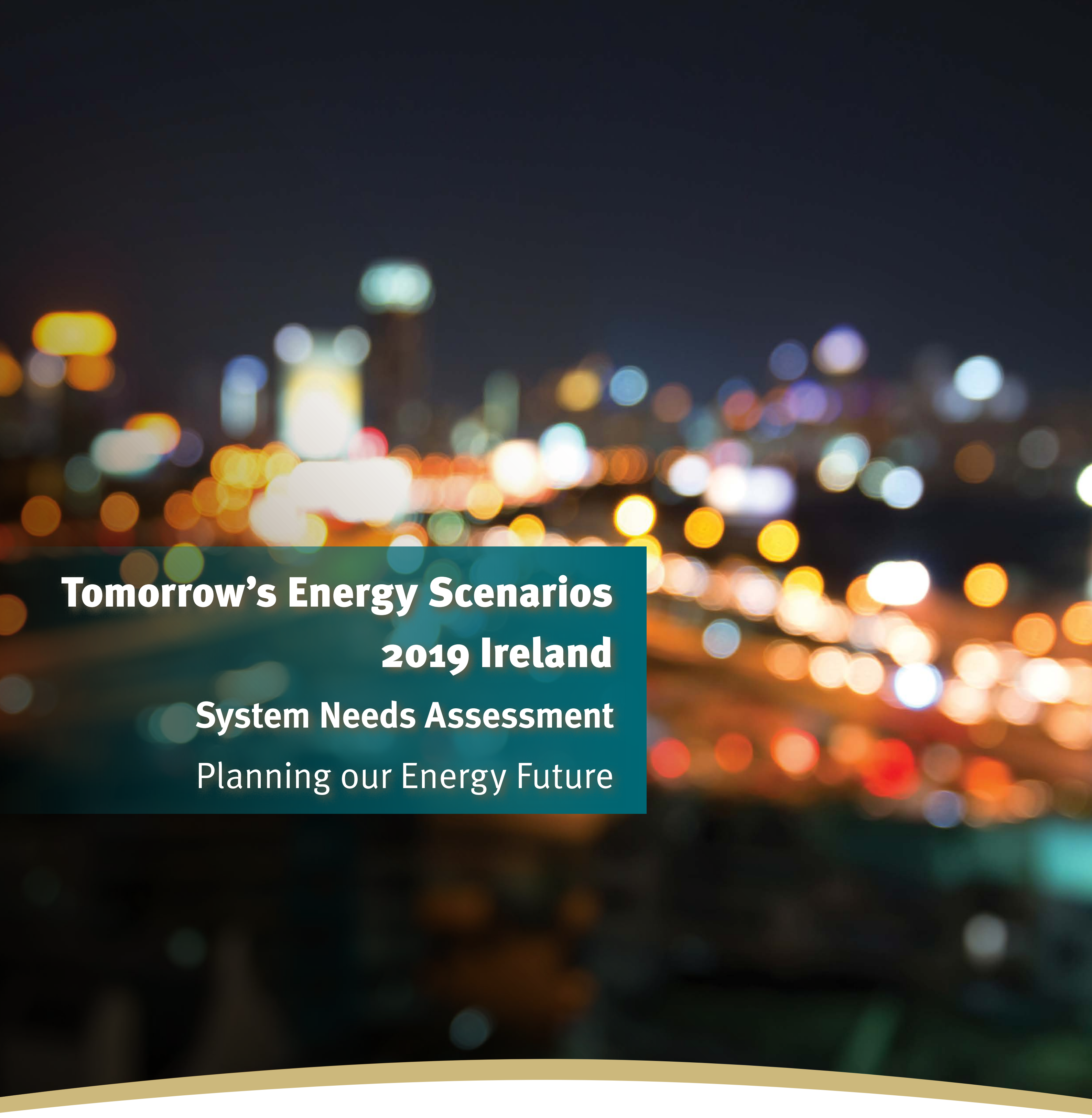

Tomorrow's Energy Scenarios 2019 Ireland

System Needs Assessment

Planning our Energy Future

EIRGRID

The current. The future.

Disclaimer

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For queries relating to this document please contact: scenarios@eirgrid.com

Published December 2019.

The Oval, 160 Shelbourne Road, Ballsbridge, Dublin 4, D04 FW28, Ireland.

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Foreword

EirGrid, as transmission system operator for Ireland, is pleased to present the *Tomorrow's Energy Scenarios 2019 System Needs Assessment*.

The transmission grid transports electricity from where it is generated to supply power to industry and businesses that use large amounts of electricity. The grid also powers the distribution network that supplies electricity used every day in our homes, businesses, schools, hospitals, and farms.

Three scenarios, detailing credible futures for the electricity sector in Ireland, were developed as part of *Tomorrow's Energy Scenarios 2019*. Our stakeholders helped to shape and enhance these scenarios, providing valued feedback as part of an open consultation. With respect to electricity sector targets for 2030, two of our scenarios achieve 70% RES-E, while all three achieve carbon dioxide emissions from electricity production of less than 4.5 megatonnes. A reliable transmission grid will be a central component of realising this low-carbon future.

Employing our scenarios we've identified future needs of the grid, as part of our integrated grid development process. These needs arise from changes in the usage of the grid, which is influenced by the scale and location of electricity consumption, generation, interconnection and storage. We develop new electricity infrastructure only when it is needed, and we work for the benefit and safety of every citizen in Ireland.

We are already tackling some of the needs identified, as detailed in our *Transmission Development Plan 2018-2027*. We will continue to monitor and assess these, along with other investment needs, as conditions change and new information becomes available. We are also embarking on developing a holistic work programme to deliver grid solutions, in both infrastructural and technological terms, in order to facilitate the electricity targets set out in the Government's *Climate Action Plan 2019* and the *National Energy and Climate Plan 2021-2030*.

We very much welcome your feedback on this document and look forward to working with all our partners to facilitate Ireland's low carbon future.

Mark Foley
Chief Executive, EirGrid Group
December 2019

Document structure

This document contains a glossary of terms, an executive summary, five main chapters, a next steps chapter, and appendices. The structure of the document is as follows.

The **Glossary of terms** explains some technical terms used in the document.

The **Executive summary** summarises the main findings of the document.

Chapter 1 explains the purpose of the *TES System Needs Assessment*, outlines why we use scenarios, and lists other related publications.

Chapter 2 describes the scenario development cycle and summaries our three scenarios.

Chapter 3 describes our grid development strategy and our grid development process.

Chapter 4 outlines the approach taken to identifying needs and the types of needs and drivers.

Chapter 5 presents the results of the *TES System Needs Assessment* by area and scenario.

The **Appendices** outline the grid assumptions used and provide figures summarising the grid simulation results.

Glossary of terms

Area [Need]
A part of the transmission grid that contains a number of needs.

Capacitor
A technology that can help limit a drop in voltage.

Circuit
An element of the transmission grid that carries electricity.

Conventional generation
A large power plant which typically uses fossil fuel(s) to generate electricity.

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

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

Driver
A factor that influences a need.

EirGrid
The independent statutory electricity transmission system operator in Ireland.

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

Fault
An unexpected loss of a grid element, such as a generation unit, transmission line, transformer or other electrical element.

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

Limit exceedance
An instance of a grid element performing outside of the technical planning standards.

Need [grid development]
A future deficiency identified on the grid that arises as a result of one or more drivers.

Rating
An operating limit for an element of the grid.

Reactor
A technology that can help limit a rise in short circuit level or voltage, depending on its installation and configuration.

Series compensation
A technology that can increase the power flow on an existing line.

STATCOM, SVC or synchronous condenser
Technologies that can help regulate the voltage in both directions (high and low).

System Operator Northern Ireland (SONI)
The licensed 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 grid is designed to meet. Our technical planning standards are a licence obligation and are approved by the Commission for Regulation of Utilities (CRU).

Transmission grid [electricity]
The typically meshed network of high voltage (400 kV, 275 kV, 220 kV and 110 kV) circuits and other equipment used to transmit bulk electricity supplies around Ireland. The terms grid, network and system can be used interchangeably.

Transmission system operator [electricity]
The licensed entity that is responsible for transmitting electricity from generators to regional or distribution operators.

Executive summary

The *Tomorrow's Energy Scenarios 2019 System Needs Assessment* highlights the needs of the transmission grid in Ireland under the future scenarios outlined in *Tomorrow's Energy Scenarios 2019*[1].

As part of the Tomorrow's Energy Scenarios (TES) 2019 cycle, we developed a set of scenarios outlining three credible futures for the supply and consumption of electricity in Ireland:

- **Centralised Energy**
- **Delayed Transition**
- **Coordinated Action**

Although our scenario pathways extend to 2040, focus here is placed on communicating the needs identified out to 2030.

Changes in grid usage across scenarios and locations drive varying levels of need over time in different areas.

These needs were calculated using a series of computer model simulations. These models are based on the data from our final scenarios, which incorporate stakeholder feedback received about the scenarios. Using the dispatch modelling results from TES 2019, we conducted thousands of grid simulations in order to appraise the performance of the grid against our technical planning standards.

The outcome of this process determines the areas of the existing grid that may need to be further developed or strengthened.

We have identified six areas of the country where we believe there is a potential need to develop the grid in order to facilitate a low-carbon future.

Our assessment of the scale of the need at each location is based on two factors. Firstly, the cause or driver of the local challenge to the grid, and secondly what kind of problem or need this creates.

With regard to the drivers of the needs, we've identified four categories:

- Increased demand for electricity, particularly large energy users.
- New sources of electricity generation or storage, including onshore wind, offshore wind, and solar photovoltaics.
- Closures of electricity generators, particularly those relied upon for voltage support.
- New interconnection, including high voltage direct current (HVDC) interconnectors.

In terms of needs, we've assessed two types:

- **Power-Transfer Capacity:** when the amount of electricity to be carried by local lines or cables is too high for their rated capacity.
- **Voltage Support:** when there is not enough capability in the region to control voltage and reliably supply the electricity that is needed. We have further categorised this need by direction (high voltage and low voltage).

These areas of need, under our future scenarios, are summarised in Figure 1.

1 EirGrid, Tomorrow's Energy Scenarios 2019

Area 1 Dublin Mid-East

The grid in this area mainly consists of 220 kV underground cable and overhead lines, with two 400 kV lines connecting to the rest of the country. The anticipated growth in large energy users, such as data centres, yields needs for voltage support. The expected growth in onshore wind generation across the country and offshore wind generation in the Irish Sea results in a need for power-transfer capacity. Increasing renewables on the system displaces conventional generation in the area, resulting in voltage support needs. The need for grid development in this area is high to very high across our scenarios.

Area 2 West

This area of the grid relies on low capacity 110 kV lines, and has some 220 kV connections to the wider grid. While the North Connacht 110 kV project improves power-transfer capacity in the north of the area, further onshore wind connections create further power-transfer needs in the north and also in the south of the area. These large transfers of power create voltage support needs, which are exacerbated by the decommissioning of conventional generating units in Moneypoint and the Midlands. The need for grid development in this area is moderate to high across our scenarios.

Area 3 North-West Border

The grid in this area is made up of long 110 kV lines, which are relatively isolated from the 220 kV grid. Onshore wind connections create power-transfer needs in the area and these large transfers of power also create voltage support needs. The cause of these issues is the forecasted connection of new renewable energy projects in this area. The decommissioning of conventional generating units in the Midlands further increases the voltage support need. The need for grid development in this area is moderate to high across our scenarios.

Area 4 Midlands

The grid in this area consists of 110 kV and 220 kV lines, with power flowing mostly west to east through the area. Onshore wind generation to the north and west of the area cause a high need for power-transfer capacity. The decommissioning of conventional generation in the area creates voltage-support needs. There is a moderate to high need for grid development in this area across our scenarios.

Area 5 South-West

This area includes some underground cables in Cork and in the west of the area, but otherwise consists of 110 kV and 220 kV overhead lines. Onshore wind growth and new high voltage direct current (HVDC) interconnection create power-transfer capacity needs in the area. There is a moderate to high need for grid development in this area across our scenarios.

Area 6 South-East

As with other mostly rural areas of the grid today, this area uses 110 kV and 220 kV overhead lines. There is a lot of power moving through this area to large electricity demand centres in Dublin and Cork. Growth in offshore wind generation and new HVDC interconnection creates a need for power-transfer capacity in the area. The need for grid development in this area is moderate to high across our scenarios.

Figure 1: Summary of system needs

1. Introduction

1.1. Report purpose

The *TES System Needs Assessment* is a planning screening study, which highlights the potential development needs of the electricity transmission grid under our future scenarios outlined in *TES*. These needs are brought about by the changes to the electricity portfolio, such as electricity generation, demand, interconnection and storage. Focus is placed on the 2025–2030 timeframe, so as to highlight development requirements related to facilitating Government energy policy.

Some of the needs identified are being addressed by projects in our *Transmission Development Plan (TDP)*[2]. Needs not covered in the TDP will undergo further investigation. If verified, these needs will appear in future editions of the *TDP* along with an associated development project.

Our scenario planning process does not identify short-term needs or constraints, for example those arising from unforeseen plant closures, new connections or project delays. The grid development process adapts to these changes as they occur.

1.2. Why we use scenario planning

Scenario planning allows us to assess the performance of the electricity grid against a credible range of potential futures.

As the licensed transmission system operator in Ireland, we are responsible for the ongoing development of the transmission grid so that it continues to meet the needs of electricity consumers into the future.

In 2017 we introduced scenario planning as part of our grid development process so that it continues to support Ireland's economic growth, changing generation mix and expanding population, recognising the uncertainty present in the planning horizon.

This process helps us maintain required levels of system safety, security and reliability over the long-term.

1.3 Related publications

EirGrid produce a number of network planning documents that share a relationship with TES. These are shown in Figure 2. Alongside TES they provide a holistic view of the future electricity transmission system. TES aligns with these reports and provides a wider view of the electricity transmission grid beyond a ten-year planning horizon.

The *All-Island Generation Capacity Statement (GCS)*[3] outlines the likely generation capacity required to achieve an adequate supply and demand balance for electricity in Ireland and Northern Ireland over ten years. This report forms the basis for underlying demand growth assumptions used in TES.

The *All-Island Ten Year Transmission Forecast Statement (TYTFS)*[4] provides detailed data by transmission network node, which provides the basis for the existing electricity grid model used in the *TES System Needs Assessment*. The *TYTFS* also provides other information such as demand and generation opportunities on the transmission grid.

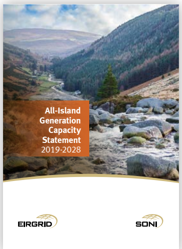
The *TDP* outlines projects for the transmission grid over a ten year period. Needs identified in the *TES System Needs Assessment*, as part of step 1 of the grid development process, may lead to projects listed in future editions of the *TDP*.

2 EirGrid, TDP 2018 - 2027
3 EirGrid Group, Generation Capacity Statement 2019-2028
4 EirGrid Group, TYTFS 2018

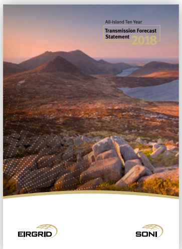
The *TES* outlines future electricity scenarios incorporating stakeholder feedback received as a part of a consultative process. The *TES System Needs Assessment* uses these scenarios to identify needs of the electricity transmission system brought about changes to electricity demand, generation, interconnection and storage. The TES reports are reviewed and updated every two years.

The *Ten Year Network Development Plan (TYNDP)* process[5] of the European Network of transmission system operator for electricity and gas is an important reference for TES. It provides guidance on the European-wide energy transition, and is central to understanding European Union (EU) Projects of Common Interest (PCIs).

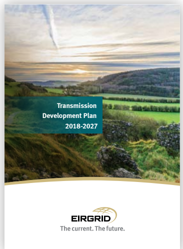
Ten-year-horizon planning publications



All Island Generation Capacity Statement
Ten year electricity demand forecast.



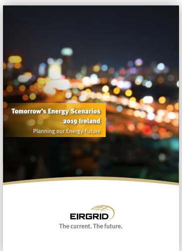
All Island Ten Year Transmission Forecast Statement
Detailed information on demand and generation opportunities.



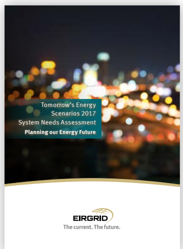
Transmission Development Plan
Ten year network and interconnection development plan.

Twenty-year-plus-horizon planning publications

Ten Year National Development Plan - Scenarios Report
Energy scenarios for Europe out to 2040.



Tomorrow's Energy Scenarios
Electricity scenarios for Ireland out to 2040.



TES System Needs Assessment
Long-term needs of the electricity transmission grid out to 2040.

Figure 2: Related planning publications

5 ENTSOs, TYNDP 2020 Scenario Report

2. Tomorrow's Energy Scenarios 2019

2.1. Scenario development

Our scenarios are reviewed every two years to include new information. You can find all of the TES publications on our Energy Future webpage. An overview of the TES 2019 scenario development cycle is shown in Figure 3. The *System Needs Assessment* concludes the TES cycle.

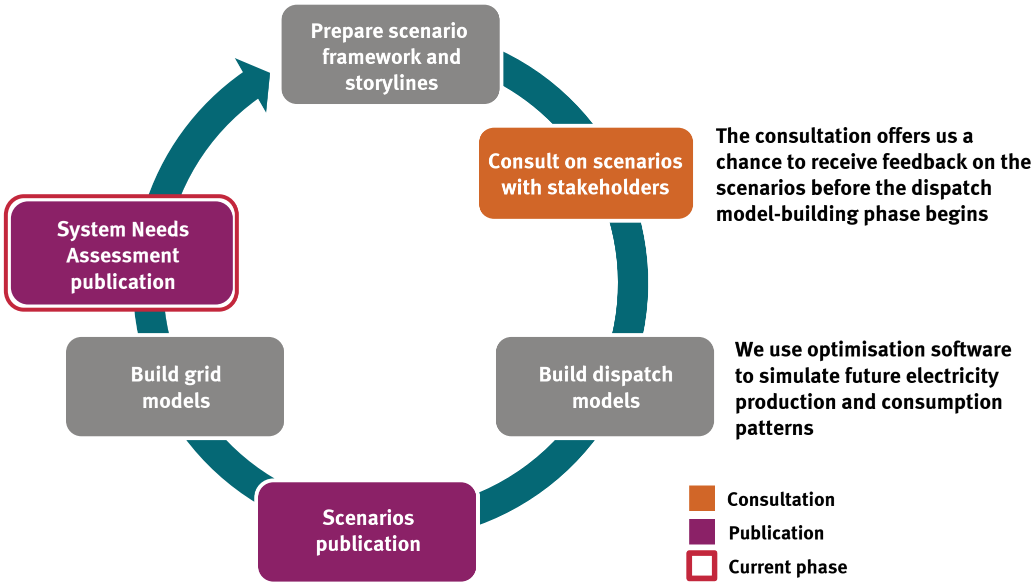


Figure 3: TES 2019 Ireland development cycle

Data captured during the consultation phases reflects the best information available at the time and remains unchanged, or frozen, since then.

SONI have produced a draft set of Tomorrow's Energy Scenarios 2019 which are described in a separate consultation report. For more information on SONI's Tomorrow's Energy Scenarios 2019 please visit SONI's Energy Future webpage.

2.2. Summary of our scenarios

In October we published *TES 2019*, a document outlining three possible futures for the supply and consumption of electricity in Ireland out to 2040:

Centralised Energy is a plan-led world in which Ireland achieves a low carbon future.

Delayed Transition is a world in which decarbonisation progress is made, but the pace is not sufficient to meet long-term climate objectives.

Coordinated Action is a scenario where sustainability is a core part of decision making. Government and citizens recognise climate change as a risk and take appropriate action.

The *TES 2019* dataset is a key input to the *System Needs Assessment* analysis. It provides an envelope for the future capacity levels and locations of electricity demand, generation, interconnection and storage. A summary of the scenario portfolios is given in Table 1.

