NETWORKS

Review of Distribution Overhead Line Standards for Extreme Wind Events

Interim Report

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Contents

Executive Summary

On January 24th, 2025, following a nationwide Red Warning alert, Storm Éowyn caused unprecedented damage to Ireland's electricity network. With record-breaking gusts up to 184 km/hr the storm triggered over 10,000 faults and impacted 768,000 customers at the peak. In October 2025, ESB Networks published the 'Storm Éowyn Review' report. Among the key findings of this report was the recommendation for a review of the distribution design standards. This report covers a review of the standards applied to distribution overhead lines at low voltage (LV), medium voltage (MV) and 38 kV focused on the strength of designs to withstand extreme wind events.

This review examines the exposure of Ireland's overhead electrical distribution network to extreme wind events using a global reanalysis dataset of historical wind gusts for the period from 1985–2025 and modelled projections to 2050. Analysis of historical wind shows that severe windstorms are rare and difficult to predict. Mapping wind data against network assets has helped identify the most exposed parts of the network and the wind speed thresholds they have experienced over the 40-year period considered.

Future projections examined are based on two climate change scenarios (RCP 4.5 and RCP 8.5). These indicate that increased global warming could lead to higher wind exposure across the network, although there is significant uncertainty in forecasting future extreme wind events. This uncertainty is reflected in the National Climate Change Risk Assessment (NCCRA) published in June 2025, which highlights Ireland's exposure to windstorms but sets out that confidence in projection of extreme wind speeds is considered very low due to the limited availability of global, regional and national projections, with further investigation required. The growing societal reliance on electricity supply reinforces the need to consider high levels of resilience and reliability in network standards, particularly for rare but severe events.

The assessment of overhead network standards shows that most existing LV and MV standard designs provide strong mechanical resilience. It is estimated that the overhead network designs constructed on approximately 98-99% of the LV and MV network (by length) are capable of withstanding wind gusts of up to 180 km/hr or greater considering mean wood pole strength. Only a small proportion of the network standard designs, including certain MV and 38 kV configurations with larger conductors, are identified with a lower mechanical strength below 180 km/hr wind gusts. It is estimated that the overhead network designs constructed on approximately 95% of the 38 kV overhead network (by length) are capable of withstanding wind gusts of up to 180 km/hr or greater considering mean wood pole strength. When additional mitigating factors such as network exposure are considered, the current level of vulnerability/exposure based on the mechanical strength of the distribution overhead line standard is considered to be low relative to storms experienced in the past (including Storm Éowyn).

Comparison with overhead line standards in the United Kingdom (UK) indicates that Irish designs generally compare favourably with the UK empirical design approach adopted for wood pole lines.

The greatest benefits to overall windstorm resilience will come from areas such as forestry and vegetation management, asset replacement programmes and storm planning. In the example of Storm Éowyn, over 59% of damage assessments recorded hedgerow timber or forestry as the primary cause of damage. Notwithstanding this, enhancing standards to increase resilience is also an important intervention to make where it is beneficial and cost effective.

The recommendations stemming from this review are as follows:

1. **On MV overhead network, three-phase 150 mm² AAAC is one of several standard designs (currently representing approximately 1% of the total MV overhead network). It is recommended to increase the minimum pole size up one pole class for intermediate structures on three-phase 150 mm² AAAC MV overhead network for new construction and as part of any asset replacement or upgrade works.**
2. **On 38 kV overhead network, single-pole structures are one of several standard structure types used (currently representing approximately 23% of 38 kV structures on the overhead network with 100/150 mm² conductor). For 38 kV network with 100/150 mm² conductor the single-pole structure is identified as the least reliable component for high wind events. It is recommended to increase the strength of the pole on single-pole structures for new construction and as part of any asset replacement or upgrade works in order to achieve greater resilience to wind events across the 38 kV network as network development and renewal is undertaken.**
3. **This review has identified some specific network which has greater vulnerability due to the lower mechanical strength of the network and the historical exposure of this network to severe windstorms. ESB Networks plans to complete proactive interventions to increase the mechanical strength of this network over the course of the Price Review 6 period (2026 to 2030). The interventions envisaged will involve strengthening specific isolated structures across ~900 km of MV overhead network and ~1400 km of 38 kV overhead network. These interventions will be future-proofed to ensure the strength of these structures has capacity to withstand wind gusts in excess of 180 km/hr.**
4. **Documentation relating to mechanical design parameters, materials and standard designs should be reviewed and updated where necessary to ensure that the mechanical strength which is inherent in the combination of these standards is preserved to an appropriate level to meet the potential severity of windstorms impacting the overhead network. Enhancements to the 38 kV and MV standards as proposed above are to be included in these updates. The updates to this documentation will have no material change to the mechanical strength of the network as set out in this report apart from the enhancements stated, unless upon subsequent analysis decisions to enhance other areas of the standard are made. The updated standards will be reflected in a revised National Normative Aspects (NNA) to the European standard EN 50341.**
5. **The anticipated Met Éireann TRANSLATE weather models for wind gusts in Ireland will be reviewed once available and further trending of data will be completed up to the end of the century for the various climate change scenarios.**

The interim report has been developed largely in the context of Storm Éowyn, with initial findings that identify several aspects of overhead line standards that can be enhanced immediately.

