Kells to Rasharkin 110 kV circuit in 2040 with additional TDPNI projects included

Such a risk only arises should large scale offshore generation development occur off the north coast, and may be addressed by the TDPNI project 'North West of NI Large Scale Reinforcement'.

8.2. Coolkeeragh to Strabane

Driver: renewable generation development

A large increase in renewable generation capacity at Killymallaght, Slieve Kirk and Strabane, from both new developments and the replanting of existing sites, presents risks to the Coolkeeragh to Strabane corridor, area (2) in figure 8.1. This is in spite of proposed uprates to all of these circuits outlined in TDPNI.

This risk is present in both 2030 and 2040; the N-1 contingency loadings for the Coolkeeragh to Killymallaght circuit in 2030 for all scenarios are shown in figure 8.3.

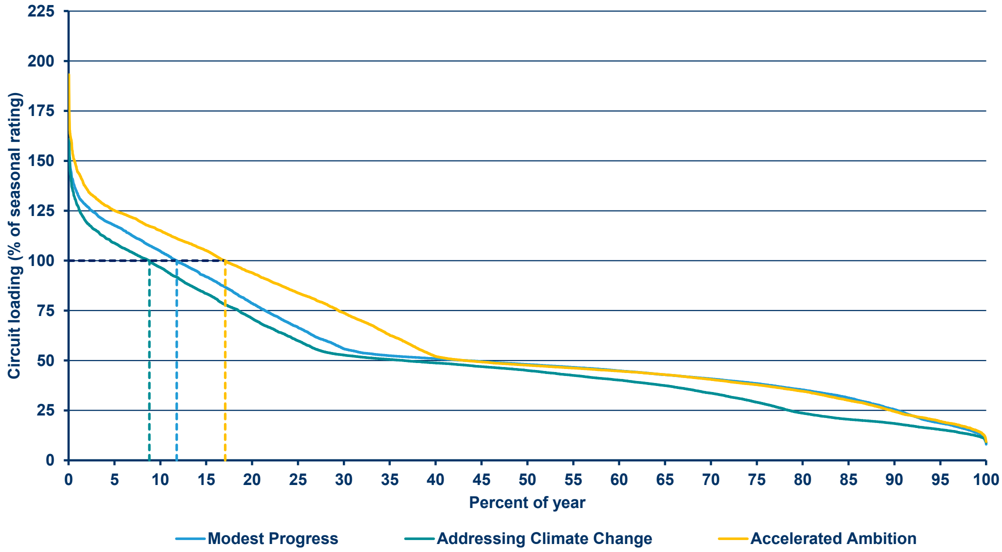


Figure 8.3: N-1 Loading on the Coolkeeragh to Killymallaght 110 kV circuit in 2030 with additional TDPNI projects included

This risk arises if significant development of renewable generation capacity occurs in the impacted area. It may be addressed by the TDPNI project 'North West of NI Large Scale Reinforcement'.

8.3. Omagh to Tamnamore

Driver: renewable generation development

110 kV circuits in the corridor between Omagh and Tamnamore, area (3) in figure 8.1, continue to be at risk of overloading during contingency events. The risk is present in 2030 but isn't a significant issue until 2040, as indicated in figure 8.4, which shows the N-1 contingency loading for the Tamnamore to Tremoge 110 kV circuit in 2040 for all scenarios.

The Tamnamore to Tremoge circuit is the most impacted, as the result of additional renewable generation assumed to connect at this cluster in all scenarios. However, both the replanting of older wind farm sites and new generation developments in the western area of Northern Ireland could see all circuits in the Omagh to Tamnamore corridor significantly impacted.

The identified risk may be addressed by the TDPNI projects 'North West of NI Large Scale Reinforcement', and 'East Tyrone Reinforcement Project'.