	Centralised Energy	Delayed Transition	Coordinated Action
Variable renewables installed capacity	5.5 GW Onshore wind 3.5 GW Offshore wind 0.6 GW Solar PV	5.8 GW Onshore wind 1.0 GW Offshore wind 0.9 GW Solar PV	8.2 GW Onshore wind 1.8 GW Offshore wind 2.0 GW Solar PV
Percentage of which is distribution-connected	44% Onshore wind 0% Offshore wind 59% Solar PV	54% Onshore wind 0% Offshore wind 60% Solar PV	56% Onshore wind 0% Offshore wind 68% Solar PV
Fossil fuel-fired generation phased out	Peat: Yes Coal: Yes Oil*: Yes Unabated/non-renewable Gas**: No	Peat: Yes Coal: Yes Oil*: Yes Unabated/non-renewable Gas**: No	Peat: Yes Coal: Yes Oil*: Yes Unabated/non-renewable Gas**: No
Interconnectors in-service	EWIC, North South, Celtic, Greenlink	EWIC, North South, Celtic	EWIC, North South, Celtic, Greenlink
Electrification	500,000 electric vehicles 350,000 heat pumps	250,000 electric vehicles 270,000 heat pumps	900,000 electric vehicles 600,000 heat pumps
Large energy users	1,300 MVA max. import 9.8 TWh annual demand	1,100 MVA max. import 8.3 TWh annual demand	1,700 MVA max. import 12.6 TWh annual demand

*Heavy fuel oil and distillate oil for primary fuel purposes.
**Not fully abated with carbon capture and storage or not fully renewable via 100% of supply from biomethane or hydrogen.

Table 1: *Tomorrow's Energy Scenarios 2019* summary, 2030. (PV: photovoltaics)

3. How we develop the grid

3.1. Grid development strategy

EirGrid is responsible for a safe, secure and reliable electricity transmission system, now and in the future. To achieve this we must continue to maintain and develop the grid.

Our approach to the development of Ireland's electricity infrastructure is set out in the *Grid Development Strategy*[6]. Our strategy assists us to meet projected demand levels, to meet Government policy objectives, and to ensure a long-term sustainable and competitive energy future for Ireland.

The *Grid Development Strategy* is influenced by three main factors, as shown in Figure 4.

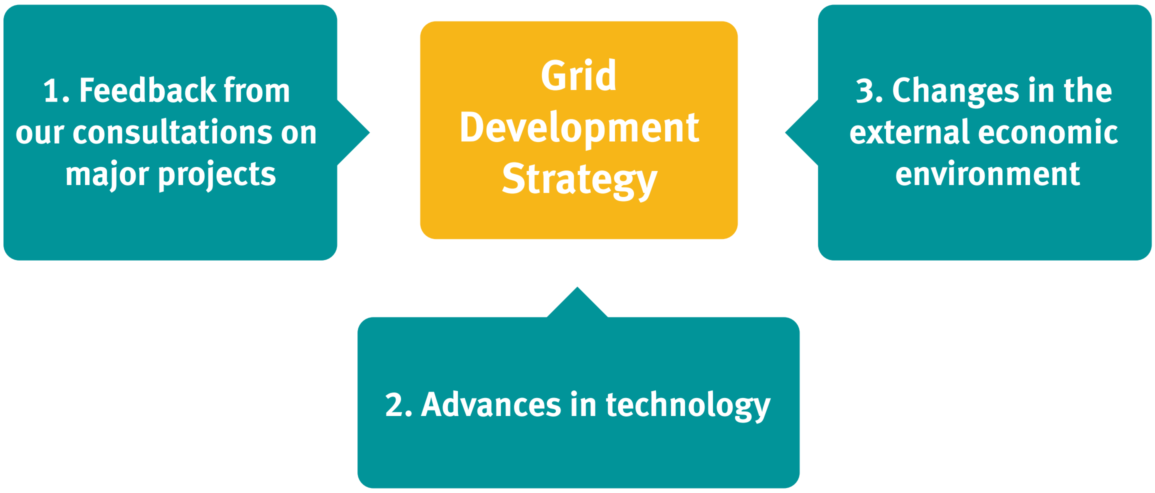


Figure 4: Factors influencing our *Grid Development Strategy*

These factors led to the development of three strategic statements which underpin our *Grid Development Strategy*. The statements are as follows:

Statement 1: We are committed to continually improving public participation and community engagement as part of grid development process. For more on our commitment to public consultation, see our *Reviewing and Improving our Public Consultation Process*[7] publication.

Statement 2: We continually review technological developments to assess their potential use on the Irish transmission system. Technologies are categorised into three types: technology available now, new technology ready for trial use, and new technology at research and development stage.

For a given grid development project, each technology is assessed for suitability with respect to cost, ease of project delivery, improved grid performance and security of supply, environmental friendliness, and system flexibility. This will assist us in determining the best transmission technology for future projects.

Statement 3: We will continue to maximise the use of the existing grid infrastructure. This can be achieved by increasing the capacity of existing infrastructure, or by using new technologies, depending on the requirements and circumstances in each case. We will build new infrastructure only when this is the right solution.

We work with industry partners, technology innovators and with other transmission system operators to identify, research and trial possible innovations.

6 EirGrid, Ireland's Grid Development Strategy
7 EirGrid, Reviewing and Improving our Public Consultation Process

3.2. Grid development process

We are committed to delivery of our grid development strategy and have designed processes that ensure our overall strategy and strategic statements are achieved. Our *Have Your Say*[8] publication details our six-step grid development process, which is shown in Figure 5.

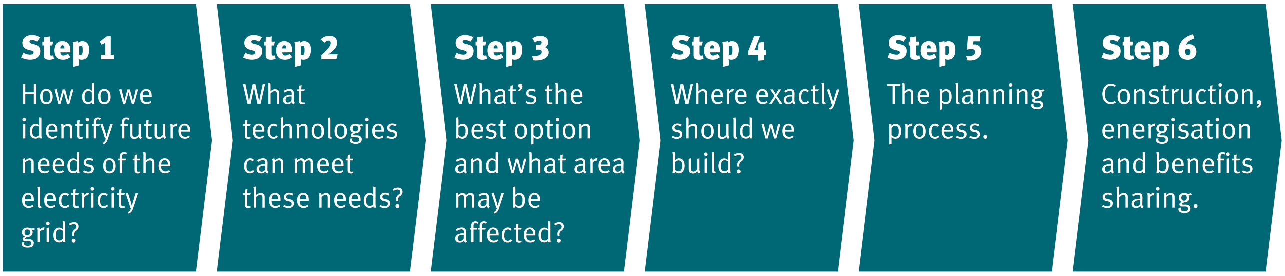


Figure 5: Grid development process

In step 1 of the process we identify future needs of the electricity transmission grid brought about by changes to:

- Electricity demand,
- Electricity generation and storage,
- Electricity interconnection, and
- Asset condition.

We use scenarios in step 1 to identify potential system needs brought about by changes to electricity demand, generation, storage and interconnection. Our scenarios are not used to identify network refurbishment needs, which instead are based on changes to the condition of electricity transmission assets.

Scenarios are used in step 1 of the grid development process to test the future performance of the grid.

Needs identified in this report are subsequently assessed in more detail before proceeding to step 2 of the grid development process.

We use our scenarios throughout the grid development process, ensuring that needs remain valid as the electricity transmission grid changes over time and more information becomes available.

8 EirGrid, Have Your Say

4. Our approach to identifying needs

Our goal is to ensure a reliable and efficient supply of electricity. By simulating future conditions, we can identify where the grid may need to be developed so that the grid remains safe, secure and reliable under a broad range of possible circumstances.

Grid conditions can alter due to, among others, changes in:

- local and system weather patterns, which impact the level of electricity generated by renewables,
- human behaviour, which impacts the shape of electricity demand,
- electricity market prices, which impacts the level of electricity imported and exported with neighbouring systems via high voltage direct current (HVDC) interconnectors.

The way electricity generation, storage, interconnection and demand change throughout the day affects the flows across the grid.

4.1. Analysing how the grid performs into the future

We simulate the future performance of the grid using our dispatch and grid simulation models. Our dispatch model determines the hourly patterns of generation, demand, storage and interconnection for each scenario (Centralised Energy, Delayed Transition, Coordinated Action) and study year (2025, 2030, 2040). Our grid model determines how these patterns impact the performance of the transmission grid.

A summary of the process used to analyse the future performance of the grid is shown in Figure 6.

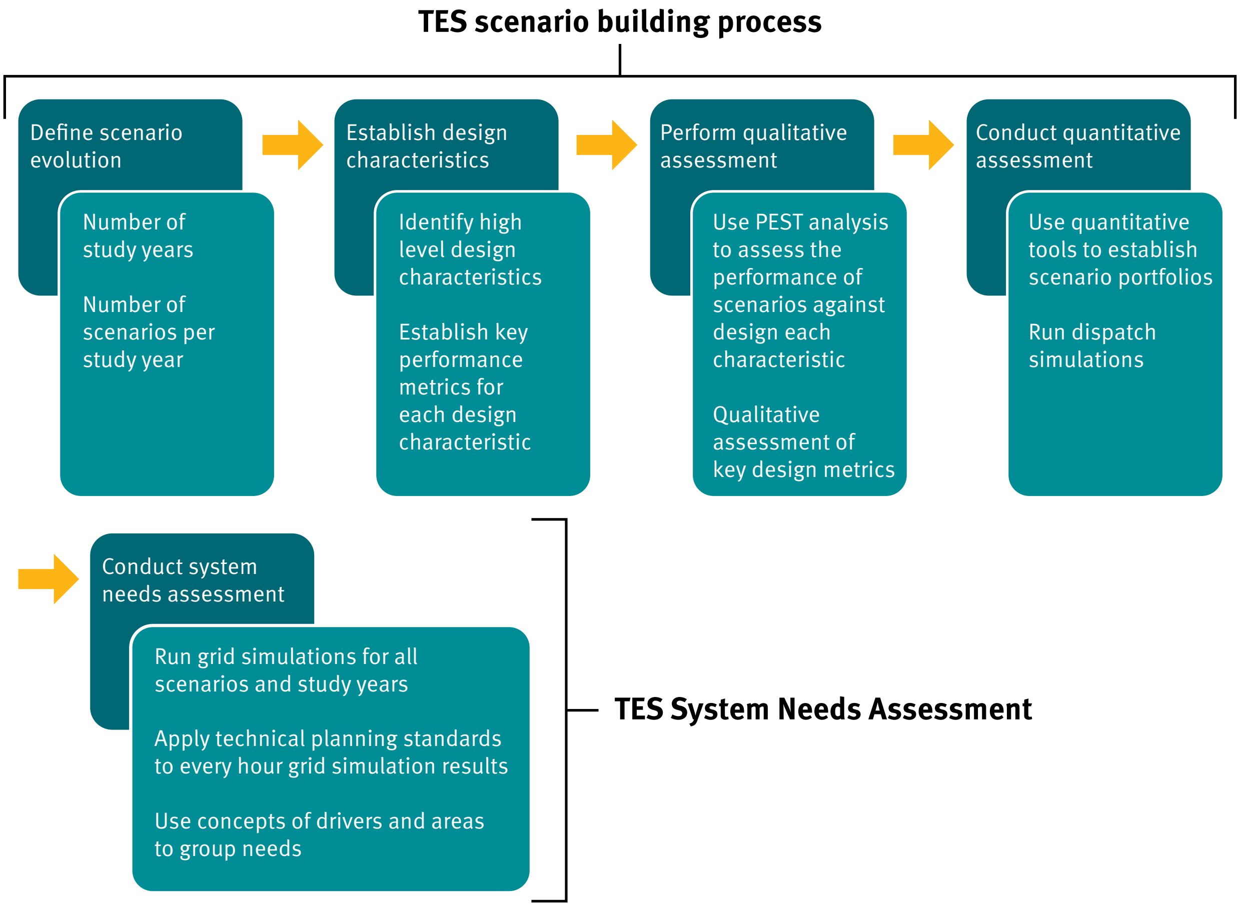


Figure 6: Overview of our approach to identifying needs.
(PEST: political, economic, social and technological)

Our technical planning standards[9] set out objective criteria, in line with international practice, to which the transmission system of Ireland is planned in order to ensure the development of a safe, secure, reliable, economical, efficient and co-ordinated electricity transmission system.

For the *TES System Needs Assessment* we assess the performance of the transmission system against intact (no fault) and N-1 (single fault) cases and monitor the impact on circuit loading, station voltage step and range.

If an element of the grid is performing outside of assessed standards, we identify it as a limit exceedance. We do this on an hourly basis for each of our scenarios and the study years of 2025, 2030 and 2040. An example of how we analyse the hourly electricity flows on each circuit and the voltage at each station in order to determine limit exceedances is shown in Figure 7. For illustrative purposes we've selected 2025 Delayed Transition and show the simulated hourly loading and voltage on a 110 kV line and station for the full year. Thermal loading limits vary across the year reflecting changes to ambient temperatures.

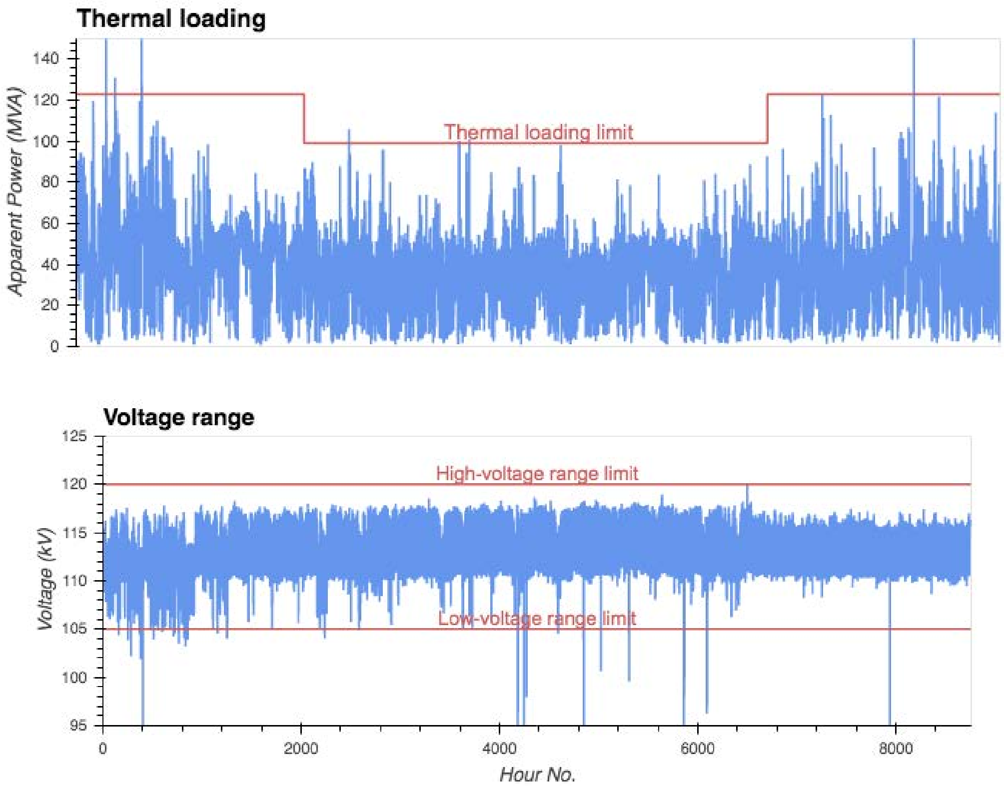


Figure 7: Illustrative example of simulated intact (a) circuit thermal loading and (b) station voltage range for each hour of the year, Delayed Transition 2025

Other development needs related to criteria in our technical planning standards not considered in this planning screening study. Needs driven by information not captured in this TES cycle may also arise. Such cases are dealt with as they arise, through our grid development process.

The grid assumptions are kept constant across scenarios. We assume today's grid and those projects that are in step 4 or later of our grid development process. More information on these grid projects assumed in our grid simulations can be found in Appendix A.

By analysing the simulation results of our dispatch model and grid model, we can pinpoint which factors influence the limit exceedances. We call these factors drivers.

9 EirGrid, Transmission System Security and Planning Standards

By grouping the limit exceedances by their driver(s) and their location on the grid, we can identify the needs of the system into coherent areas. Grouping in this way creates an area of need. By tracking each area and their drivers, we can determine how the grid performance may change across each scenario over time.

A need is a deficiency on the grid which arises as a result of one or more drivers

When determining the areas, we analyse all scenarios and study years, i.e. the presented areas show the geographic extent of limit exceedances for all scenarios and study years. Establishing areas can facilitate more local and detailed studies at later stages in the grid development process.

An example of the area concept is shown in black in Figure 8. The limit exceedances shown in this illustrative area are in relation to line loading (in blue) and to station voltage (in orange). Typically, an area can present a mixture of these forms of limit exceedances.

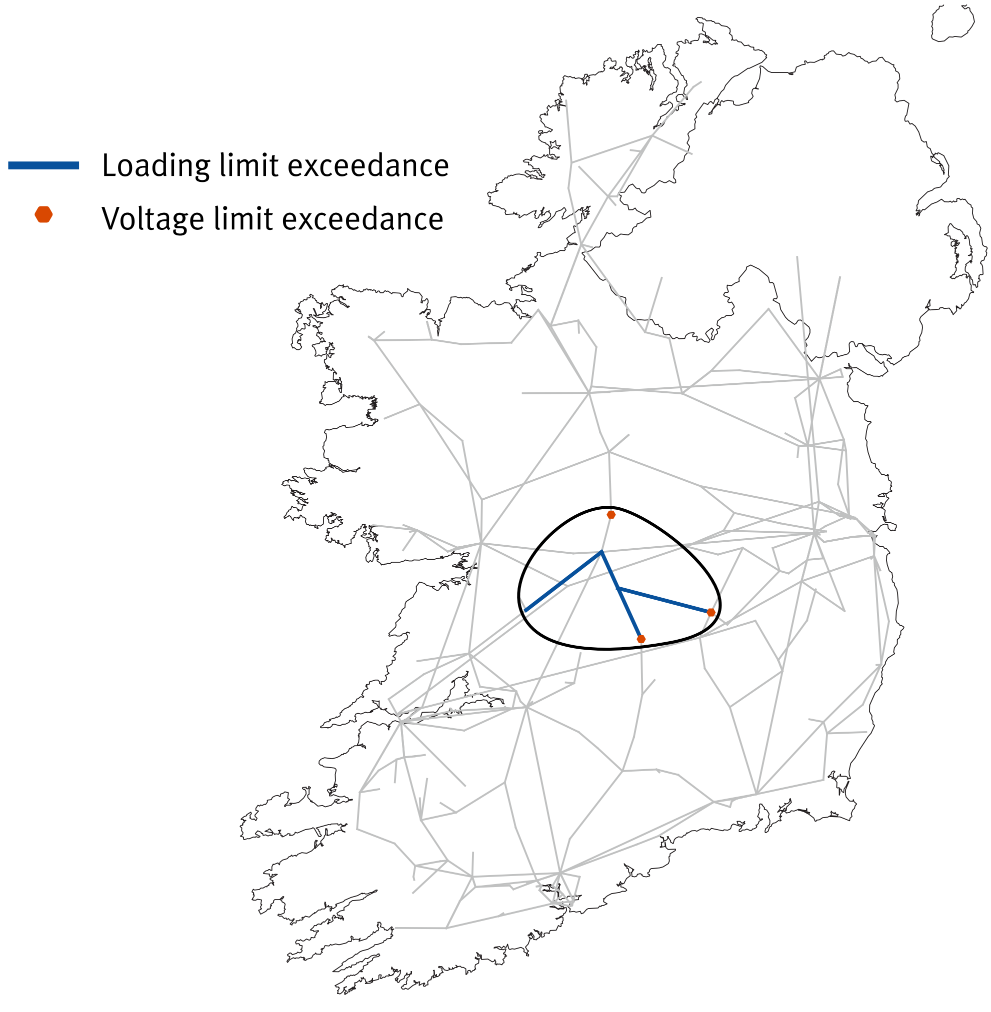


Figure 8: Needs area concept

The extent to which the grid within an area performs outside of the technical planning standards can change for different scenarios and study years. Performance against the technical planning standard is captured for each area using a need score. A need score is categorised as moderate, high or very high. A need score is produced for three types of needs: power-transfer capacity, low-voltage support and high-voltage support.

Power-transfer capacity needs arise when the amount of electricity that has to be carried by local lines or cables is too high for their rated capacity. Single faults that can result in power-transfer needs include the loss of a line or a cable.

Voltage-support needs arise when there is not enough capability in the region to control voltage and reliably supply electricity demand. Voltage-support needs can be further categorised into two directions: high and low.

- **Low-voltage support** needs arise when there are insufficient sources of upward voltage control, and typically occur during periods of high electricity demand. Single faults that can result in low-voltage support needs are the loss of electricity supply or the loss of upward-voltage control technologies.
- **High-voltage support** needs arise when there are insufficient sources of downward voltage control, and typically occur during periods of low demand, particularly in areas with a high number of cables. Single faults that can result in low-voltage support needs are the loss of electricity demand or the loss of downward-voltage control technologies.