The final report will be completed in the context of future climate risk, including the potential for Ireland to be affected by more extreme storms that further exceed all historical records. This work will incorporate continued guidance from the NCCRA and relevant expert reports, alongside further analysis of climate change impacts using Met Éireann data on future wind gusts, once available. The final report will also include considerations relating to severe windstorms experienced in other parts of Europe. Enhanced-strength overhead network designs are currently being developed, including the use of composite poles, which can be engineered to achieve significantly higher strengths than traditional timber poles. All of this work will inform the setting of long-term, future design parameters for the distribution overhead network and will be incorporated into the final report.

This review is for distribution overhead line standards which are within the remit of ESB Networks. ESB Networks plans to work jointly with EirGrid in relation to a review of transmission overhead line standards for extreme wind events.

Review of Distribution Overhead Line Standards for Extreme Wind Events – Interim Report Key Point Summary

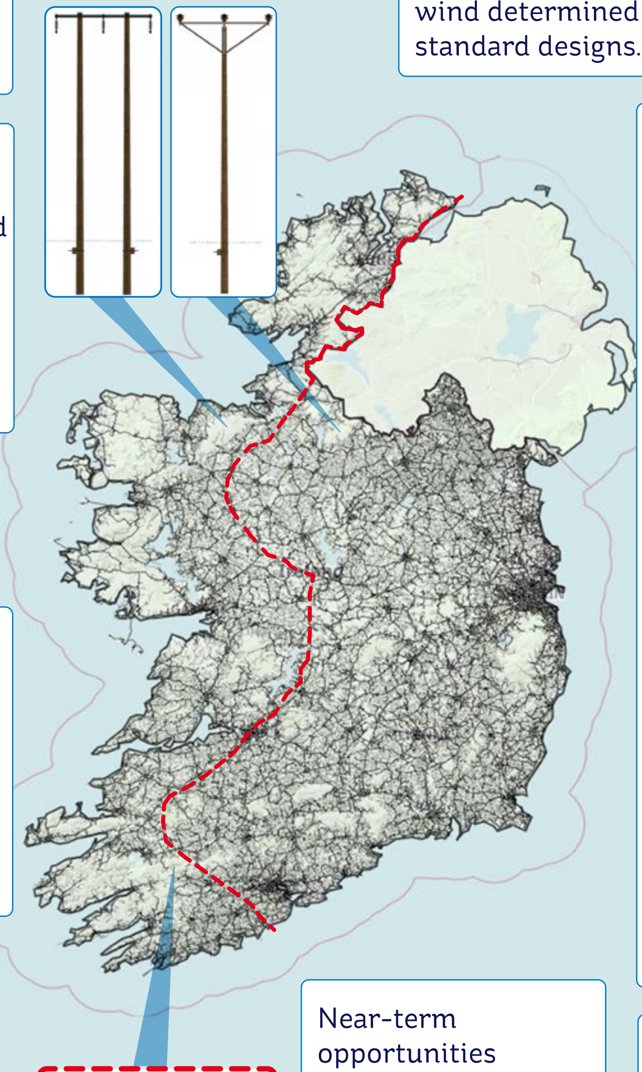
Standards review is one part of a broader suite of measures ESB Networks is undertaking to enhance resilience of the distribution network.

40 years (1985–2025) of historical wind-gust data mapped against the network.

Future wind exposure using climate projections to 2050 under RCP 4.5 and RCP 8.5 scenarios.

Mechanical strength of network for extreme wind determined based on modelling of standard designs.

Design standards provide most distribution overhead lines with capacity to withstand 180 km/hr wind gusts considering average wood pole strength.



Interim Report Recommendations:

1. Increase intermediate pole strength on 3 × 150mm² MV networks (new and refurbished)
2. Increase intermediate pole strength on 38 kV single-pole networks with 100/150 mm² conductors (new and refurbished)
3. Strengthen identified vulnerable network sections by end of 2030
4. Update standards documentation and national parameters for European standard
5. Review Met Éireann future wind-gust projections as they become available

A 180 km/h wind gust is severe and has been recorded only a handful of times in Ireland since 1945; however, more severe storms remain possible.