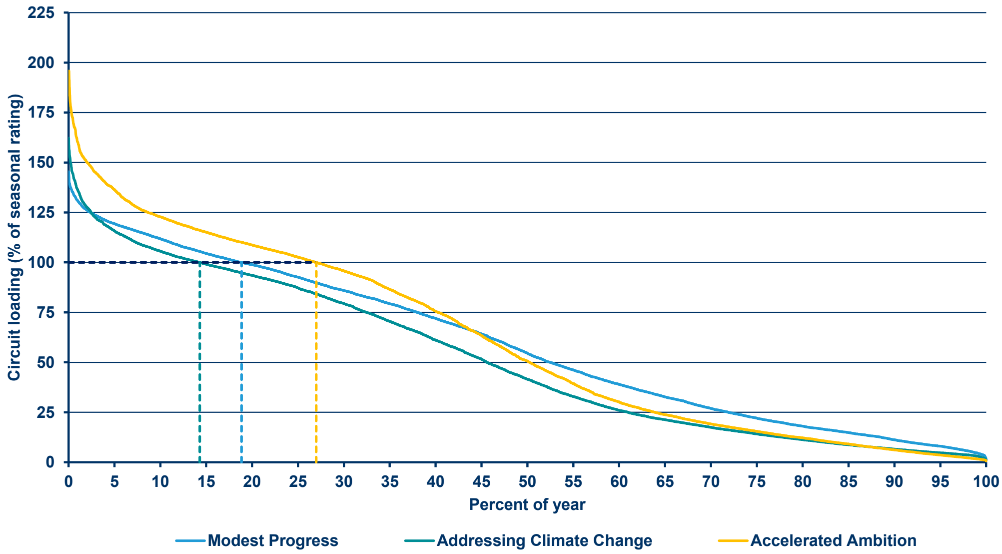


Figure 8.4: N-1 Loading on the Tamnamore to Tremoge 110 kV circuit in 2040 with additional TDPNI projects included

8.4. Dungannon bulk supply point

Driver: demand growth from electric heat and transport

Dungannon bulk supply point, (4) in figure 8.1, is already heavily loaded, close to its firm capacity. The development of electric heat and transport in the scenarios sees Dungannon at risk of extensive and heavy overloading. The issue is significant by 2030 in **Accelerated Ambition**, due to its rapid uptake in electric heat and transport, and in all scenarios by 2040.

The identified risk may be addressed by the TDPNI projects 'North West of NI Large Scale Reinforcement', and 'East Tyrone Reinforcement Project'.

8.5. Newry bulk supply point

Driver: demand growth from electric heat and transport

Newry bulk supply point, (5) in figure 8.1, is heavily loaded. The development of electric heat and transport in the scenarios sees Newry at risk of extensive and heavy overloading in the long term. The issue is significant by 2040 in both **Addressing Climate Change** and **Accelerated Ambition**, due to significant uptake in electric heat and transport in these scenarios by 2040.

As Newry is supplied by a long 110 kV double circuit from Tandragee grid supply point, the risk of overloading extends to these circuits, as indicated in the results in **section 6**.

8.6. Ballylumford to Kells

Driver: generation at Islandmagee

The TDPNI projects to uprate and/or reconfigure the Carnmoney to Castlereagh and Carnmoney to Eden 110 kV double circuits, coupled with a reduction in thermal generation utilisation in future years, sees a reduction in risks to the Ballylumford to Kells 110 k V circuits. However, should new generation capacity develop in the Islandmagee area, such as the CCS CCGT in **Accelerated Ambition** by 2040, these circuits can be at risk of more significant and extensive overloading, as indicated in figure 8.5.