Need scores for each area are depicted using charts, an illustrative example of which is shown in Figure 9. The three axes represent the needs score associated with power-transfer capacity, low-voltage support and high-voltage support. The greater the grid development need in an area, for a given scenario and year, the greater score on the relevant axis.

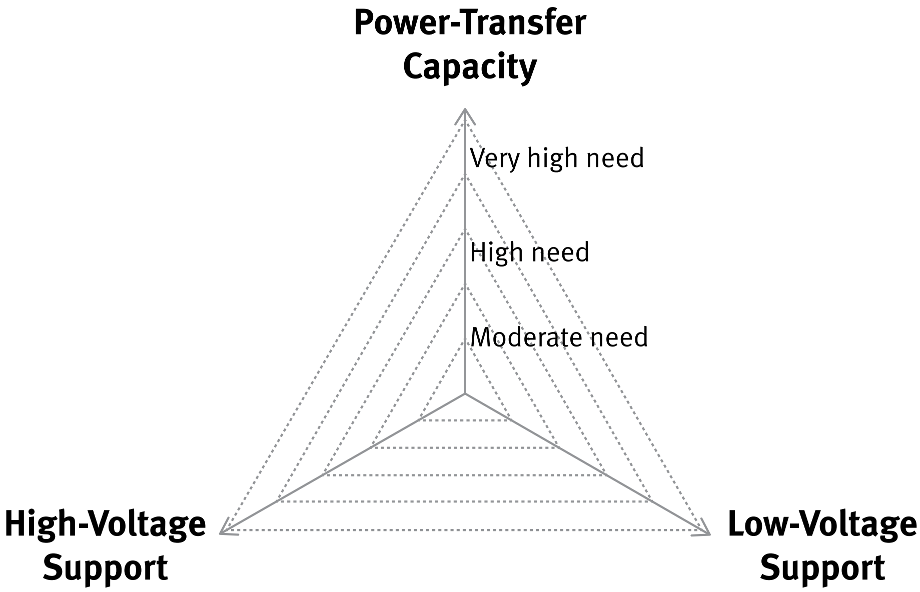


Figure 9: Need scores example. Each needs score chart is produced for a given area under a given scenario

Solutions to power-transfer capacity needs include (but are not limited to) new overhead lines or underground cables, uprating existing lines, or installing power controlling devices. Incentives for congestion management could also alleviate a power-transfer need. Note that the scale of the need indicates which of these solutions are appropriate for a given case. The greater the need the greater the likelihood that a new line or cable is required.

Solutions to voltage support needs include (but are not limited to) network devices such as capacitors for low-voltage; reactors for high-voltage, static synchronous compensators (STATCOMs), synchronous condensers, static var compensators (SVCs) for both high and low-voltage support needs.

Other sources of voltage-support capability of new generation, storage and interconnection on the supply-side. This can be a result of grid code specifications or System Service incentives. For example, retrofitting existing or mothballed units or the installation of new generation, storage or interconnection could improve the voltage support capability in an area. The extent of the improvement depends on a number of factors, including, among others, the size of the technology and the connection type, e.g. ac or dc, line or cable.

The greater the voltage support need the greater the likelihood that a dedicated network device is required.

There can also be interdependency between needs, for example instances large power transfer can worsen the voltage performance in an area. Thus a solution to remove a power-transfer need, such as a new new circuit, can improve voltage performance.

4.2. Types of drivers

Drivers are a key part of understanding needs, as they identify what is influencing a need. Our analysis identifies a number of driver types. The predominant influencing factors identified in this analysis are due to changes in:

Electricity demand: Demand growth and the connection of new demand customer can give rise to higher electricity flows. The changes in demand identified as having the greatest influence on needs are:

- Large energy users, such as new data centres. Large energy users can give rise to a step change in electricity flow at specific grid locations.

Electricity generation: New connections or closures of generators can have a significant impact on electricity flows. The changes in generation mix identified as having the greatest influence on needs are the addition of:

- Variable renewables, such as onshore wind, offshore wind, and solar PV generation. Renewable generation can often be located in remote areas, meaning that the electricity they produce may need to be transported over a large distance to places of electricity demand.
- Conventional generation or storage, such as new gas turbines or battery energy storage, can give rise to a step change in electricity flow at specific grid location. The closure of conventional generating units can also create needs, due to the loss of its voltage-support capability.

Interconnection: New interconnectors can result in large electricity flows into and out of particular grid locations. Such connectivity with other countries can result in a step change in electricity flow at specific grid locations.

As the scale of a given technology increases across scenarios and study years, it can become a driver of needs. Each scenario, due to the portfolio and location mix assumed, has a distinct impact on the usage of the grid. The key drivers of needs, for each scenario, are shown in Figure 10. (See *TES 2019* for full details on the portfolio and location assumptions.)

Note that changes to the assumed locations of future grid connections may result in needs that have not been captured in this assessment.

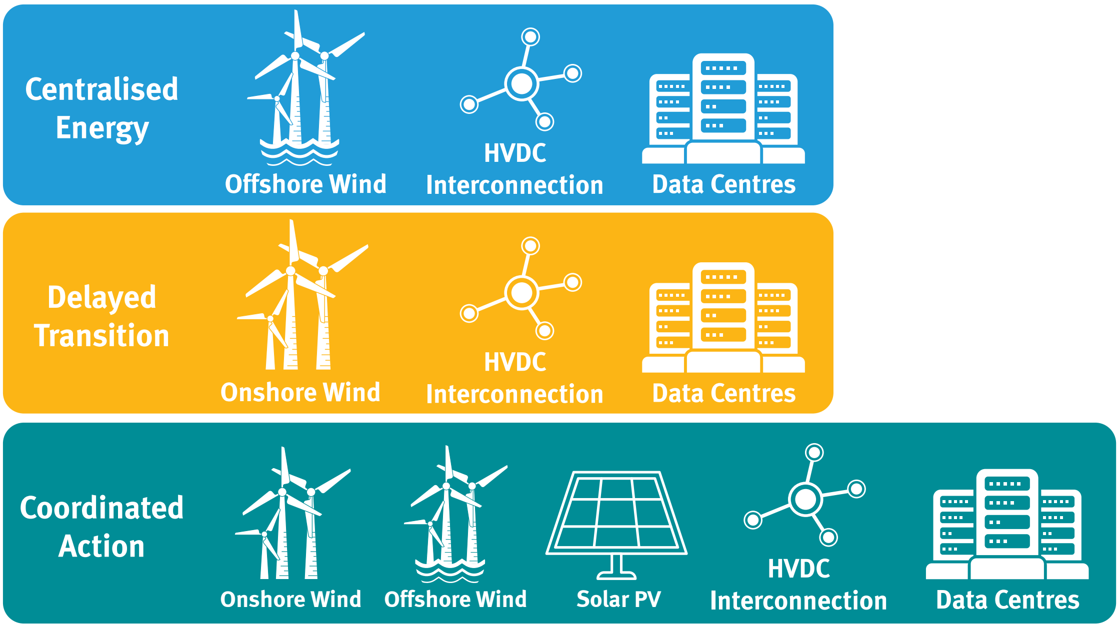


Figure 10: Key drivers by scenario, 2025–2030

4.3. Ireland's regions

EirGrid uses regions to help communicate the development of the transmission system in Ireland. The eight regions are shown in Figure 11. These regions are referred to in this report when describing the geographic location of areas and drivers of needs.

Figure 11: Ireland's regions as per the Nomenclature of Territorial Units for Statistics (NUTS) 3 classification[10]. The three Assembly regions, Northern and Western; Eastern and Midlands; and Southern, are groupings of these NUTS 3 regions

10 Ordnance Survey Ireland, NUTS 3

5. System needs

We have identified six areas of need. Each area is treated individually, and is accompanied with a description of the types of drivers, the types of needs, and the change in need scores over time and across scenarios.

These grid development needs should be understood in the context of the dispatches used to initialise the grid simulations. During the day-to-day operation of the electricity transmission system, it is ensured that circuit loadings and station voltages are within operating limits for intact and credible fault conditions. In order to ensure that this operational-security objective is met, operational constraints – also referred to as transmission constraint groups (TCGs) – from the *Operational Constraints Update*[11] are employed.

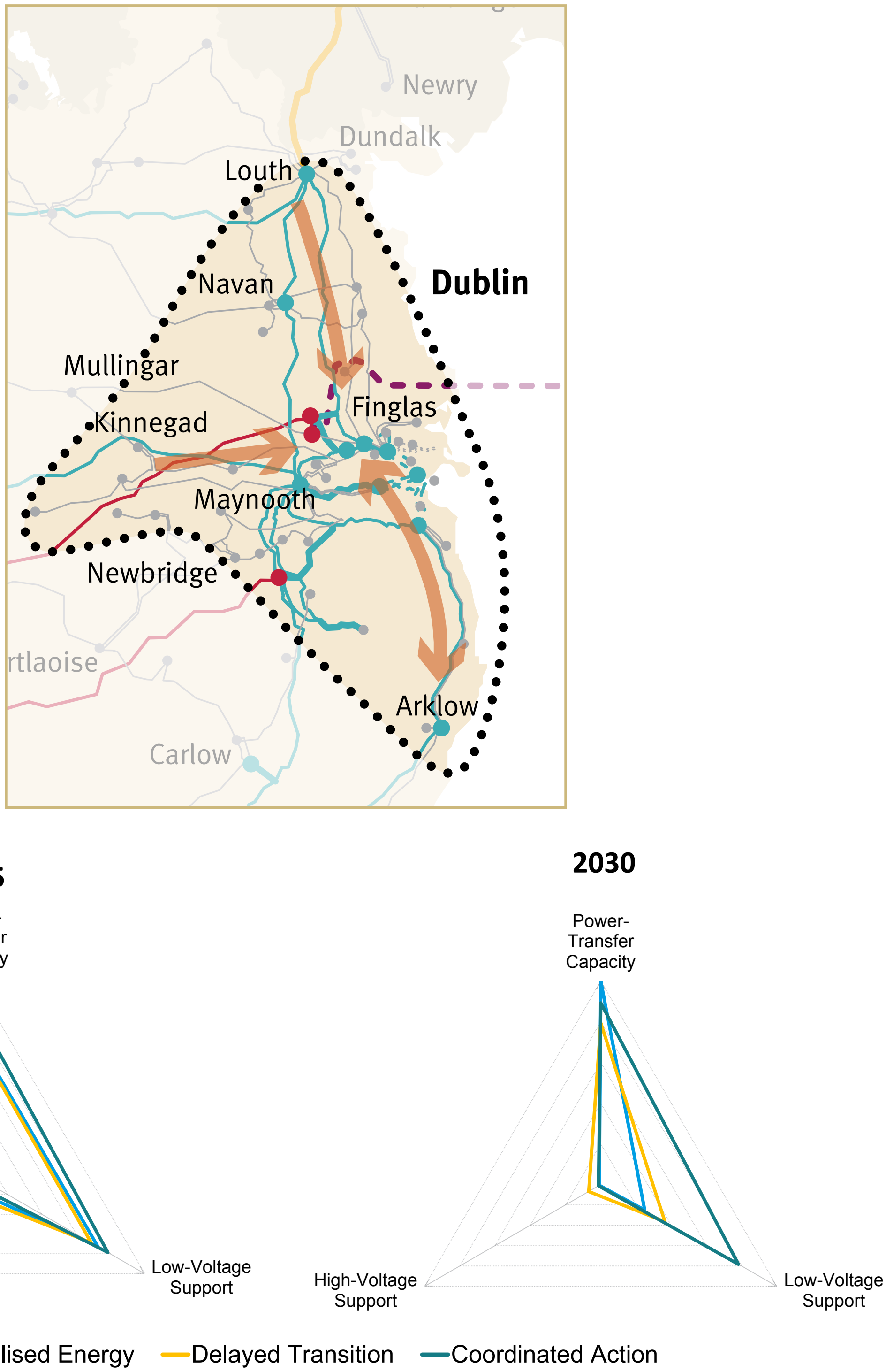
A relaxed set of TCGs are used in the TES dispatch simulations in order to facilitate *Climate Action Plan 2019*[12] targets of 70% RES-E and 4.5 megatonnes of carbon dioxide emission from the electricity system by 2030. (See *TES 2019* for full details on the dispatch assumptions.) Employing this planning method allows us to:

- identify the needs that arise from future changes to the portfolio (e.g. increase in variable renewables and electricity demand) and changes to operational rules, which are required to facilitate climate objectives;
- develop solutions to remove these needs and maintain the reliability of electricity supply.

A summary of the projects used in our grid simulations can be found in Table A-1 (Appendix A).

11 EirGrid and SONI, Operational Constraints Update
12 DCCAE, Climate Action Plan 2019 to Tackle Climate Breakdown

5.1. Area 1 – Dublin Mid-East



Driver(s)	Large energy user demand growth, renewable energy source integration

Figure 12: Geographic extent, and need scores and driver(s) for Area 1

Area introduction
Area 1 is located in the Dublin, Mid-East and Midlands regions. The area comprises mainly of 220 kV grid, much of which is underground cable. Two 400 kV lines provide the area with high capacity connections to the rest of the grid. The role of this grid is to ensure flexible power transfer into, around and through the area for varying system conditions. It is characterised by having conventional generation and a high level of electricity demand.

Noteworthy faults
Line or cable faults result in power-transfer capacity and voltage support needs in this area, particularly when coinciding with low levels of local generation. Faults of note are the following:

- the loss of 400 kV lines, which results in power-transfer and voltage support shortfalls into the area,
- the loss of 220 kV lines or cables, which results in a shortfall in power-transfer capacity and voltage support within and out of the area.

Voltage support needs also arise due to the loss of local voltage support capability. Due to increased renewable integration, there is a reduction in local conventional generation. This reduction not only causes voltage support needs but also reduces the redundancy of the voltage support in the area; the remaining online conventional generators are relied upon to a greater extent for voltage support, meaning that the loss of these generators causes significant voltage support needs. This is also the case for the loss of the voltage support capability from offshore wind generation, if installed.

Drivers of needs
The power-transfer capacity need is greatest for the following conditions:

- high levels of electricity being transferred into the area, for example:
    - onshore wind generation across the country, or
    - conventional generation and HVDC imports from the South-West and South-East regions, or
    - onshore wind generation and HVDC imports from the South-West and South-East regions, or
- high offshore wind generation, or
- high conventional generation within the area, or
- high demand from large energy users within the area.

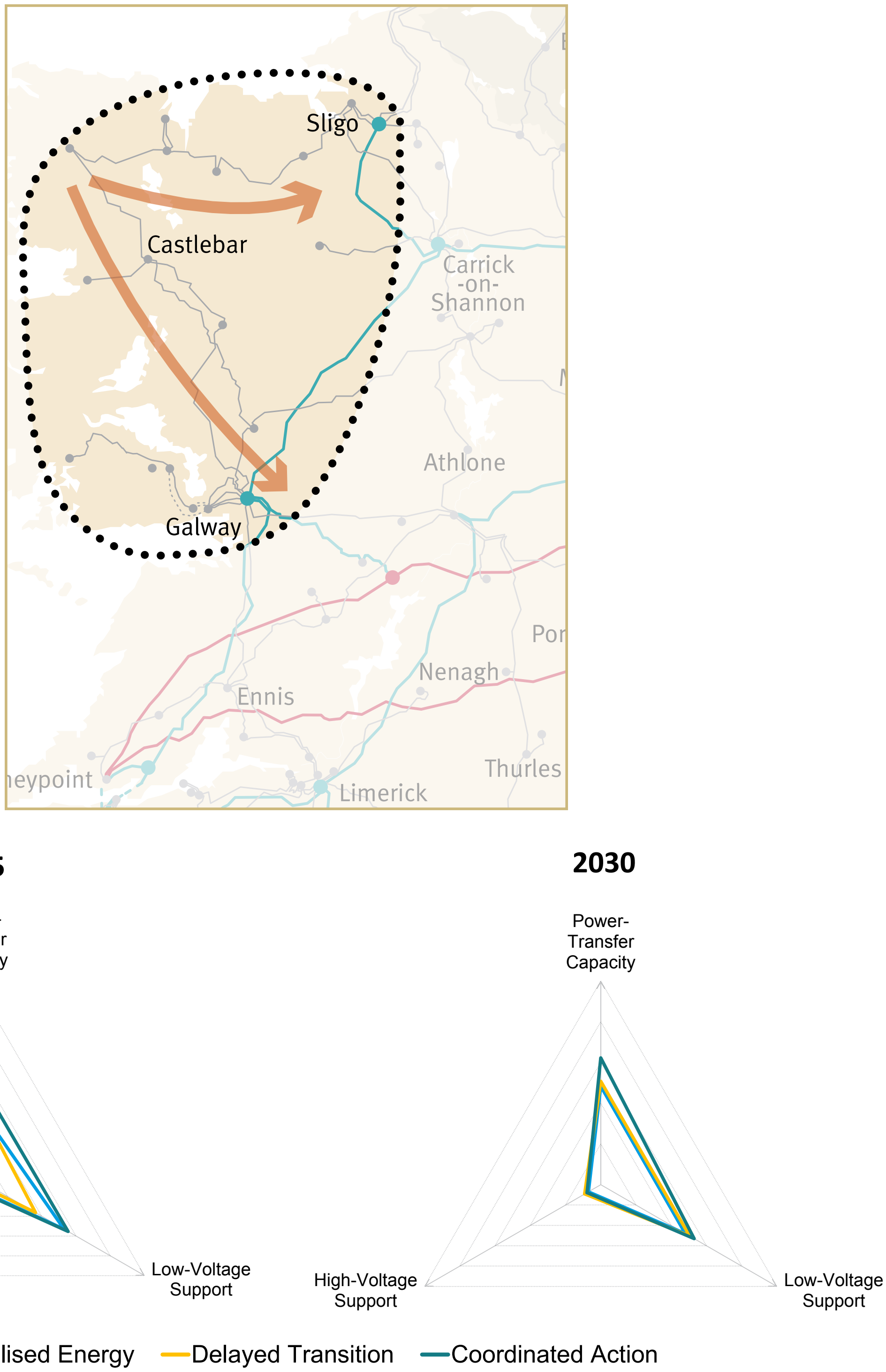
Low-voltage support needs are greatest for the following conditions:

- high demand within the area, or
- high levels of electricity being transferred into the area.

High-voltage support needs in this area occur during hours of low demand.

Needs identified
Figure 12 shows the need scores for the Dublin Mid-East area across scenarios and study years. The need for power-transfer capacity is very high in Coordinated Action by 2025 due to high demand from large energy users and high transfers of onshore wind generation into the north of the area. Offshore wind generation connections in the Irish Sea, along with moderate demand growth, drive a high need for power-transfer capacity in Centralised Energy by 2025 and a very high need by 2030 as offshore wind capacities reach 3.5 GW installed. The installation of offshore wind generation reduces the occurrence of large transfers of power into Dublin; however it creates other local power transfer needs in Dublin. High power-transfer capacity needs also exist in Delayed Transition for the same reasons as Coordinated Action, albeit lower due to a lower onshore wind installed capacity and lower demand. There is a high need for low-voltage support by 2025 due to high growth in data centres. Low-voltage needs are lower in Centralised Energy due to lower demand from data centres and due to the higher installed capacity of offshore wind generation, whose voltage support capability and proximity to the area somewhat offsets the displacement of local conventional generation and load growth. Demand growth in the area assists in resolving the need for high-voltage support, which are greater in 2025 compared to 2030. However, additional voltage support capability is still required in the area, as the conditions that cause the worst low-voltage needs in Dublin have system-wide consequences.

5.2. Area 2 – West



Driver(s)	Renewable energy source integration, conventional generation decommisioning

Figure 13: Geographic extent, need scores and driver(s) for Area 2

Area introduction
Area 2 is located in the West and Border regions. The area mainly comprises of 110 kV grid. It is characterised by a strong wind resource and a low electricity demand.

The North Connacht project, which is assumed in-service by our first study year of 2025, ensures that transfer capacity in the north of the West area is improved. However, as additional onshore wind generation connects in the area there is a need for additional power-transfer capacity. These circuits in the south of the area have a low capacity, which can be upgraded.