Climate change linked to global warming may increase risk for extreme weather events.

Network most impacted in exposed Atlantic zone based on 40 years of storm data

Near-term opportunities identified to strengthen design standards for severe windstorms.

Final report will incorporate latest information on future climate risk, Met Éireann projections, extreme European storms, and enhanced design solutions to inform long-term network standards.

Glossary of Terms

Term	Description / Definition
Representative Concentration Pathways (RCPs)	Term used to describe climate change scenarios represented by different greenhouse gas emission outcomes up to the year 2100.
National Climate Change Risk Assessment (NCCRA)	Climate change risk assessment led by the Environmental Protection Agency (EPA) which provides a prioritised national climate risk register for Ireland.
TRANSLATE	TRANSLATE project is a Met Éireann led initiative to standardise future climate projections for Ireland.
Sectoral Adaptation Plan (SAP)	A formal plan required under Irish legislation that sets out how a specific sector will adapt to the impacts of climate change.
Rationalisation	Used in this context refers to the process of limiting the number and type of different materials or components used.
Low voltage (LV) network	Used in this context refers to distribution power lines which directly feed to typical customers.
Medium voltage (MV) network	Used in this context refers to distribution power lines which transmit power to the low voltage network (or large load customer).
38 kV network	Used in this context refers to distribution power lines transmit power to the medium voltage network (or large load customers).
Conductor	Term used to describe overhead wires that transmit electricity.
Stays	Steel wire used to support some pole structures.
Crossarm	Steel section which attaches at the top of a pole which is used to support the insulators which in turn support the overhead wires.
Single-pole structure	Structure which comprises of one pole and a steel crossarm on top.
Portal structure	Structure which comprises of two adjacent poles joined by a steel crossarm across the top of the poles.
Single-phase overhead network	Type of overhead network which consists of two wires supported between structures.
Three-phase overhead network	Type of overhead network which consists of three wires supported between structures.
National Normative Aspects (NNA)	Document that sets out nationally determined parameters (requirements chosen by each country) to be adopted in design, linked to a European standard for the design of overhead lines.
Empirical design	Design theory based on practical experience and observation over time.
Probabilistic design	Design theory based on probability and statistics.
AAAC	Type of conductor used on the overhead network. Stands for 'All-Aluminium Alloy Conductor'.
ACSR	Type of conductor used on the overhead network. Stands for 'Aluminium Conductor Steel Reinforced'.
Aerial Bundle Conductor (ABC)	Type of conductor used on the low voltage overhead network which consists of several insulated wires which are twisted together in a bundle and hung between structures.

Glossary of Terms

Term	Description / Definition
Pole class	Term used to describe the size/strength of a pole used on the overhead network.
Span	Distance between structures which are supporting overhead wires.
Wind span	The distance along an overhead wire for which when loaded by wind contributes to the load applied on a structure. This distance equates to half the span length on each side of a structure.
99th percentile, 95th percentile etc.	A statistical measure that indicates the value below which the stated percentage of the data falls (e.g. 99% and 95% respectively in the examples shown).
Finite element modelling	Computer based models which are commonly used in engineering design to determine the strength of structures for different applied loading.
Utilisation	In this context refers to the degree to which a component (e.g. pole, steel crossarm, stay or conductor) is utilised for a given applied load relative to its structural capacity.
Three-second gust wind speed	The average wind speed which is experienced over a three second period.
Mean wood pole strength	Mean wood pole strength is the average strength achieved by wood poles based on mechanical testing.
Geographic Information System (GIS)	Computerised mapping system which is used to record the network.
25 mm^2, 50 mm^2, 92 mm^2 etc.	Designations which refer to the cross sectional area (size) of conductors which are used in overhead lines.
Circuit	Used in this context refers to a particular area of overhead network.
Intermediate pole	A pole which supports overhead conductor at positions where it is continuous and travels straight through.
Light / medium / heavy angle pole	A pole which supports overhead conductor at positions where it is continuous but where there is a change in the direction of the line. The designation of light, medium or heavy refers to the size of the angle at which the line changes direction at the pole.
End pole	A pole which supports overhead conductor at positions where the overhead lines terminates/ends.
Double End Pole	A pole which supports overhead conductor at positions where the overhead line turns at a right angle (i.e. 90 degrees).

Glossary of Terms

Term	Description / Definition
Mechanical strength	Used in this context refers to the loading which a component or standard design can resist before failure due to overloading.
Bare conductor	Term used to describe overhead lines or overhead line conductors which have no form of insulation surrounding the conductor.
Orography factor	A factor applied in determining a design wind speed which accounts for the effects of land gradient/slope.
Drag factor	A factor applied in determining a design wind pressure which accounts for the effects of aerodynamic drag when, wind in this case passes around an object.
Reliability level	In the context of the European standard for the design of overhead lines (EN50341) three reliability levels are defined, each relating to a different probability of an event occurrence. Reliability levels 1, 2 and 3 correspond to a 1 in 50 year, 1 in 150 year and 1 in 500 year probability respectively.