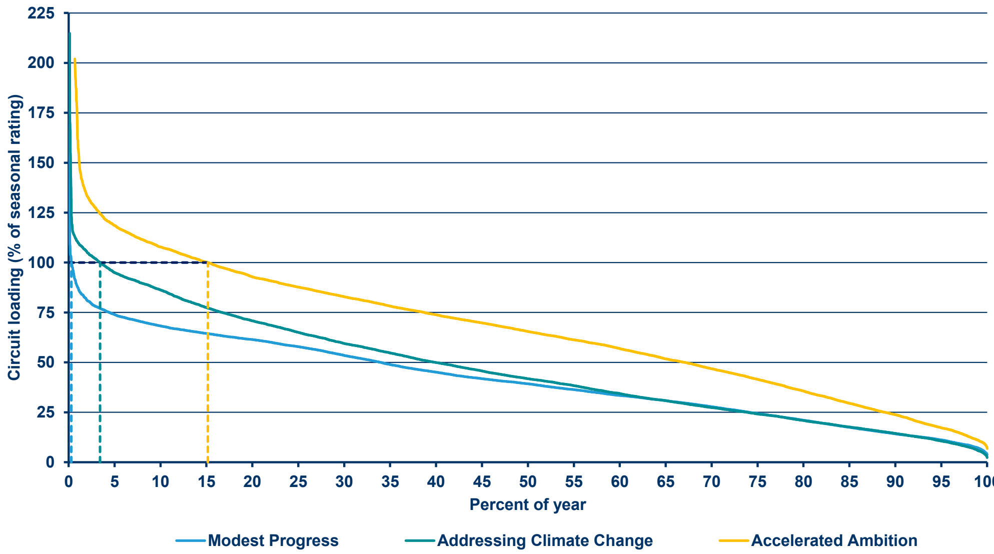


Figure 8.5: N-1 Loading on the Ballylumford to Ballyvallagh 110 kV 'A' circuit in 2040 with additional TDPNI projects included

The identified risk is a long-term issue, and dependent on how the generation portfolio develops into the future.

8.7. Reactive power compensation

Driver: renewable generation development

The large growth in capacity of renewable generation in the scenarios results in an increasing need for reactive power compensation, particularly from 2030. The TDPNI project 'Coolkeeragh reactive compensation', combined with an increase in network capacity provided by other TDPNI projects, helps resolve most voltage issues identified in the scenarios in 2030.

By 2040, further growth in renewable generation, combined with a decrease in usage of thermal generation and its associated dynamic reactive power provision, results in a need for further reactive power compensation. The issue is most pronounced in **Accelerated Ambition**, with a number of non-convergent hours noted in the analysis. **Addressing Climate Change** also sees a need for further reactive power compensation by 2040.

The identified risk is dependent on many variables, including future growth in renewable generation, the location of renewable generation, future network development, the extent of the relaxing of operational constraint and subsequent utilisation of thermal generation, among others.

8.8. Coolkeeragh and Magherafelt phase angle difference

Driver: renewable generation development

This risk arises if significant development of renewable generation capacity occurs in the north-west area. It concerns the voltage phase angle difference between Coolkeeragh and Magherafelt following the unplanned loss of the 275 kV double circuit between the two substations. If the difference is greater than 20°, the circuits cannot be reclosed.

Whilst the increased network capacity provided by projects in the TDPNI reduces the number of hours there is an issue regarding the phase angle difference, by 2040 both **Modest Progress** and **Accelerated Ambition** see a large proportion of the year where the difference exceeds 20°.

The risk may be addressed by the TDPNI project 'North West of NI Large Scale Reinforcement'. As demonstrated by **Addressing Climate Change**, the risk can also be mitigated with development of renewable generation towards the east of Northern Ireland.

8.9. Bulk supply point capacity

Driver: large growth in PV generation

Some bulk supply points are identified as at risk of exceeding their firm capacity to a significant extent in future years. Typically, such issues arise from large growth in demand. However, at a number of sites, the driver is a rapid growth in large scale PV generation, particularly in **Accelerated Ambition**. This issue stems from the assumption that many of these potential PV sites would connect at distribution level, as transmission connections may be prohibitively expensive.

This risk to these bulk supply points is very much dependent on the future growth of large scale PV generation, and may be addressed by the implementation of a clustering policy, such as that which was developed for onshore wind generation in Northern Ireland.

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