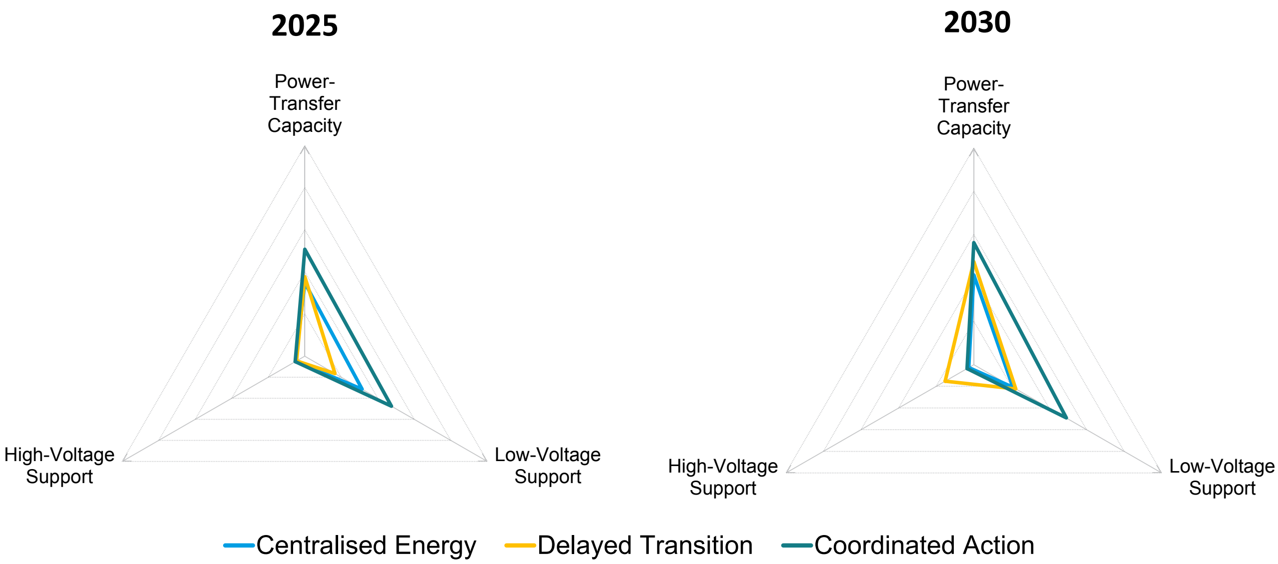
Noteworthy faults
Line faults, particularly those in the north of the area, result in a power-transfer capacity and voltage support shortfalls.

Drivers of needs
A need for power-transfer capacity arises during high onshore wind generation, which is exported to areas of higher electricity demand outside the area. These large power transfers also cause low-voltage support needs. High-voltage support needs can arise during periods when wind output is low and electricity demand is low. With a deficit of voltage support capability in the area, the loss of nearby voltage support capability due to the decommissioning of the conventional generation at Moneypoint and the Midlands exacerbates the need for voltage support.

Needs identified
Figure 13 shows the need scores for the West area across scenarios and study years.

The need scores indicate that, by 2025, there is a high need for power-transfer capacity in Coordinated Action and Delayed Transition and a moderate need in Centralised Energy, due to their respective installed capacities of onshore wind in the area. The need continues to rise in 2030. Voltage support needs are highest in Coordinated Action, arising from the highest levels of power transfer from the area.

5.3. Area 3 – North-West Border



Driver(s)	Renewable energy source integration, conventional generation decommisioning

Figure 14: Geographic extent, need scores and driver(s) for Area 3

Area introduction
Area 3 is located in the Border region. The area is relatively isolated from the 220 kV network. It comprises of 110 kV grid, many of which are long lines, and is characterised by a strong wind resource and a low electricity demand.

Many of the circuits in and out of the Cathaleen's Fall hydro station near Ballyshannon, which is the confluence point to the remainder of the network, are already uprated.

Noteworthy faults
Line faults, particularly to the south and the north of the area, result in a power-transfer capacity shortfall to the rest of the grid.

Drivers of needs
A need for power-transfer capacity arises during high wind output, which causes high levels of power flow out of the area to meet demand elsewhere.

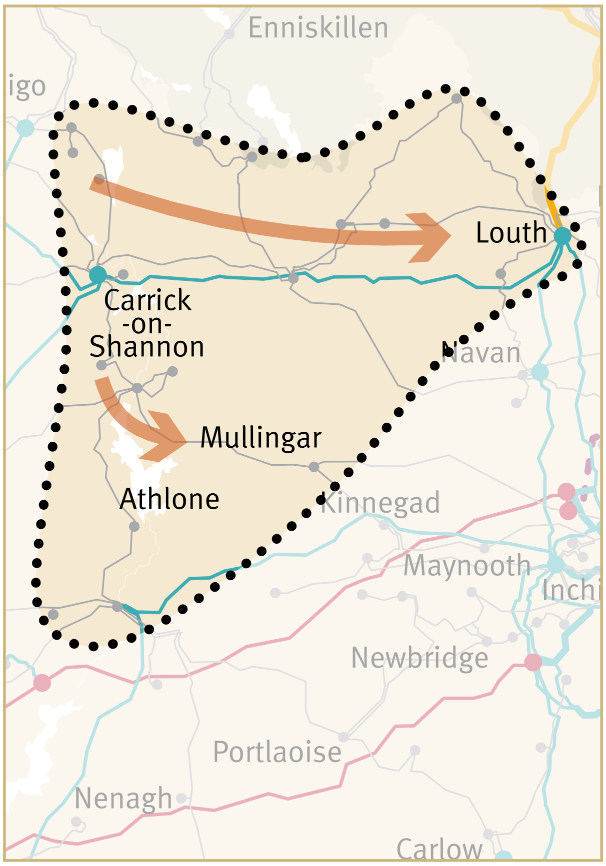
These large power transfers, as well as the isolated nature of the area's grid, also cause low-voltage support needs. With a deficit of voltage support capability in the area, the loss of nearby voltage support capability due to the decommissioning of the conventional generators in the Midlands exacerbates the need for voltage support.

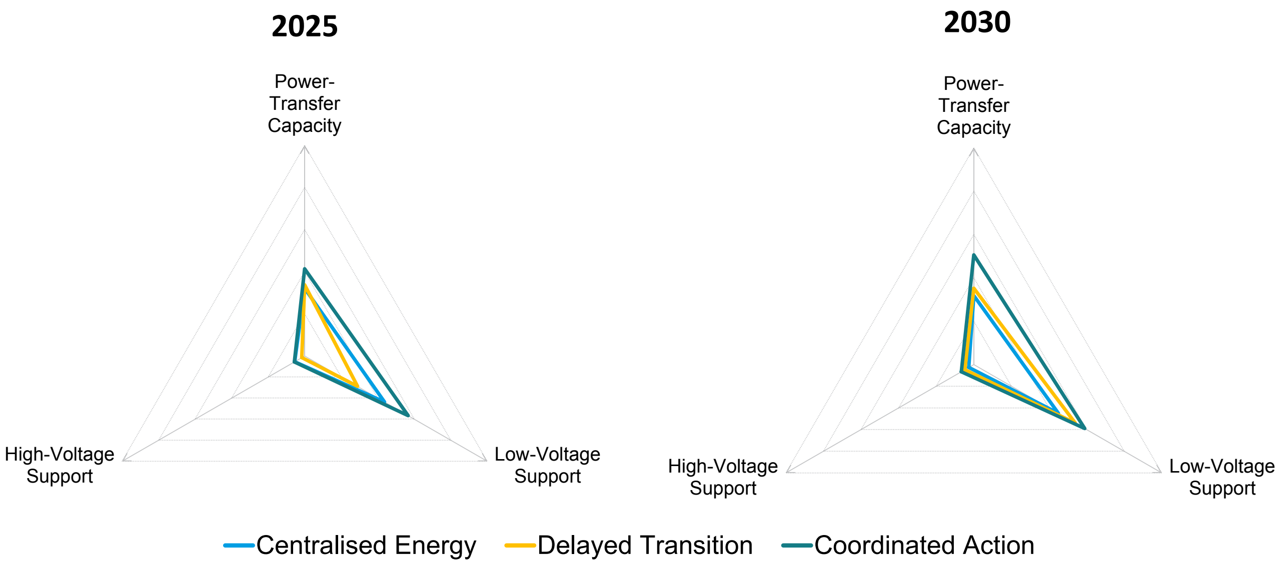
The ability to mitigate high-voltage support needs during periods of low wind output and low electricity demand is dependent on the availability of local hydro generation.

Needs identified
Figure 14 shows the need scores for the North-West Border area across scenarios and study years. The need scores indicate that from 2025 onwards there is a high need for power-transfer capacity in Coordinated Action and a moderate need in Delayed Transition and Centralised Energy, due to their respective installed capacities of onshore wind in the area.

Voltage support needs are highest in Coordinated Action, arising from the highest levels of power transfer from the area.

5.4. Area 4 – Midlands





Driver(s)	Renewable energy source integration, conventional generation decommisioning

Figure 15: Geographic extent, need scores and driver(s) for Area 4

Area introduction
Area 4 is located in the Midlands, Border, Mid-East and West regions. The area includes 110 kV and 220 kV grid and acts as a corridor for high levels of West-to-East power-transfer. Some of the 110 kV circuits in this area are already uprated, meaning that there is limited scope for improving the power-transfer capacity of existing circuits in the area.

Noteworthy faults
Line faults, particularly the 220 kV lines within the area, result in a power-transfer capacity shortfall to the rest of the grid.

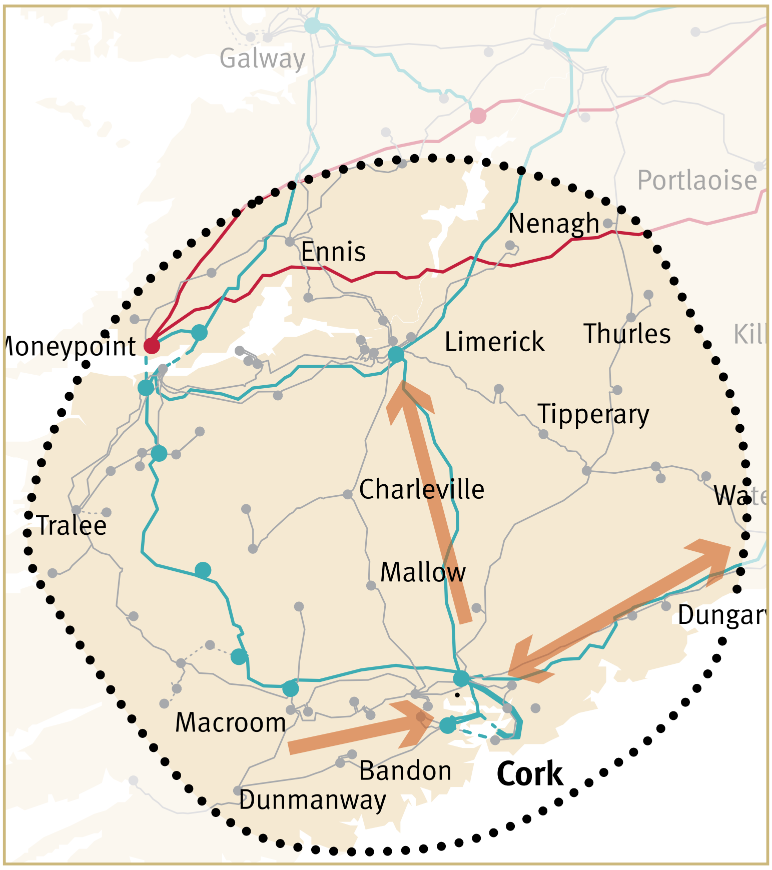
Drivers of needs
The need for power-transfer capacity arises during high onshore wind generation outputs to the north and west of the area. These power transfers also create a need for voltage support in the area.

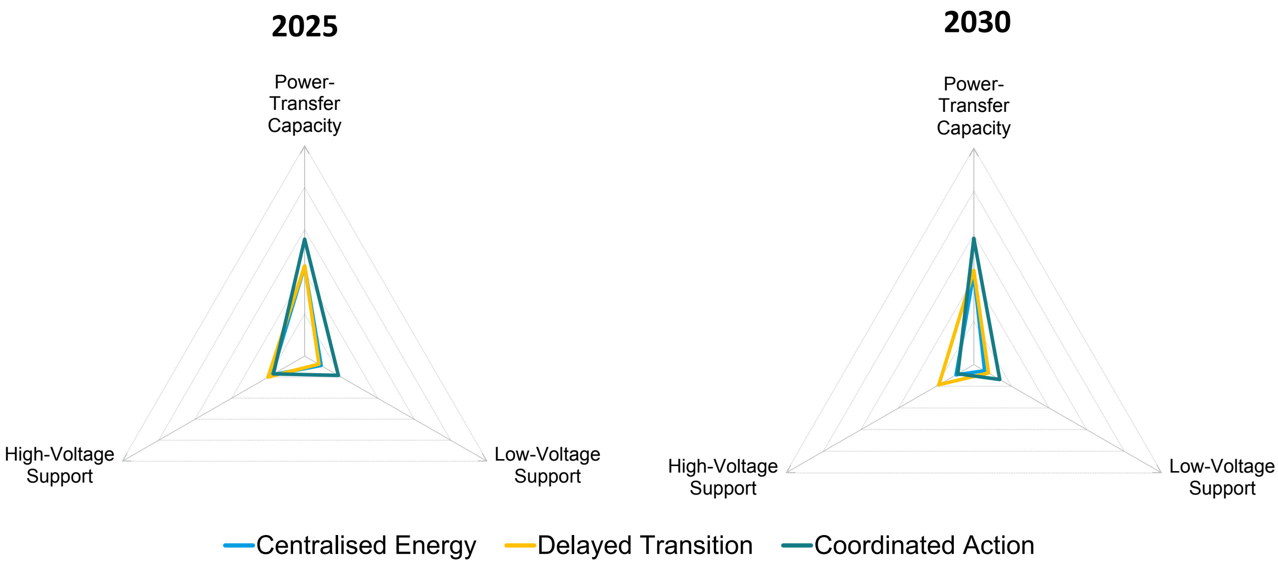
Due to the decommissioning of conventional generators in the area, there is a significant reduction in voltage support capability.

Needs identified
Figure 15 shows the need scores for the Midlands area across scenarios and study years. By 2025 there is a high need for power-transfer capacity in Coordinated Action due to its high level of onshore wind connections within the area and to the west and north of the area. Centralised Energy and Delayed Transition exhibit a moderate need for power-transfer capacity.

The closure of the peat-fired generating units causes a need for voltage support in all scenarios, which is exacerbated by the transfer of power through the area.

5.5. Area 5 – South-West





Driver(s) | Renewable energy source integration, new HVDC interconnection

Figure 16: Geographic extent, need scores and driver(s) for Area 5

Area introduction
Area 5 is located in the South-West, Mid-West and South-East regions. It includes 110 kV and 220 kV grid and is characterised by high levels of power transfer through the area, conventional generation within the area and high levels of electricity demand within the area. The Celtic interconnector is expected to connect into this area.

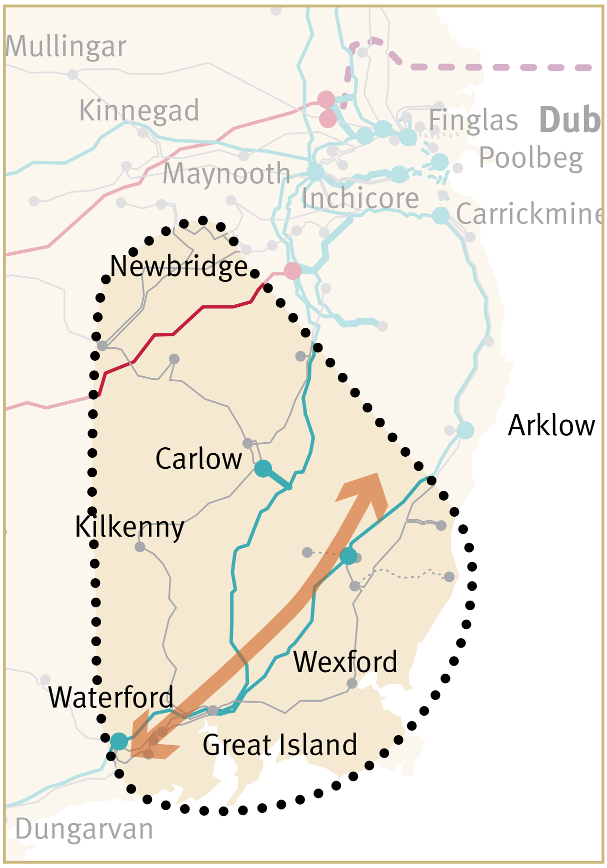
Noteworthy faults
Line faults, particularly 220 kV lines within the area, result in a power-transfer capacity shortfall to the rest of the grid.

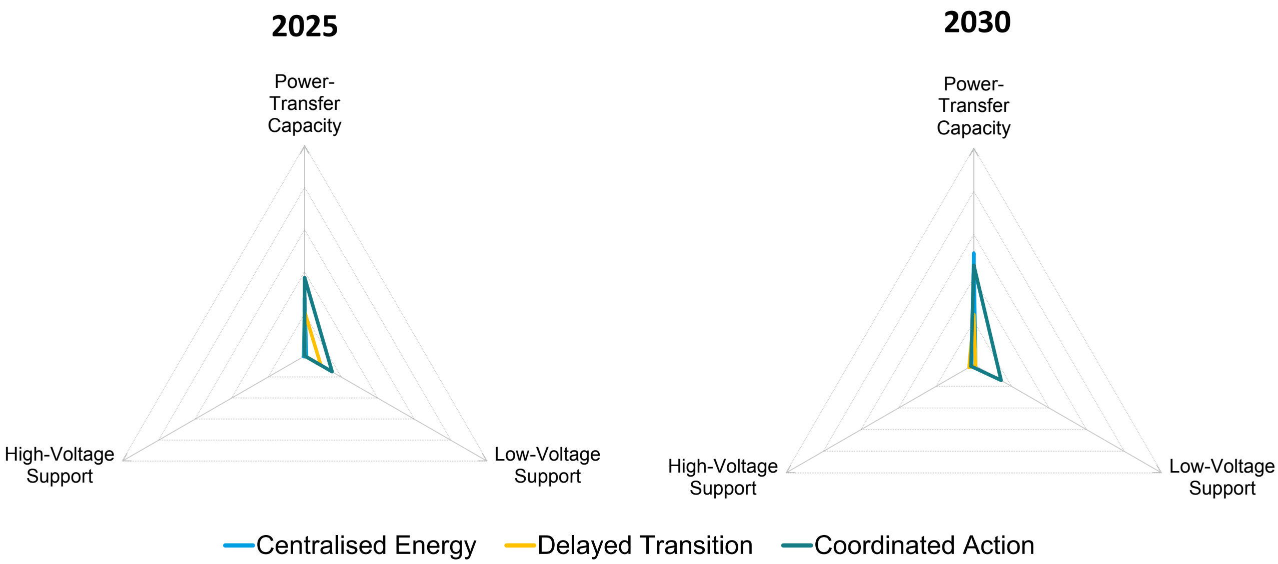
Drivers of needs
This need is greatest for the following conditions:

- high onshore wind generation in the area and HVDC interconnection export, or
- high conventional and onshore wind generation within the area, or
- high conventional generation within the area and HVDC interconnection import.

Needs identified
Figure 16 shows the need scores for the South-West area across scenarios and study years. The need is most influenced by increases in onshore wind capacity connecting to the west of the area, as can be seen in Coordinated Action and Delayed Transition, which have a high need for power-transfer capacity by 2030. Centralised Energy exhibits a moderate power-transfer capacity need.

5.6. Area 6 – South-East





Driver(s)	Renewable energy source integration, new HVDC interconnection

Figure 17: Geographic extent, and need scores for Area 6

Area introduction
Area 6 is located in the South-East and Mid-East regions. The area comprises of 110 kV and 220 kV grid. It is characterised by a high level of electricity transfer through the area to the urban centres in Dublin and Cork. The Greenlink interconnector is expected to connect into this area.

Noteworthy faults
Line faults, particularly 220 kV lines inside the area, result in a power-transfer capacity shortfall to the rest of the grid.

Drivers of needs
This need is greatest for the following conditions:

- high offshore wind generation in the Irish Sea and HVDC interconnection export, or
- high conventional generation in the South-West and South-East regions and HVDC interconnection import, or
- high conventional and onshore wind generation in the South-West and South-East regions.

The needs can be further increased by solar PV generation in the area.