1 Introduction

1.1 Background

On the night of 23rd January into 24th January 2025, Ireland was impacted by Storm Éowyn, a major storm event which brought gust wind speeds to parts of the country that exceeded all previous records (the highest gust speed recorded was 184 km/hour at Mace Head in County Galway). The storm resulted in significant damage to the electricity network and an unprecedented number of customers losing supply (~768,000 customers without supply at peak). While 90% of customers had their supply restored in one week, the restoration of supply to all customers extended beyond two weeks. In October 2025, ESB Networks published the 'Storm Éowyn Review' report[1]. Among the key findings of this report was the recommendation for a review of the distribution design standards. In the wake of such a devastating storm which had significant impacts for so many customers, it is appropriate to review the current standards which are applied to distribution overhead lines. Using available climate data and future climate models, this review seeks to assess whether current standards are adequate to provide the required levels of strength on the network for wind loading.

As the network has developed over time, so too have the standards, taking account of past network performance and significant weather events. In the coming decades there will be significant investment in the network to increase capacity and replace end of life assets. As new network is built and as existing network is rebuilt, it is imperative that the standards for this infrastructure are sufficient to meet reliability and resilience needs in the face of climate change.

This review will seek to examine the current standards for distribution overhead lines in Ireland in relation to wind loading, and seek to use future weather modelling data to examine trends in these loading events. It will put forward recommendations in relation to the standards applied to distribution overhead lines in Ireland for extreme wind events.

Further details on ESB Networks' commitment to climate adaptation can be found in its net zero strategy and climate adaptability framework[2], the Sectoral Adaptation Plan 2025[3], yearly distribution network performance reports[4] and Climate Change Advisory Council yearly climate adaptation scorecard reports[5].

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[1] *Storm Éowyn Review Report, published October 2025*
[2] *ESB Networks Net Zero Strategy and Climate Adaptability Framework*
[3] *Electricity and Gas Networks Climate Change Sectoral Adaptation Plan (SAP) 2025*
[4] *ESB Networks Yearly Distribution Network Performance Reports*
[5] *Climate Change Advisory Council Yearly Climate Adaptation Scorecard Reports*