Needs identified
Figure 17 shows the need scores for the South-East area across scenarios and study years, which possesses a moderate need for power-transfer capacity.

In 2025, the power-transfer need in Centralised Energy is reduced in comparison to Delayed Transition as the connection of the Greenlink interconnector aids in exporting onshore wind generation in the South-West to neighbouring systems, rather than flowing up the South-East corridor to Dublin. This is also the case for the Celtic interconnector in 2030. However, by 2030 the addition of onshore renewable generation in Coordinated Action, as well offshore wind generation in Centralised Energy increases the power-transfer needs along the South-East.

5.7. Scenario need scores summary for 2030

Figure 18 presents the area need scores for all scenarios in 2030.

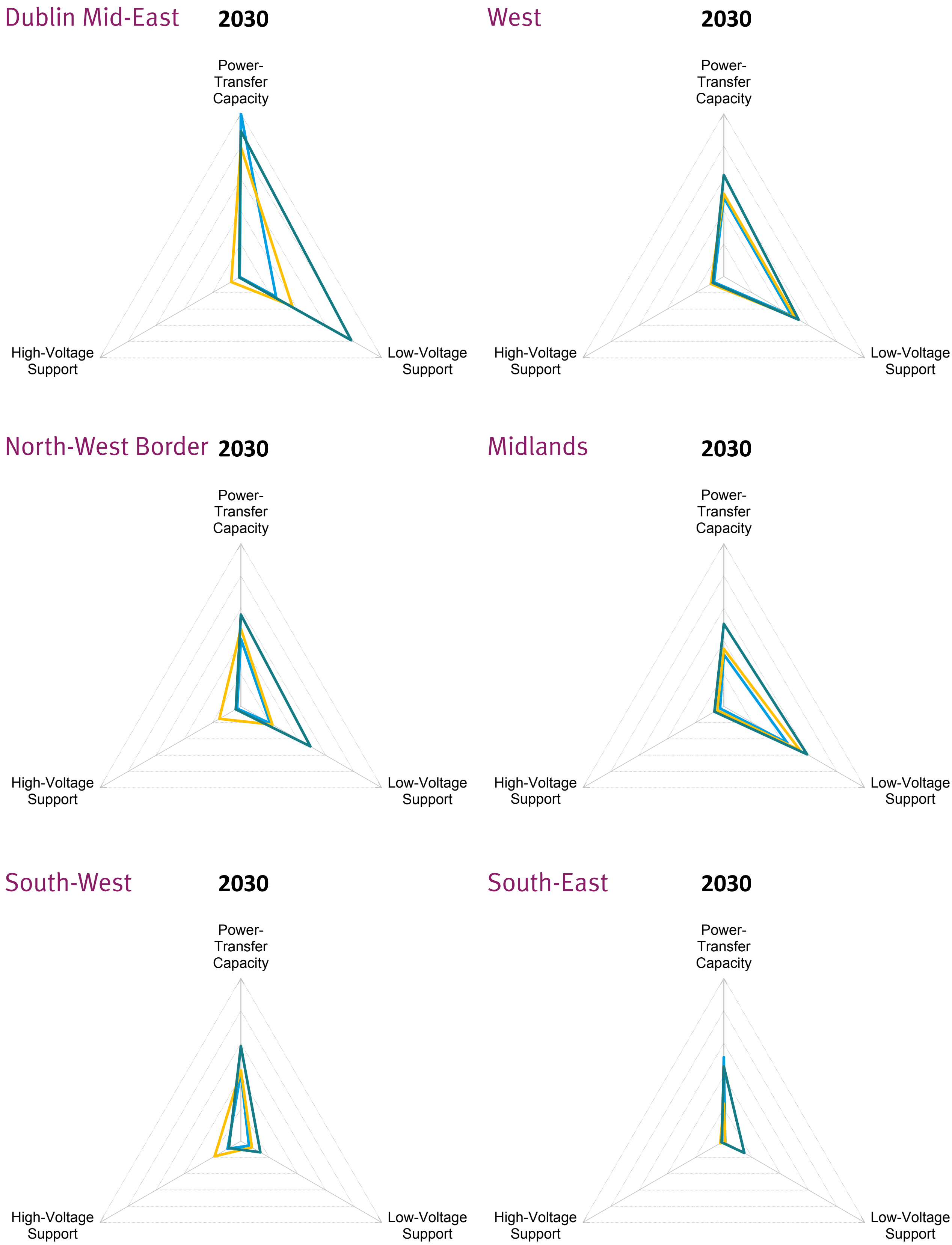


Figure 18: Needs scores per area and scenario, 2030

5.8. A note on 2040 grid simulation results

Ireland's climate targets will likely increase in ambition in the years following 2030 – take for example the European Commission's intention to enshrine 2050 climate neutrality into law[13]. The 2040 grid simulation results highlight a trend of growing power-transfer capacity needs as more variable renewables are integrated into the electricity system. Significant voltage support capability is also required across the network due to continued renewable integration and electricity demand growth. By 2040 electric vehicles, particularly in Coordinated Action, become a driver of low-voltage needs in locations of the grid other than urban centres.

The 2040 grid simulation results highlight the importance of analysing study years beyond 2030, so as to determine the longevity of any solution designed.

13 European Commission, The European Green Deal

Next steps

The *System Needs Assessment* concludes the TES 2019 cycle.

Development projects have already been initiated for some of the needs identified, as detailed in the *TDP 2018-2027*. Needs not addressed in the latest *TDP* will be investigated further and if verified these needs will appear with associated projects in future *TDP* editions.

Our biennial scenario development cycle will begin again in **spring 2021** starting with a revision of our scenarios. We will use the revised scenarios to perform the next *System Needs Assessment*.

We are committed to involving our stakeholders in how we plan the future transmission grid, as reflected in our *Have Your Say* document. We will engage with our stakeholders throughout our **TES 2021** scenario development process.

For more information on TES, or to access other TES publications, please visit our **Energy Future webpage**.

Alternatively, you can email your views on TES to: **scenarios@eirgrid.com** and one of our team will be in touch.

Appendix A –
New grid project assumptions

Projects in steps 4, 5 and 6 of the grid development process are assumed to be in place in the grid simulations. This ensures that the only future projects included are those that have a single preferred solution identified.

A summary of the main projects assumed are given in Table A-1, which presents the project name and Capital Project Identification Number (CP No.). Other projects, such as future uprates, are also included, although not listed in Table A-1 for brevity. Please refer to latest *TDP* for full details of all future projects in steps 4-6.

Project	CP No.
Ballynahulla 110 kV Statcom	CP0934
Ballyvouskil 110 kV Statcom	CP0935
Clashavoon – Dunmanway 110 kV Line	CP0501
Clashavoon – Macroom No. 2 110 kV Circuit and Increased Transformer Capacity in Clashavoon	CP0829
Cross-Shannon 400 kV Cable	CP0970
Dunstown 400 kV Series Compensation	CP0968
Knockanure 220 kV Reactor	CP0936
Laois-Kilkenny Reinforcement Project	CP0585
Moneypoint 400 kV Series Compensation	CP0967
Moneypoint – Knockanure 220 kV Project	CP0726
Mount Lucas – Thornsberry 110 kV Line	CP0197
North Connacht 110 kV Reinforcement Project	CP0816
North South 400 kV Interconnection Development	CP0466
Oldstreet 400 kV Series Compensation	CP0969
Shellybanks – Belcamp 220 kV Cable	CP0984
Thurles 110 kV Statcom	CP0933
Tievebrack/Ardnagappary 110 kV Development	CP0421

Table A-1: Summary of the main projects included in the grid simulations

Appendix B –
All island electricity transmission grid

The Ireland and Northern Ireland grid, as of September 2018, is shown in Figure B-1.

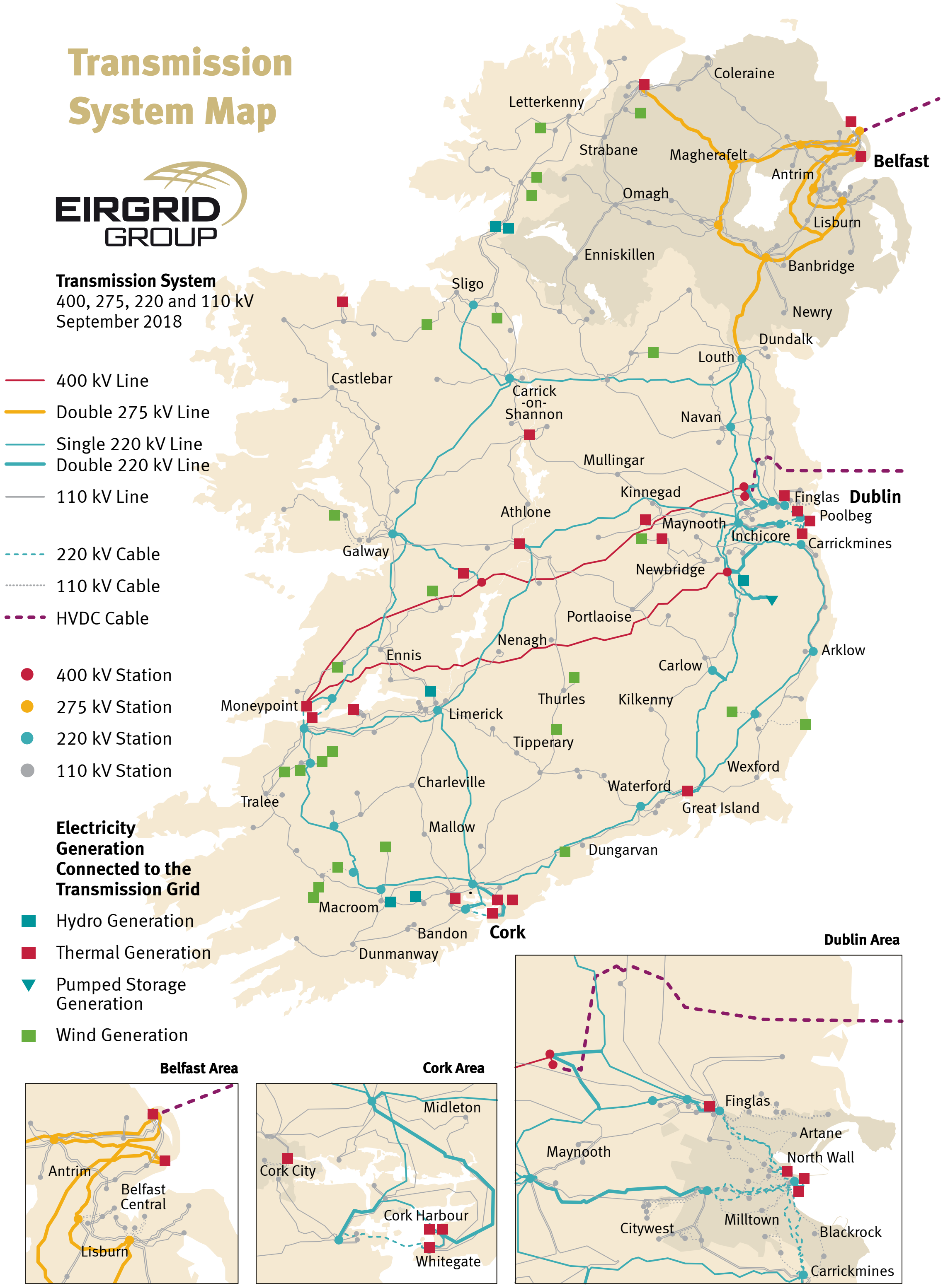


Figure B-1: Ireland and Northern Ireland electricity transmission grid, as of September 2018

Appendix C – Results data

The following figures summarise the limit exceedances that contribute to the needs presented. For each grid element in each scenario and study year, the magnitude value (worst loading/voltage/step) represents the worst-case limit exceedance recorded in the hourly simulations, and the frequency value represents the number of hours during which a limit exceedance arises. Thermal-loading limit exceedances contribute to the power-transfer-capacity need; low-voltage-range and low-voltage-step limit exceedances contribute to the low-voltage-support need; high-voltage-range and high-voltage-step limit exceedances contribute to the high-voltage-support-need. Note that frequency values are presented using a logarithmic scale.

Due to the numerical nature of power system modelling and simulation, some faults do not produce meaningful results. As a result some voltage needs are not explicitly captured in the voltage limit exceedance figures shown in this chapter. Instead the impact of such faults are reflected in the need score figures in Chapter 5.

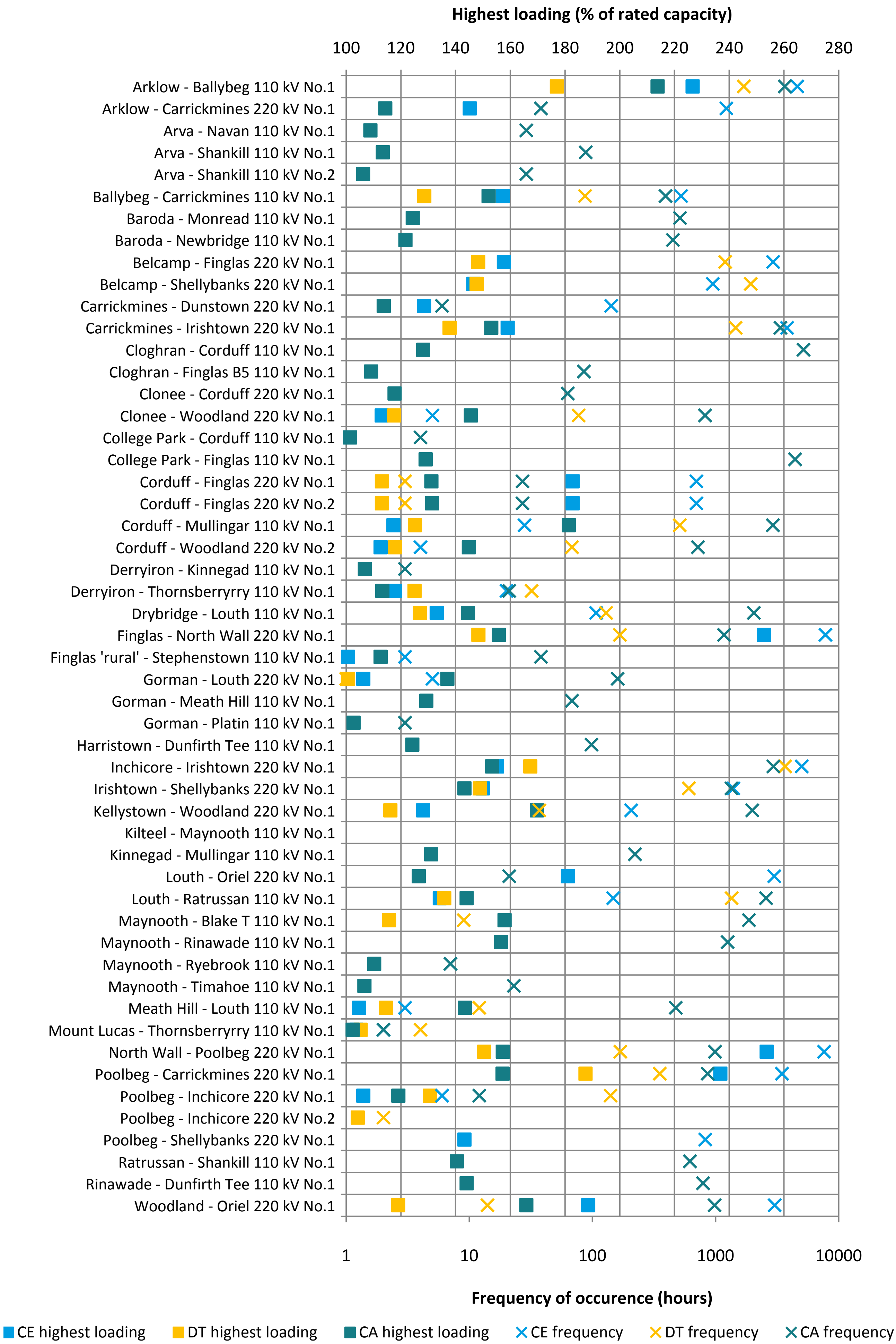


Figure C-1: N-1 thermal loading results, Area 1

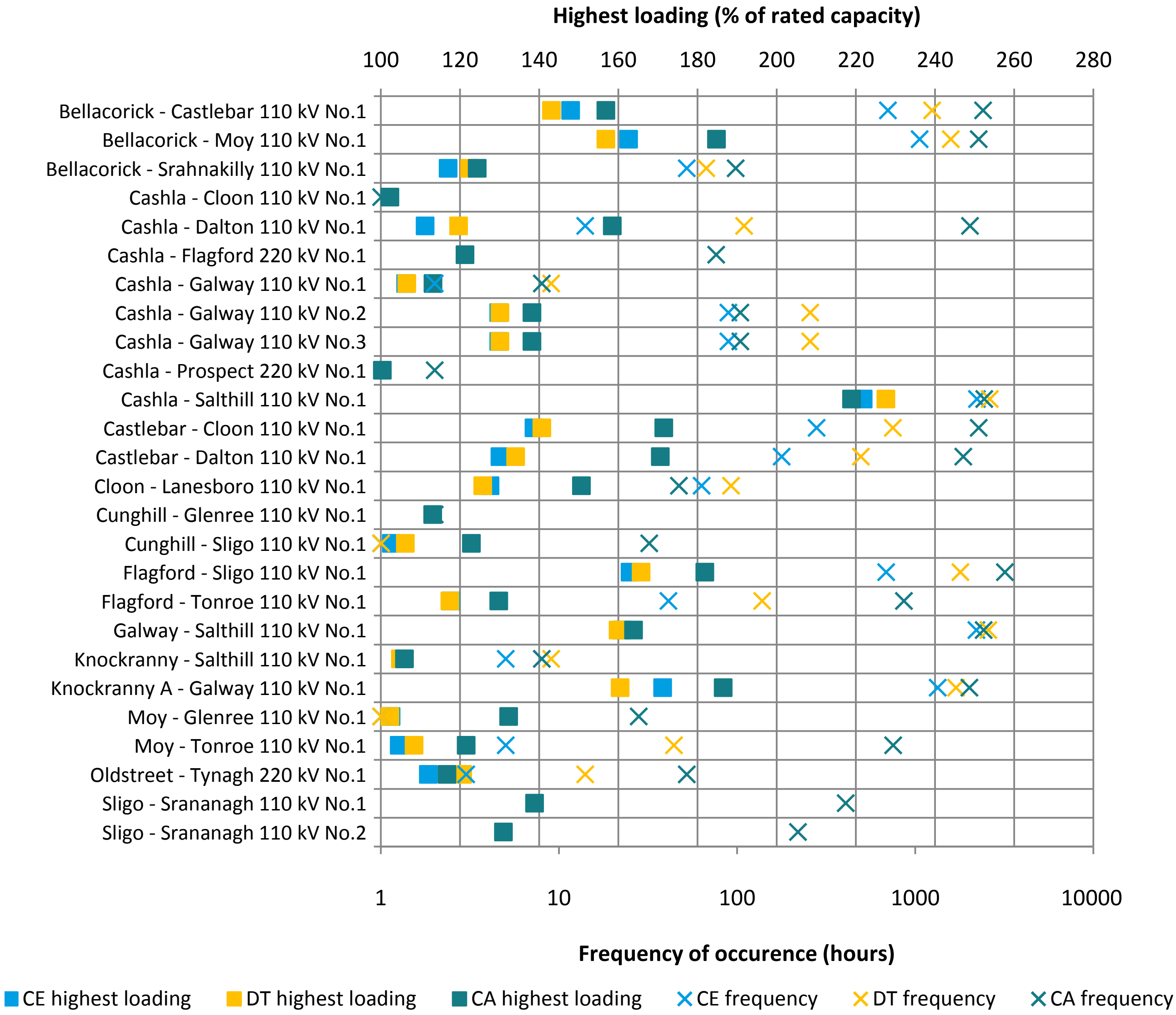


Figure C-2: N-1 thermal loading results, Area 2

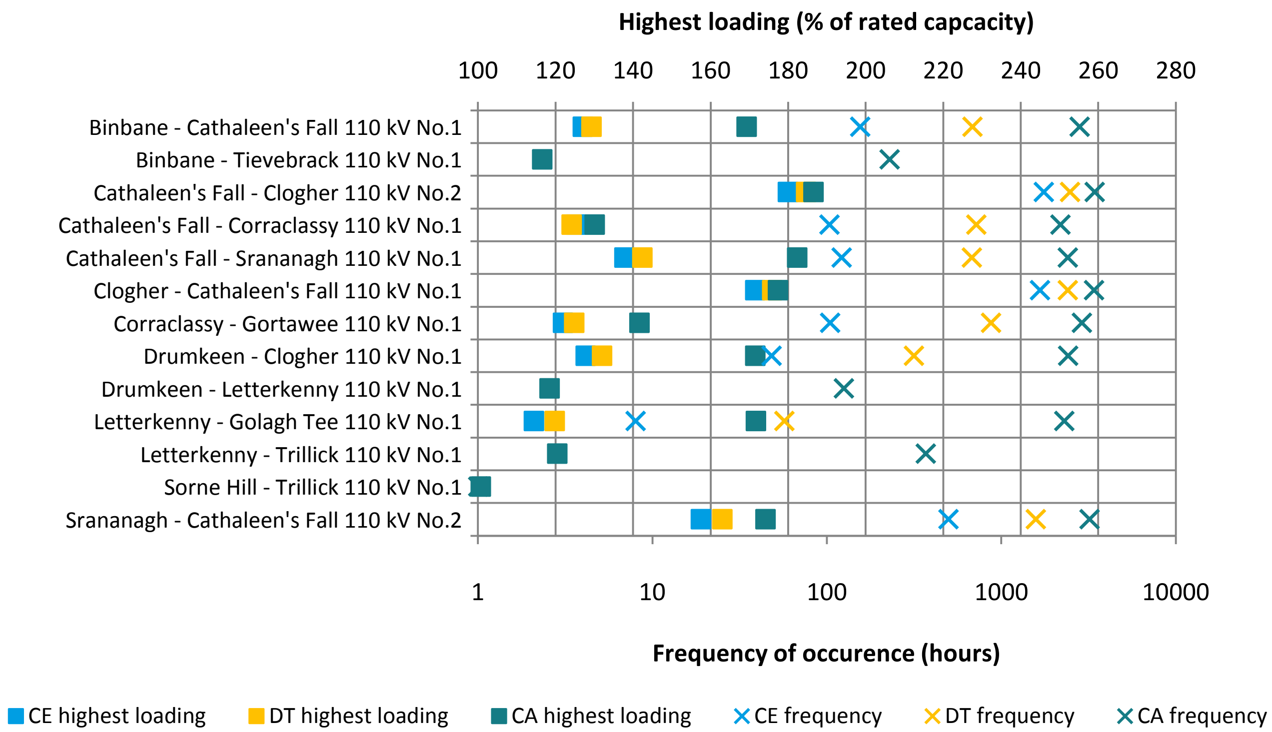


Figure C-3: N-1 thermal loading results, Area 3

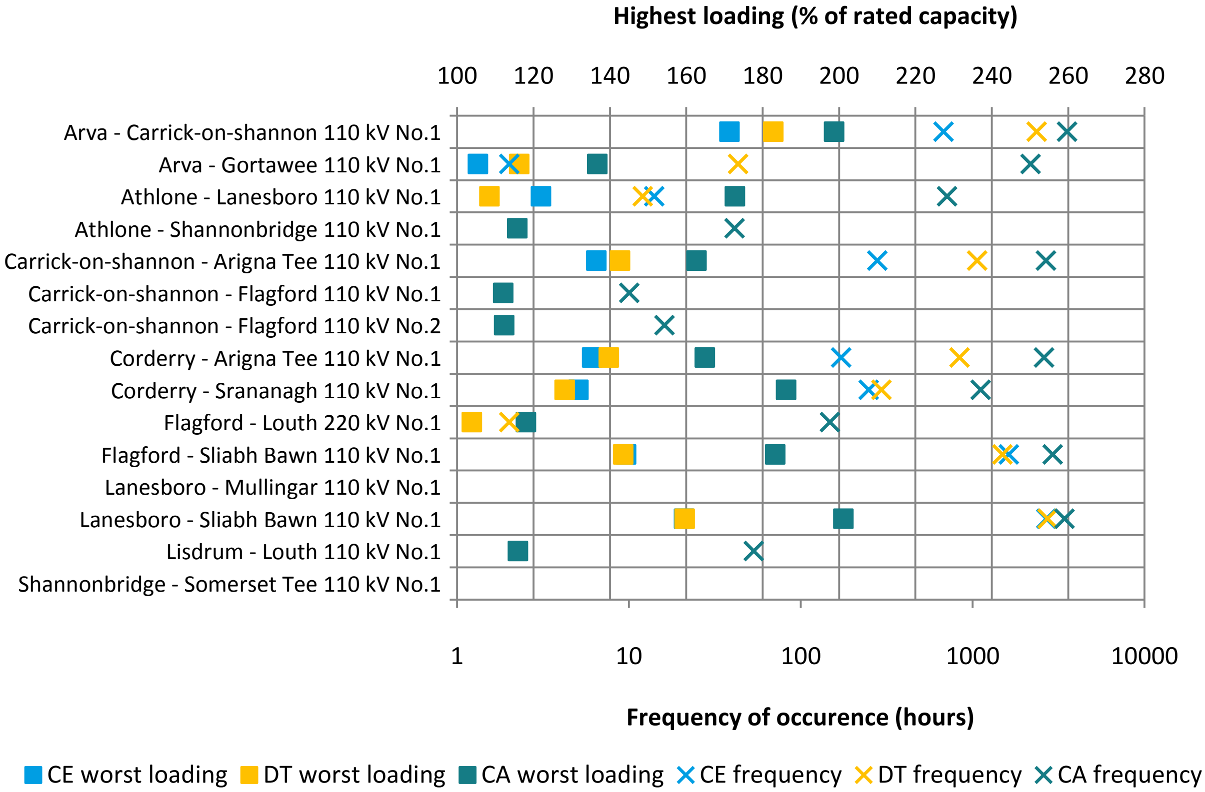


Figure C-4: N-1 thermal loading results, Area 4

Figure C-5: N-1 thermal loading results, Area 5

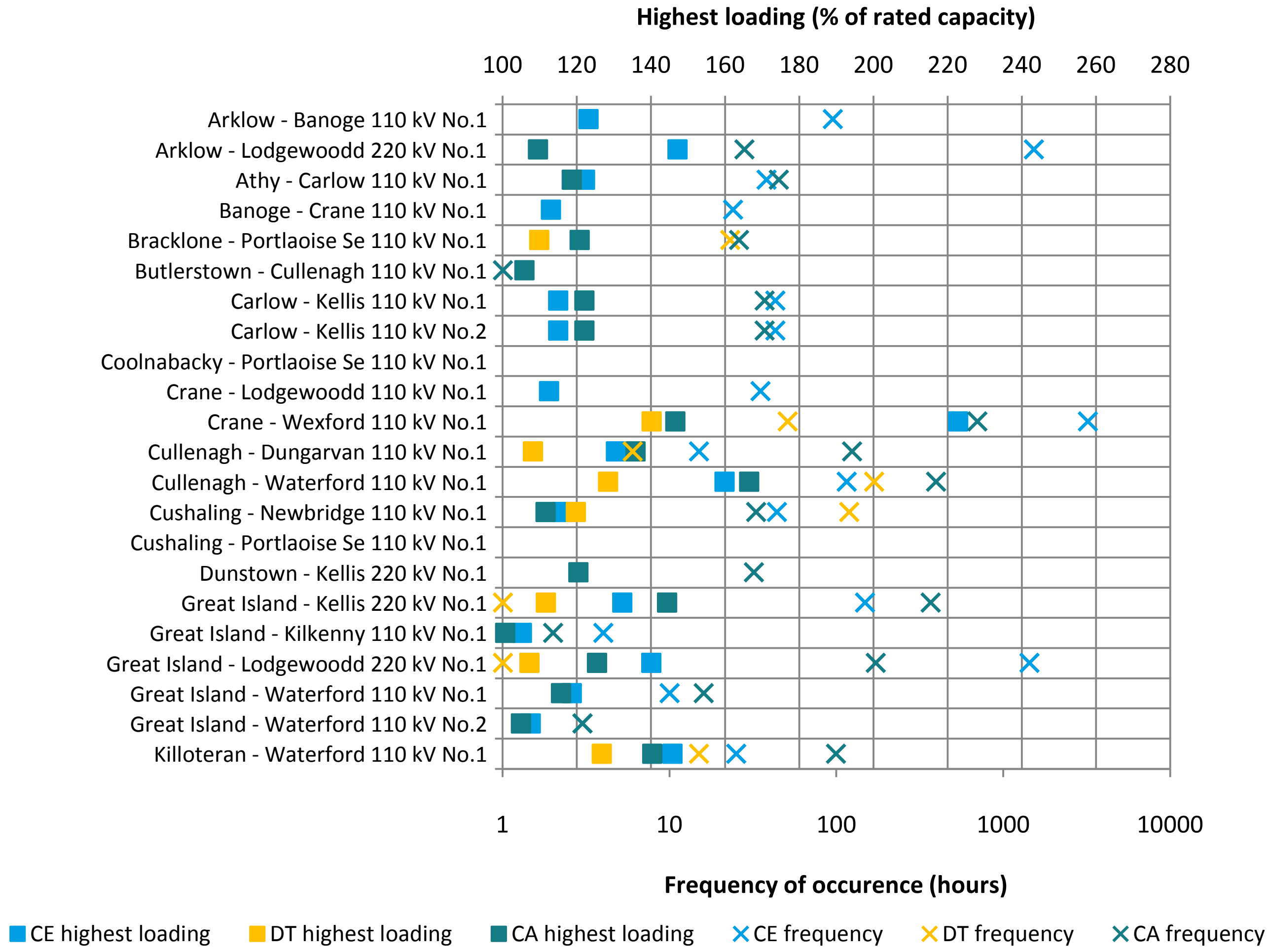


Figure C-6: N-1 thermal loading results, Area 6

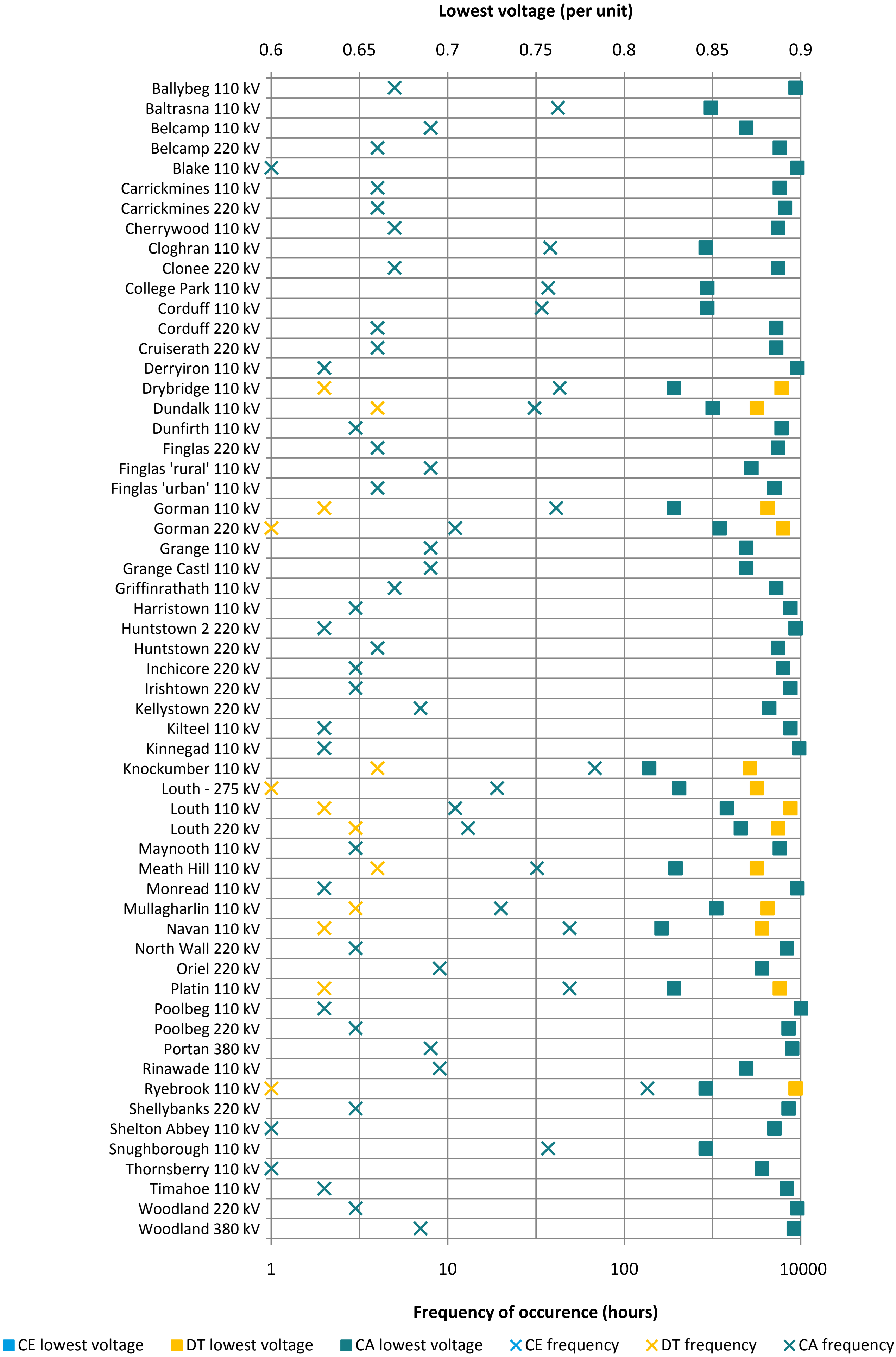


Figure C-7: N-1 low-voltage range results, Area 1

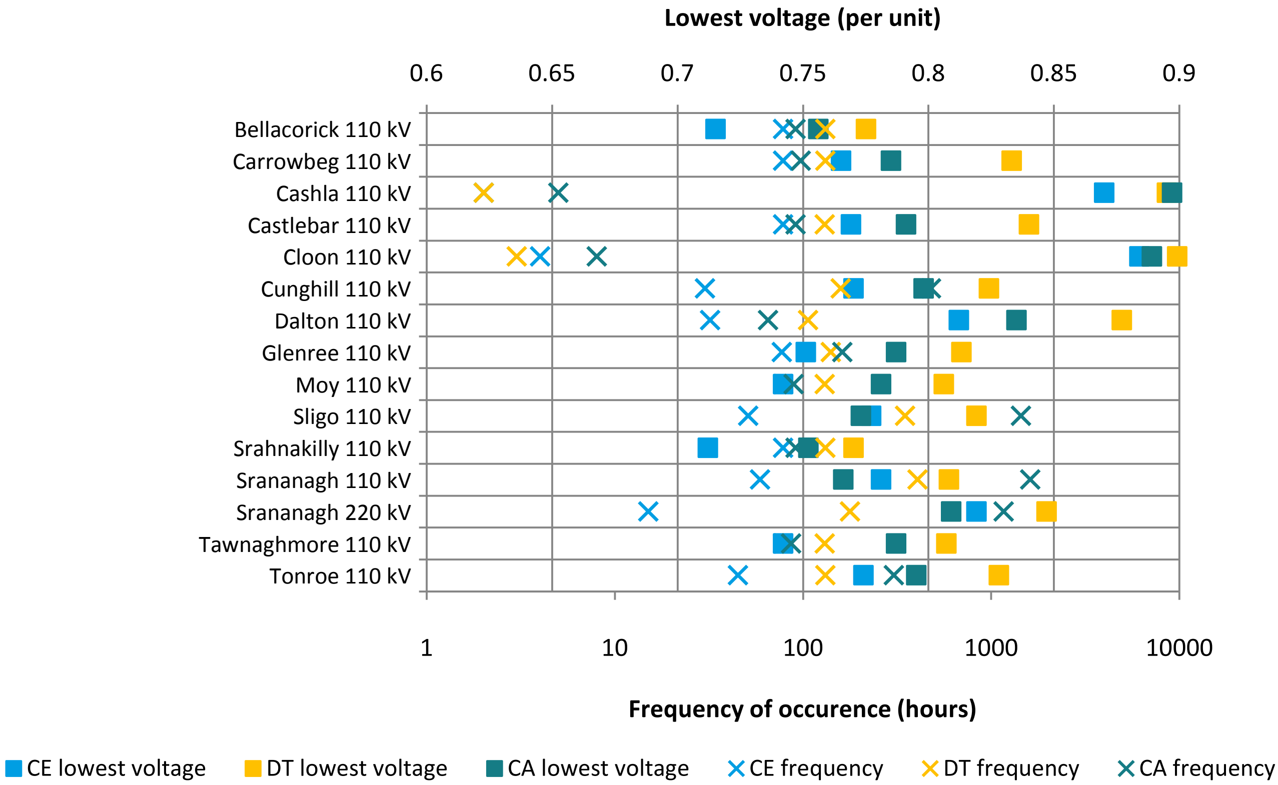


Figure C-8: N-1 low-voltage range results, Area 2

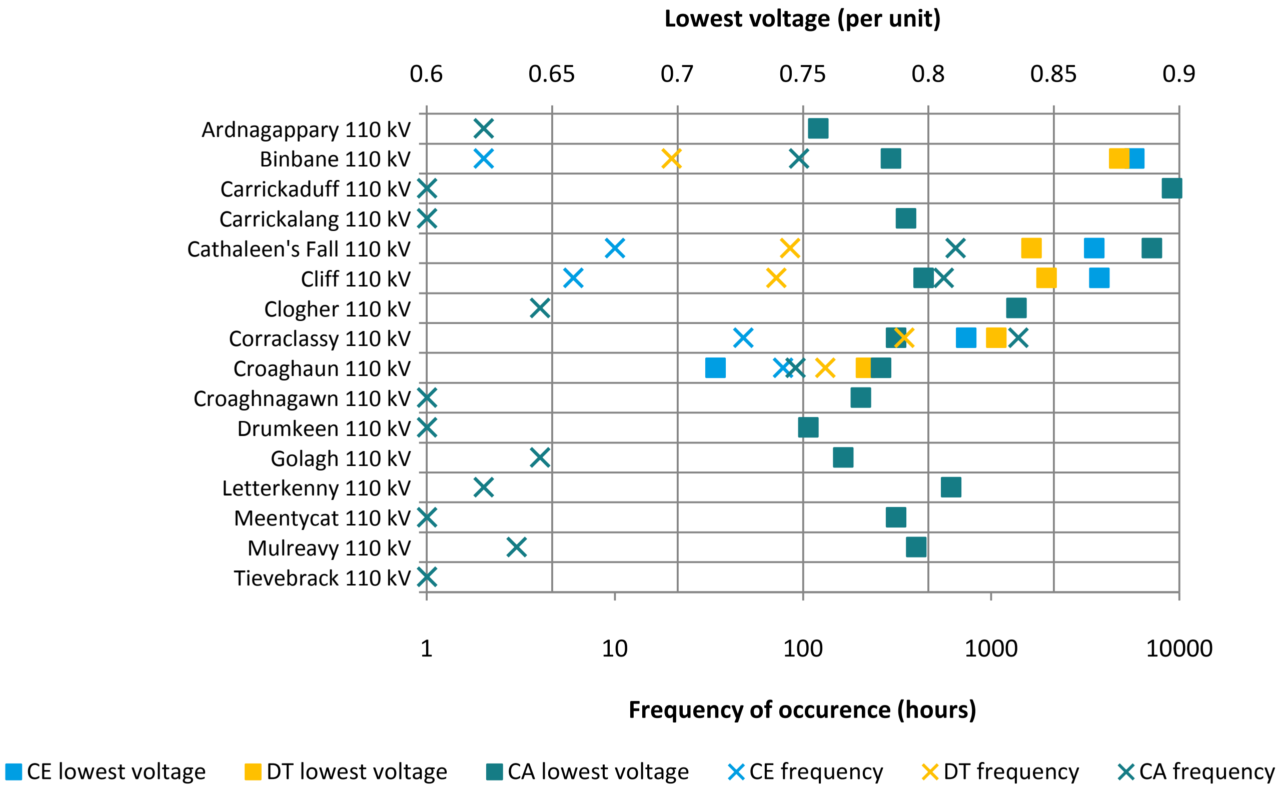