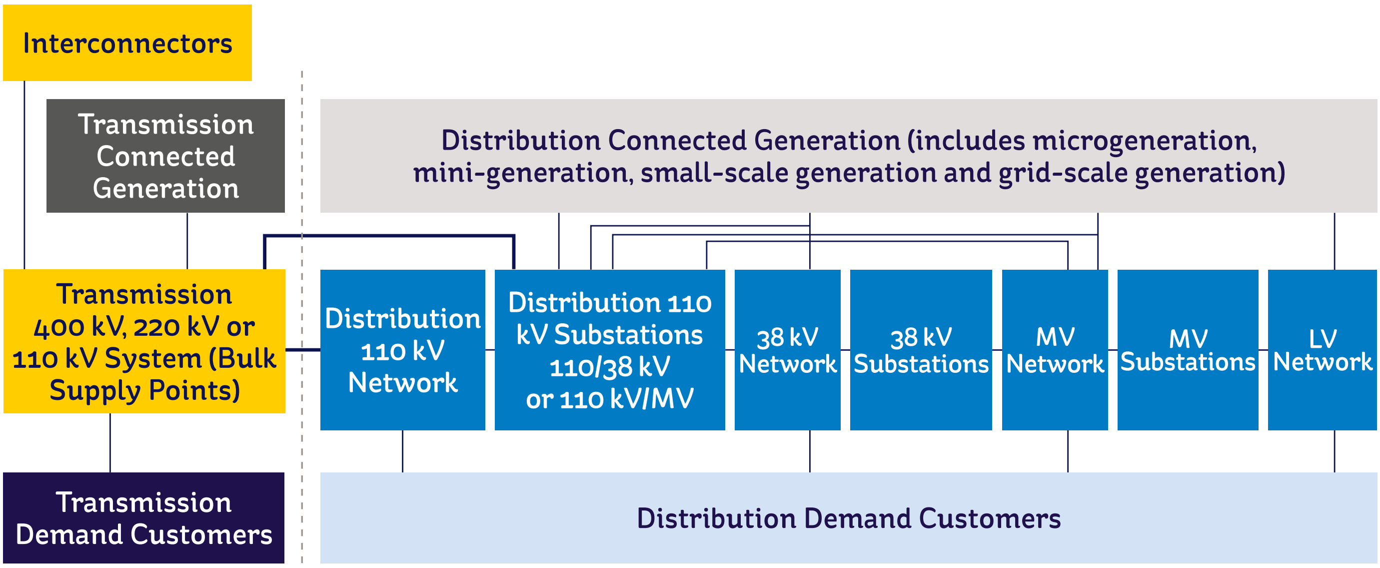
1.2 General Information

The electricity system comprises transmission network (typically voltages of 110kV and above) and distribution network (typically voltages under 110kV), and includes all substations, overhead lines, and underground cables that are used to bring electricity to Ireland's 2.5 million domestic, commercial, and industrial customers. The network comprises approximately 160,000 km of overhead network, 28,000 km of underground cables, and almost 800 high voltage substations (primarily ESB Networks-owned substations, with a smaller number of customer-owned substations).

ESB is the licensed Transmission Asset Owner (TAO) and Distribution Asset Owner (DAO) for Ireland. ESB Networks DAC, a wholly owned ringfenced subsidiary within the ESB Group is the electricity Distribution System Operator (DSO) for Ireland. In accordance with arrangements approved by the Commission for Regulation of Utilities, staff in the ESB Networks business unit carry out ESB Networks DAC's functions as DSO, in addition to the functions of ESB as the licensed TAO and DAO, under the management of ESB Networks DAC. In carrying out ESB's functions as TAO and DAO, ESB Networks staff are responsible for (a) building and maintaining the high voltage transmission system in line with requirements set out by EirGrid, the transmission system operator (TSO) and (b) carrying out all functions relating to the electricity distribution system, including asset management, planning, design, construction, maintenance, and operation of the high, medium, and low voltage distribution network.

Figure 1 shows an overview of the electricity system in Ireland and the distinction between transmission and distribution network.

Figure 1: Overview of the electricity system in Ireland



1.3 Scope of Review

ESB Networks are responsible for the standards applied to overhead lines on the distribution system. This includes the following network voltages:

- **220 V / 400 V – 'Low Voltage' (LV) network**
- **10 kV / 20 kV – 'Medium Voltage' (MV) network**
- **38 kV network**
- **110 kV distribution network**

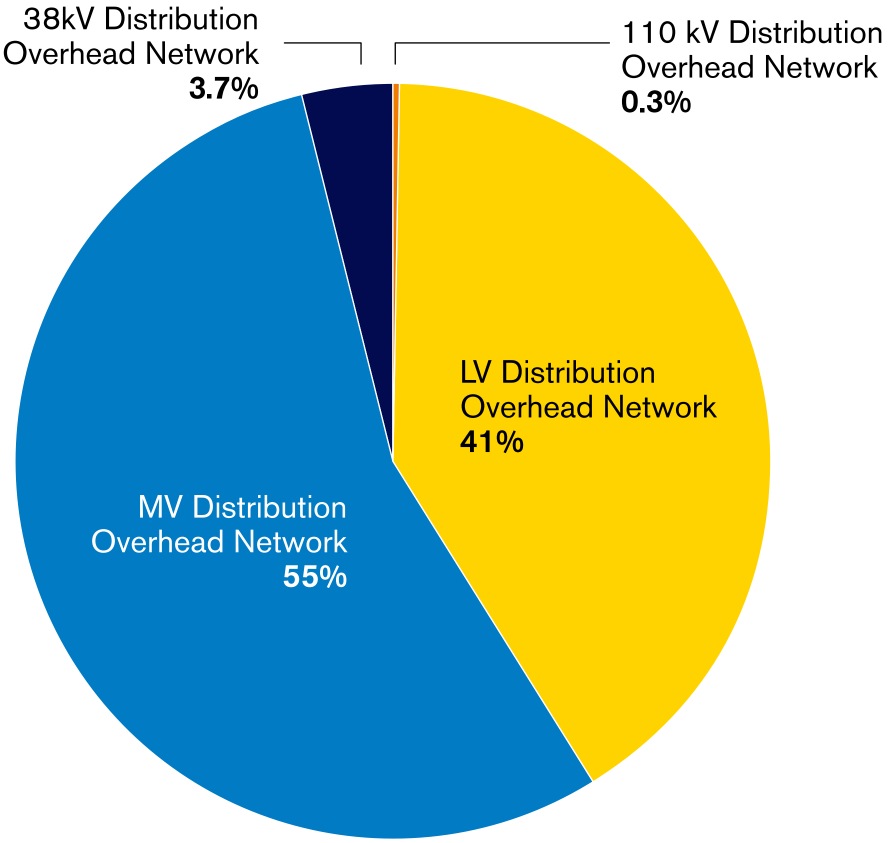
EirGrid have responsibility for the design standards that are applied to overhead lines on the transmission system. This includes the following network voltages:

- **110 kV transmission network**
- **220 kV network**
- **400 kV network**

It is noted that approximately 92% of the 110 kV overhead network is transmission network. The standard currently applied by ESB Networks for distribution 110 kV overhead lines conforms to the standards adopted for transmission 110 kV overhead lines adopted by EirGrid.

Figure 2 shows the proportions of the overhead distribution network operating at each voltage level by length.

Figure 2: Breakdown of overhead network proportions in Ireland by operating voltage and length of network



This report covers a review of the standards applied to distribution overhead lines at low voltage (LV), medium voltage (MV) and 38 kV focused on the strength of designs to withstand extreme wind events.

1.4 Methodology

1.4.1 Historical weather conditions

As highlighted in sections 1.1 and 1.3, this review covers the current standards for overhead lines at LV, MV and 38 kV as it relates to severe wind events. The review completed uses the network details from ESB Networks' network mapping. The location and asset details of the overhead network have been extracted and mapped to an analytics platform. The overhead network details have been mapped and linked with 40 years of weather data (from 1st March 1985 to 28th February 2025) as derived from the EU Copernicus Program ERA5[1] data. ERA5 is a reanalysis dataset which combines observational inputs such as satellite and weather station measurements. ERA5 provides continuous spatial coverage across the island of Ireland, avoiding the spatial gaps presented by point based weather station measurements. The ERA5 weather data includes all storm events in this period, such as the major storms of Storm Éowyn (January 2025), Storm Darragh (December 2024), Storm Ellen (August 2020), Storm Ophelia (October 2017), Storm Darwin (February 2014) and major unnamed storms in the period such as that in February 1988. The analytics platform employed allows for a variety of different reports to be run which provide details on the climatic conditions experienced on the network over the period considered. As part of the review, past wind events experienced on the network and the proportion of the network which has been exposed to these conditions is established for the 40 years of weather data assessed.

1.4.2 Future weather conditions

Future modelled weather data from the Intergovernmental Panel on Climate Change (IPCC)[2] has been examined up to the year 2050. The future modelled weather data considers the following two climate scenarios:

- RCP4.5 – Moderate mitigation resulting in intermediate emissions. Global mean temperature increase is approximately 2.4°C
- RCP8.5– No mitigation ('business as usual'), resulting in high emissions. Global mean temperature increase is over 4.0°C

These climate scenarios are linked to the level of mitigations implemented globally to reduce the emission of greenhouse gases, known as Representative Concentration Pathways (RCPs).

The RCP 4.5 and 8.5 scenarios are considered in this review for consistency with the National Climate Change Risk Assessment[3] (NCCRA) published in June 2025. Figure 3 which is taken from the NCCRA shows a graph of the global average surface temperature change predicted up to the year 2100 under the various RCP scenarios.

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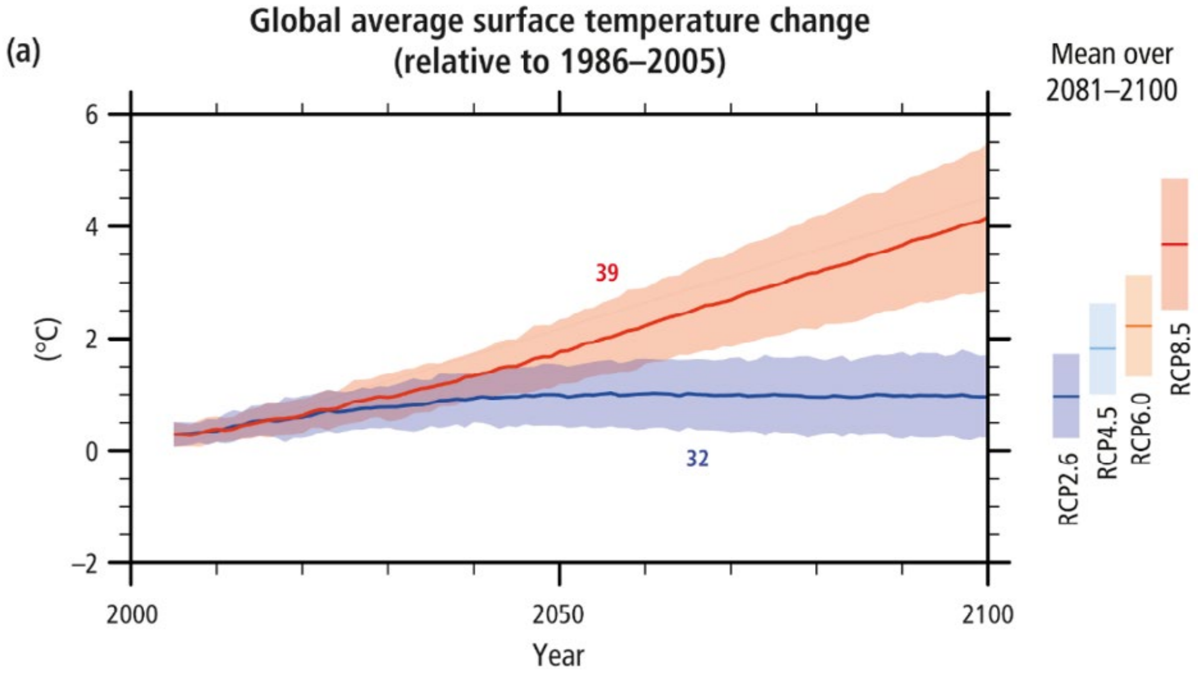
[1] *EU Copernicus Program ERA5 Data*