Figure C-9: N-1 low-voltage range results, Area 3

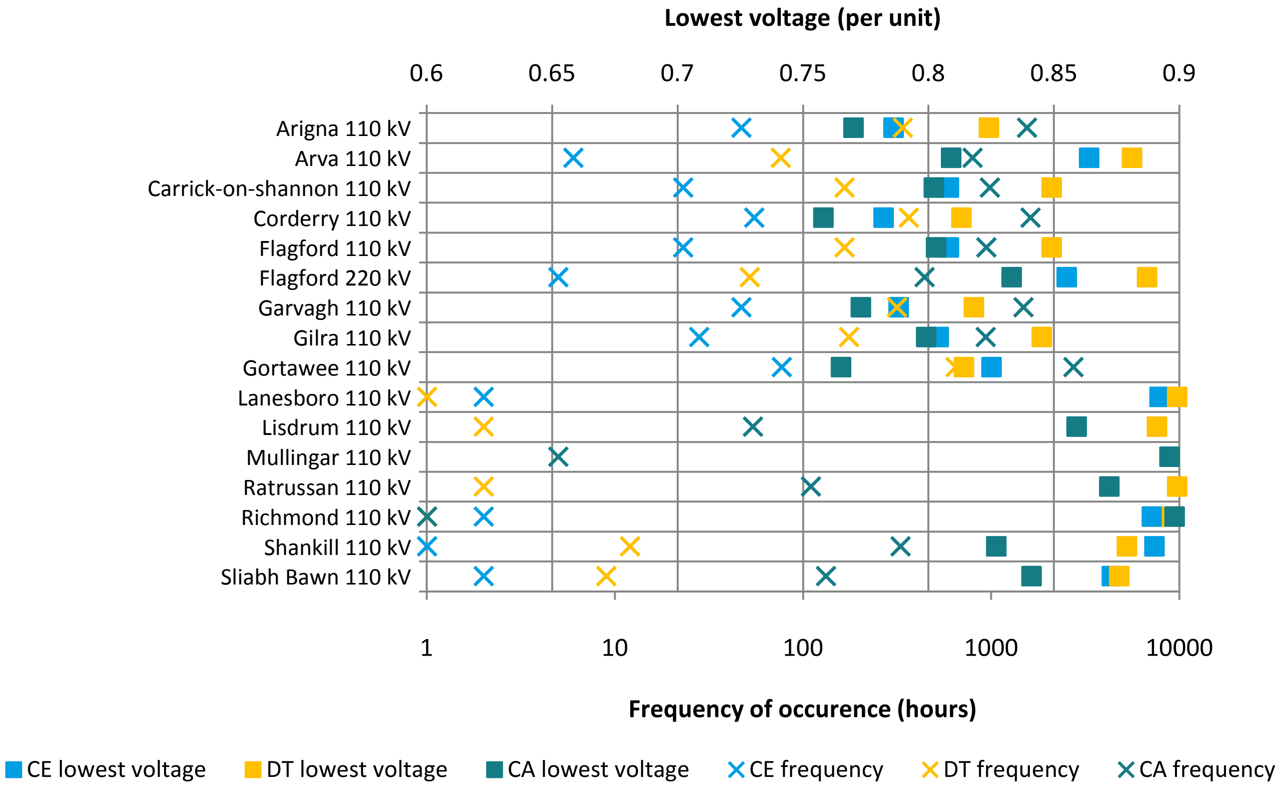


Figure C-10: N-1 low-voltage range results, Area 4

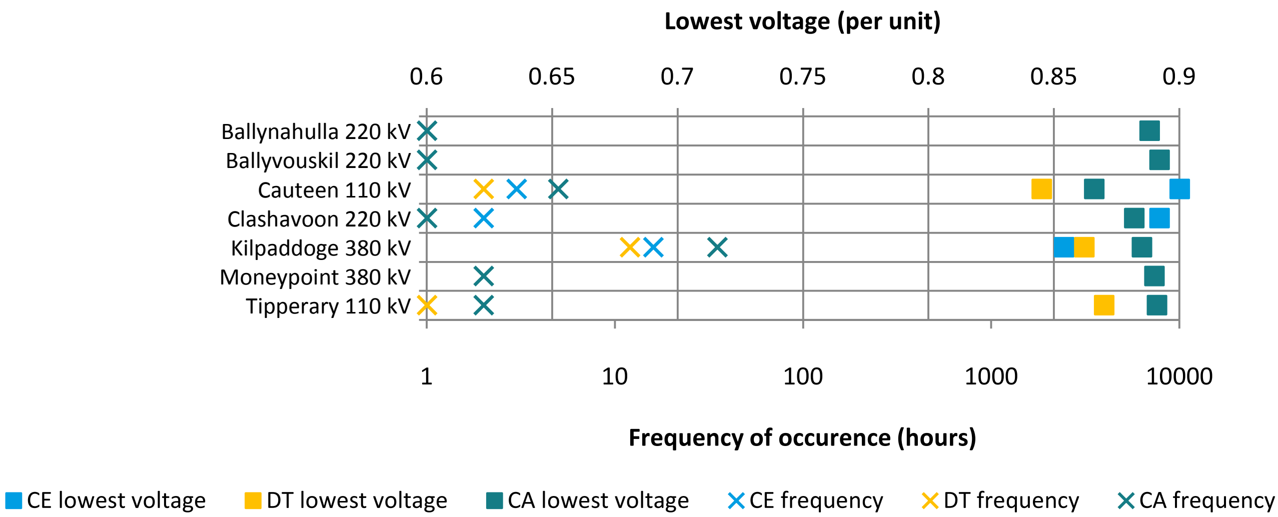


Figure C-11: N-1 low-voltage range results, Area 5

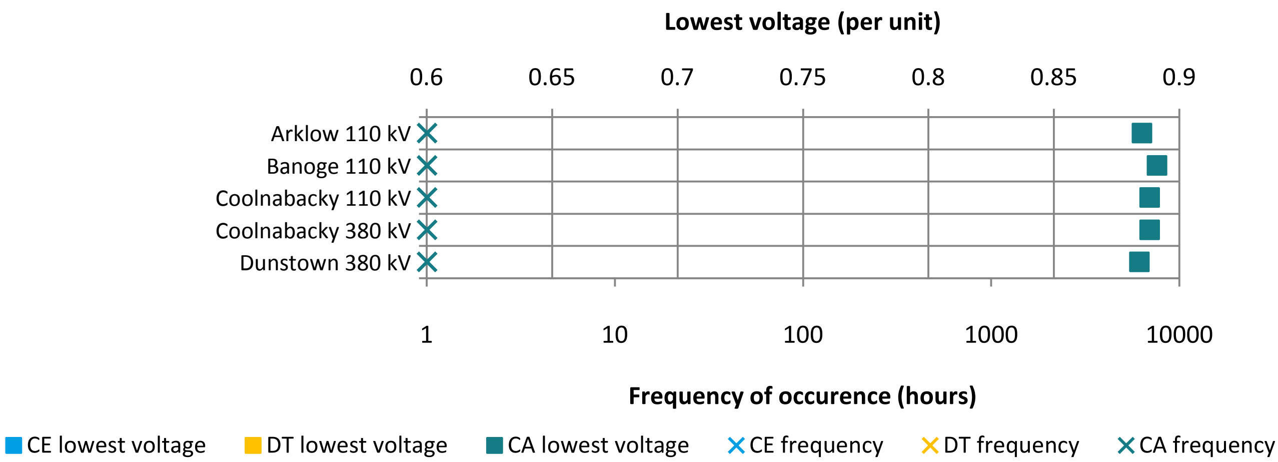


Figure C-12: N-1 low-voltage range results, Area 6

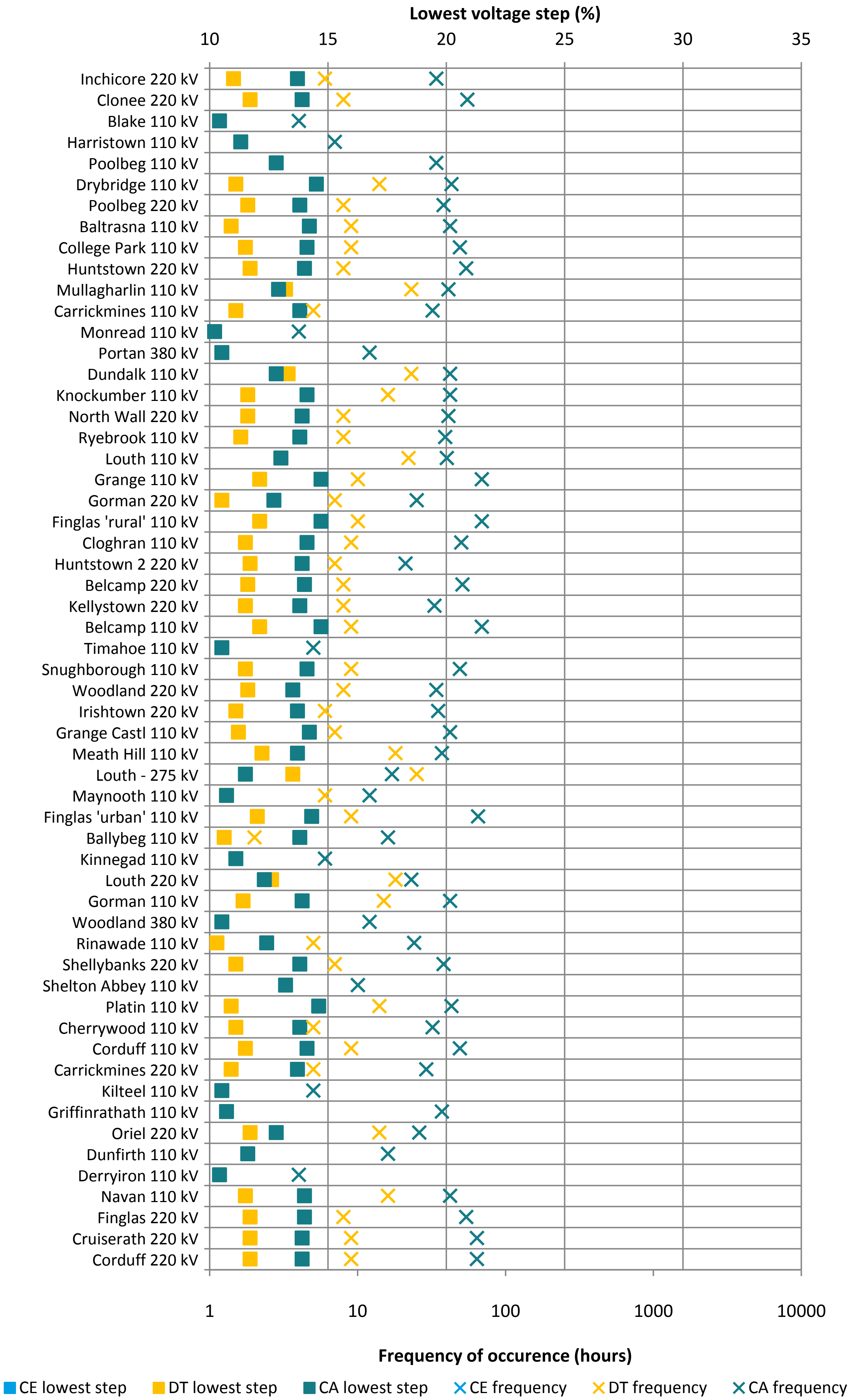


Figure C-13: N-1 low-voltage step results, Area 1

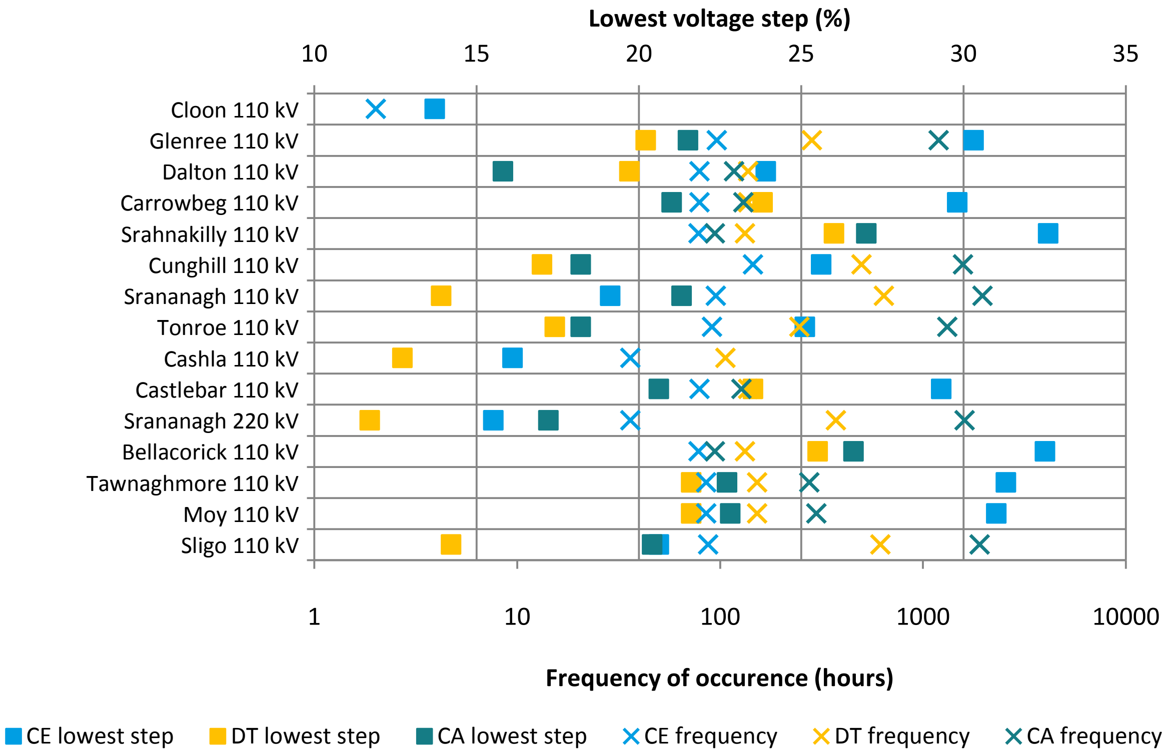


Figure C-14: N-1 low-voltage step results, Area 2

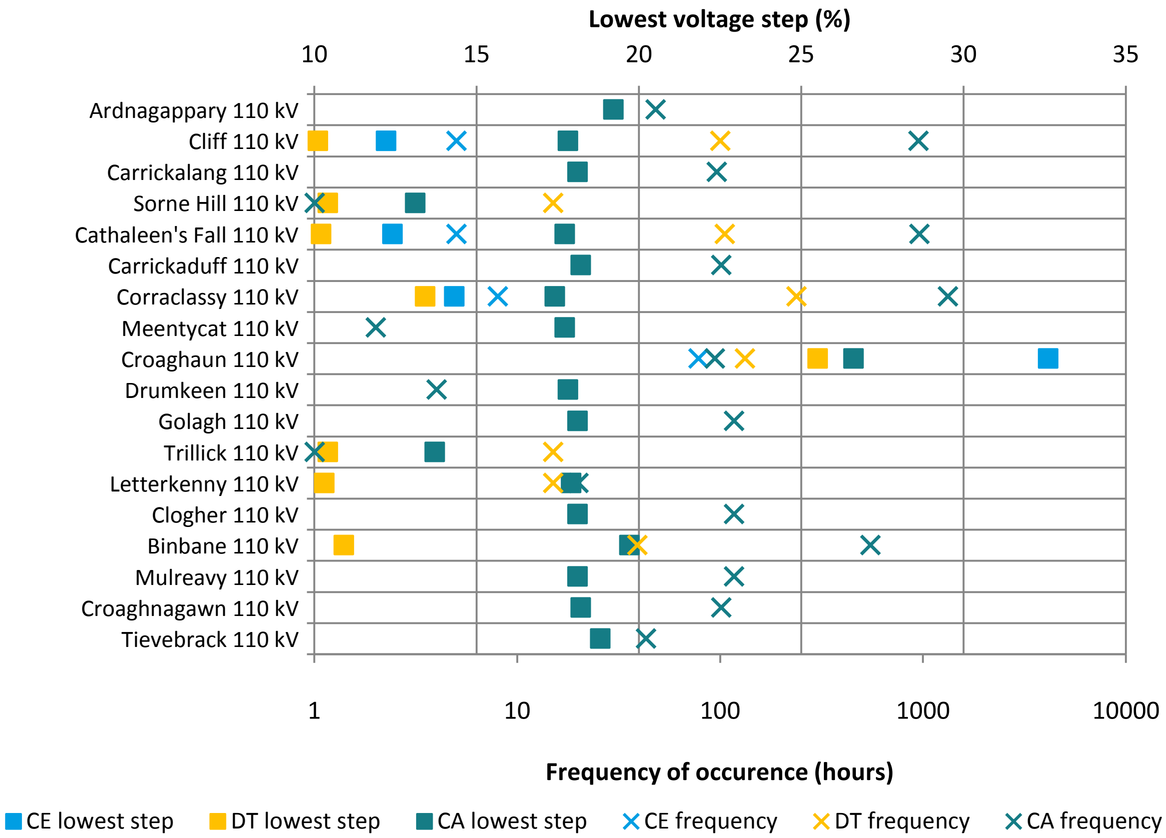


Figure C-15: N-1 low-voltage step results, Area 3

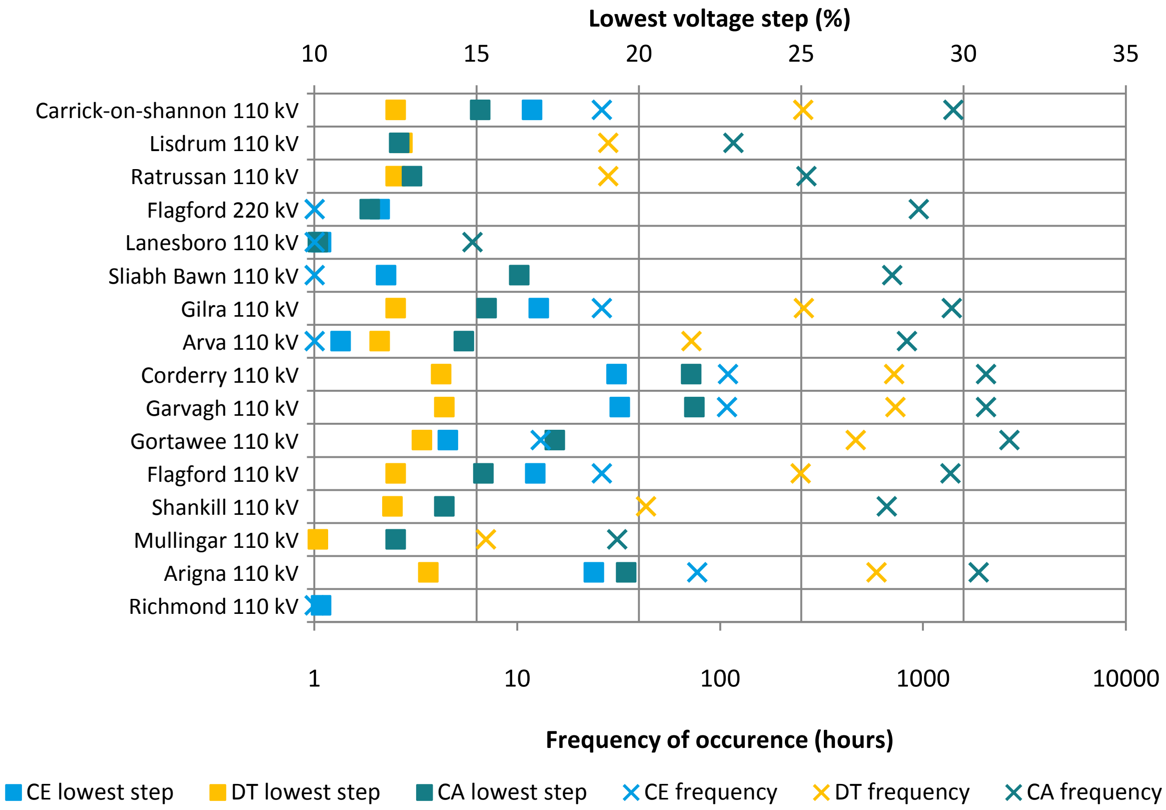


Figure C-16: N-1 low-voltage step results, Area 4

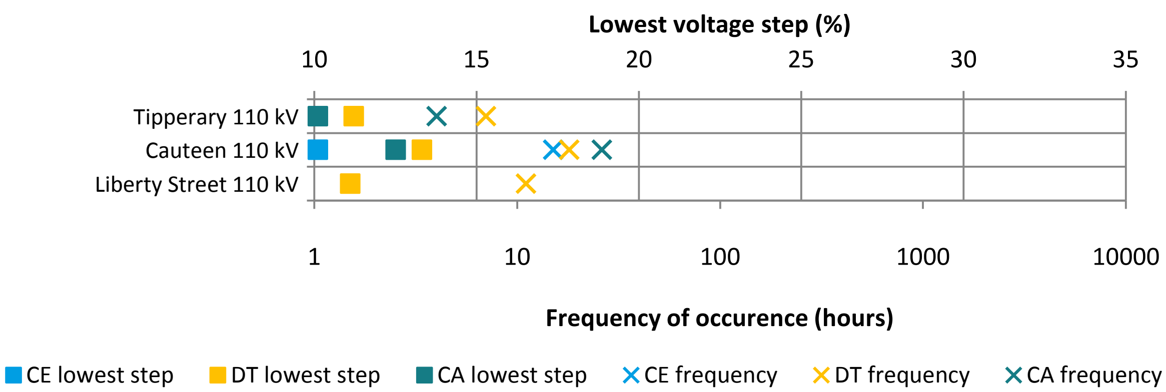