[2] *Meteorological Research Institute Earth System Model Version 2.0 (MRI-ESM2.0)*

[3] *National Climate Change Risk Assessment (NCCRA) published by the Environmental Protection Agency (EPA) in June 2025*

Figure 3: Global average surface temperature change from 2006 to 2100 as determined by multi-model simulations[1]



The future modelled weather data is examined to establish predicted trends in extreme wind storms. This is necessary to determine whether there is data indicating that the design standards relating to extreme wind for distribution overhead lines should be enhanced beyond what historical experience may indicate.

1.4.3 Mechanical strength of overhead distribution network

The mechanical strength of distribution overhead lines is determined for a variety of network construction types. There are many different parameters which affect the mechanical strength of an overhead line (at which a failure would be observed in a real-world setting). These includes parameters such as safety factors, rationalised component sizes, conductor sizes and limiting spans for ground clearance or conductor clashing. The assessment completed considers components which are of sound condition and which have been constructed in line with the relevant standards.

Finite element computer modelling has been completed to determine the mechanical strength for various line construction types. This report seeks to give an overview of the mechanical strength of distribution overhead lines to resist extreme wind exposure based on the current standards. The mechanical strength of distribution overhead lines is then compared with the observations from the ERA5 historical weather data and future modelled weather data in order to determine whether the existing standards in place are adequate for current and future overhead line design. Comparison of standards adopted by other utilities is also reviewed.

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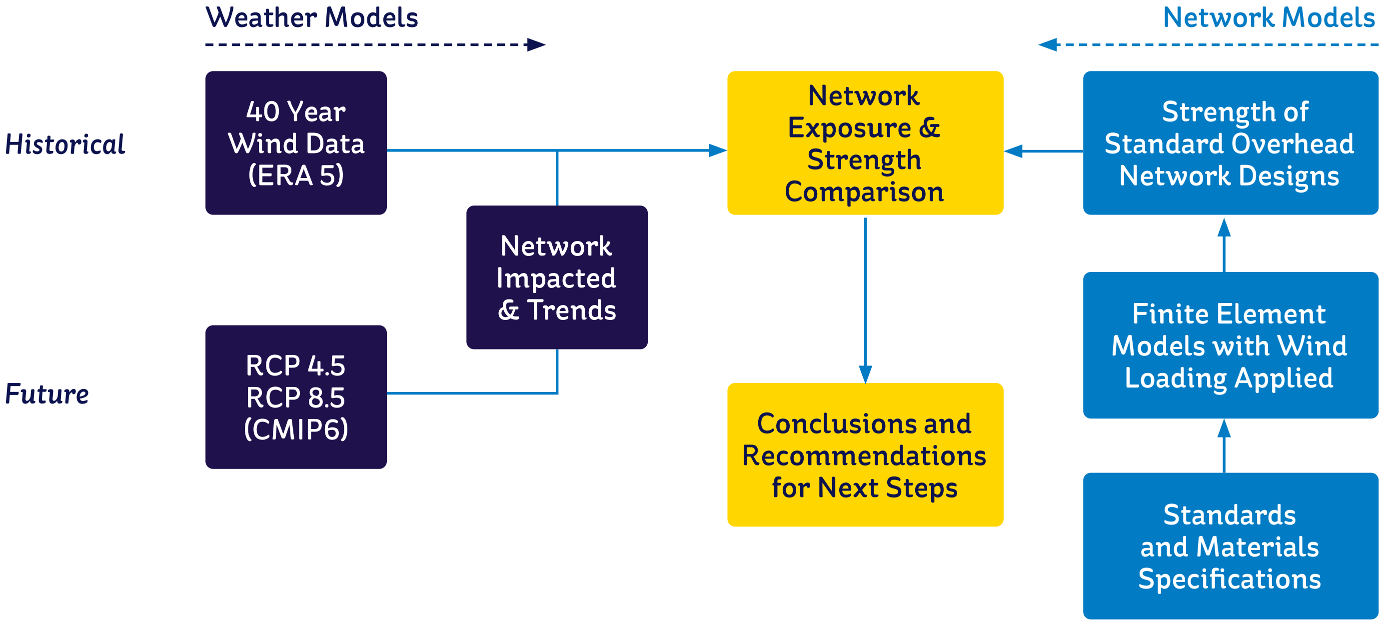
[1] *National Climate Change Risk Assessment (NCCRA) published by the Environmental Protection Agency (EPA) in June 2025*