Figure C-17: N-1 low-voltage step results, Area 5

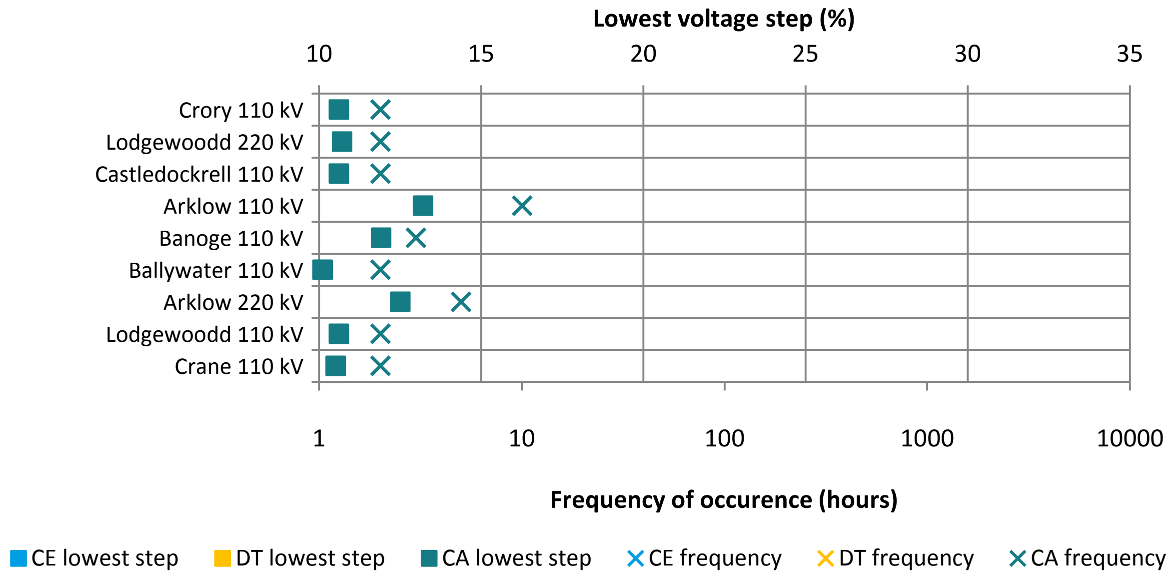


Figure C-18: N-1 low-voltage step results, Area 6

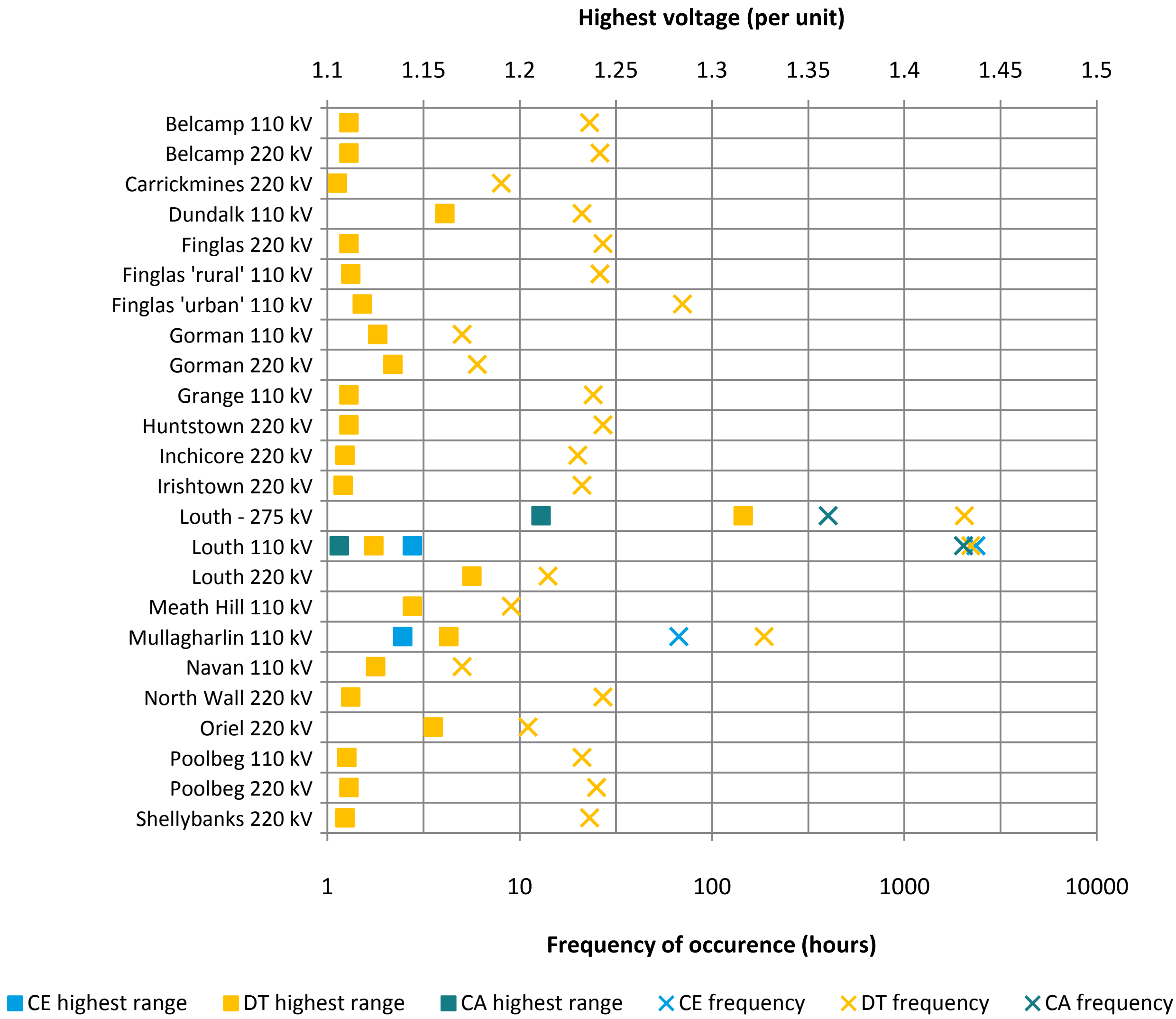


Figure C-19: N-1 high-voltage range results, Area 1

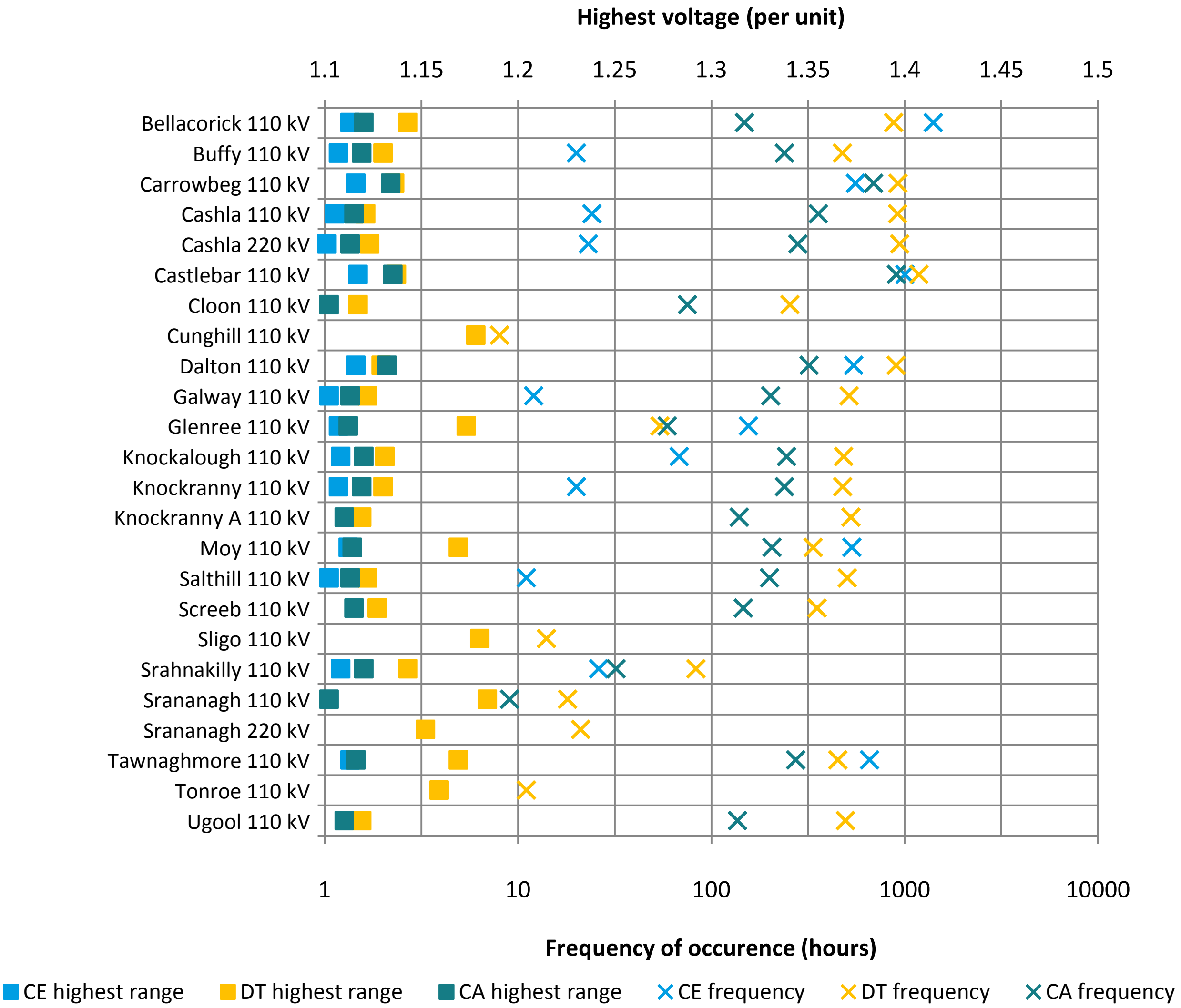


Figure C-20: N-1 high-voltage range results, Area 2

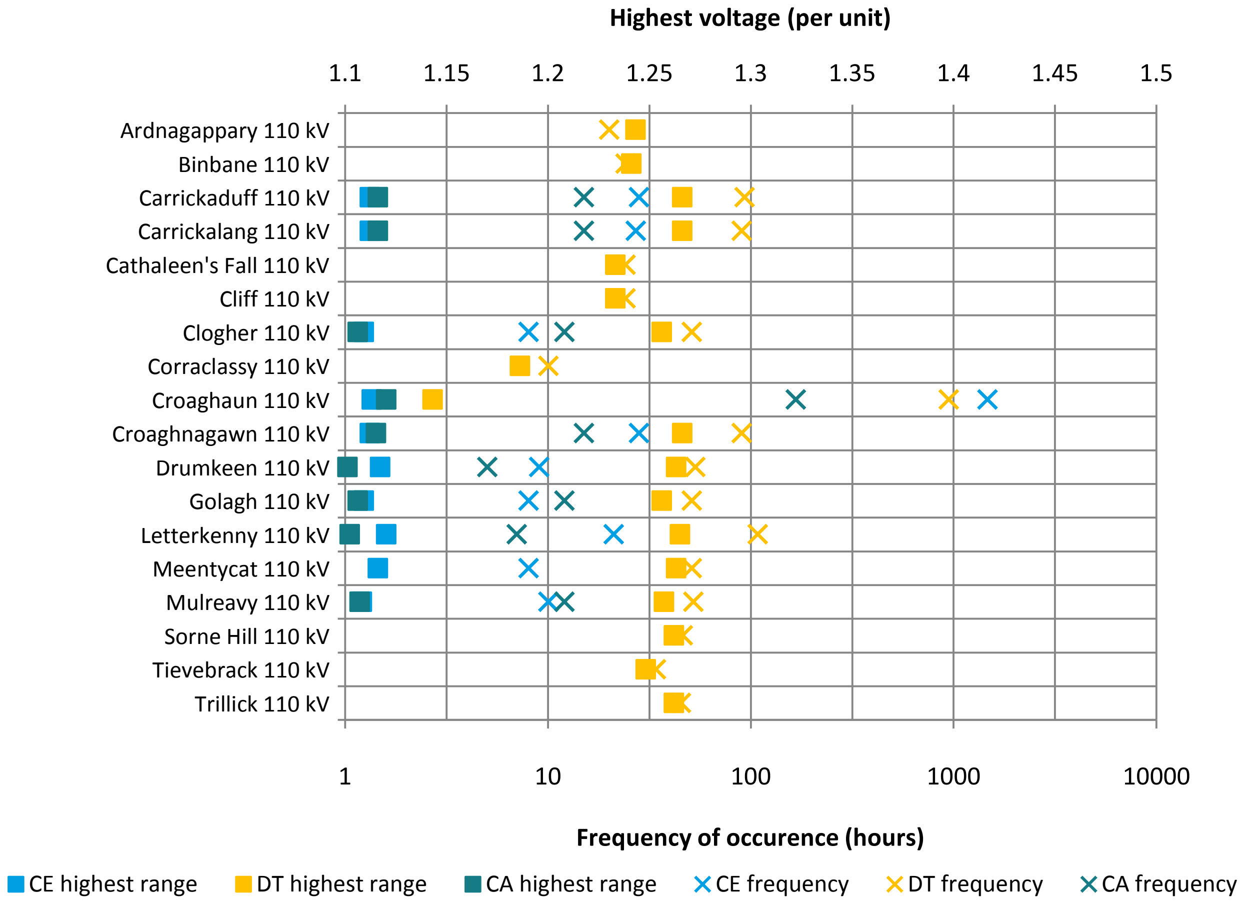


Figure C-21: N-1 high-voltage range results, Area 3

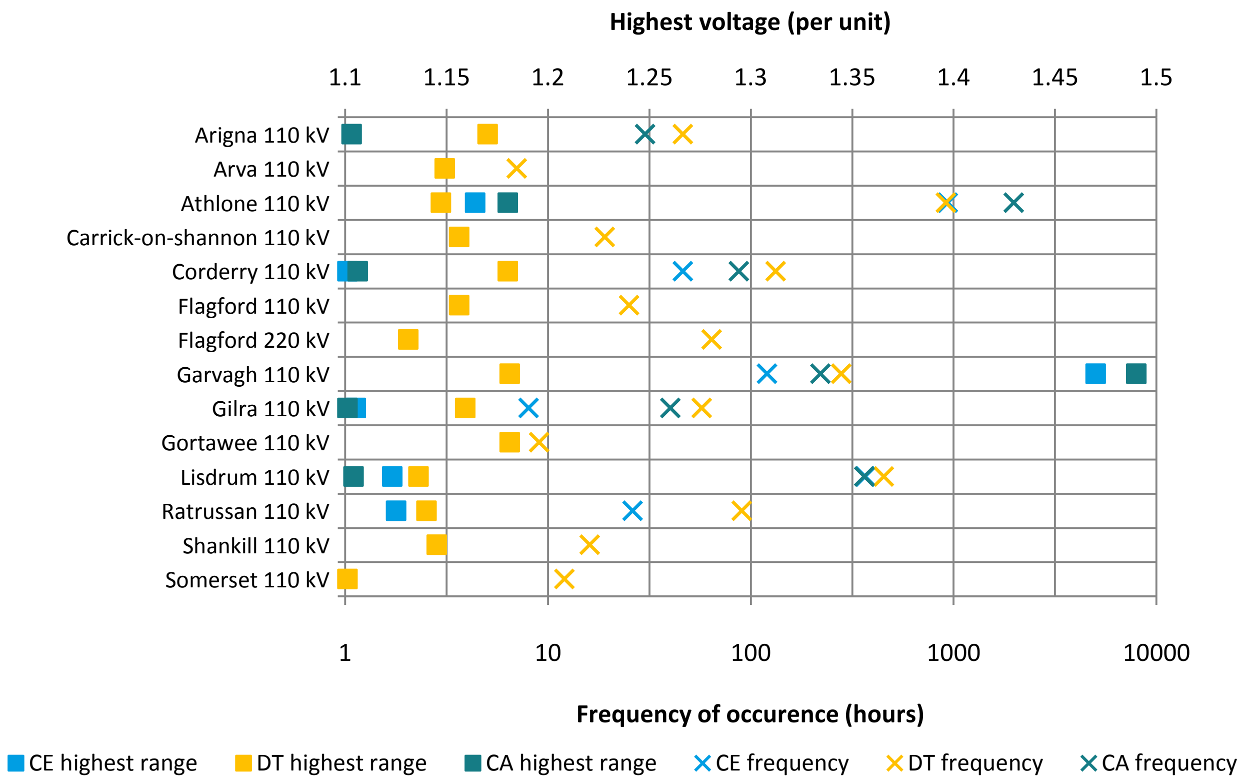


Figure C-22: N-1 high-voltage range results, Area 4

Figure C-23: N-1 high-voltage range results, Area 5

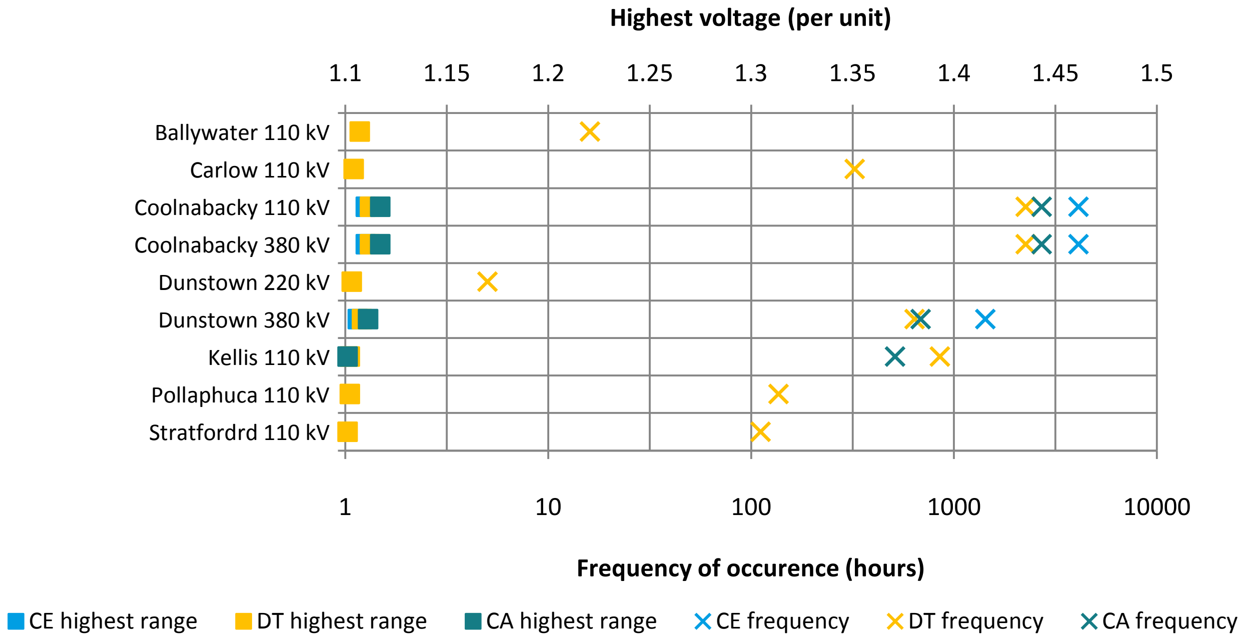


Figure C-24: N-1 high-voltage range results, Area 6

Notes:

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