Figure 4: Overview of methodology adopted in the review of overhead line standard designs



2 Records of Extreme Weather Events

The following section gives a brief overview of some of the historical extreme weather events observed on the network.

2.1 Extreme Weather Events

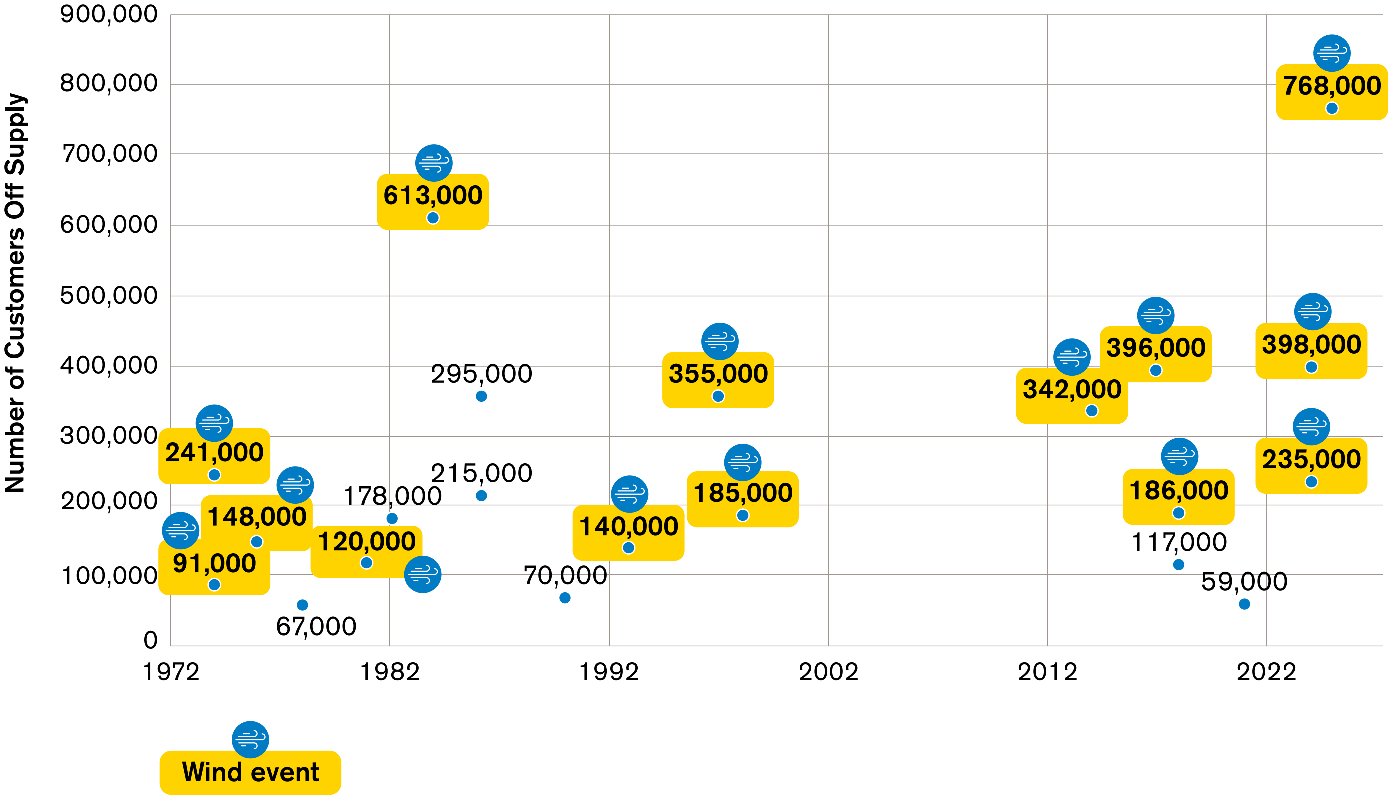
Table 1 gives a brief overview of the major weather events which have impacted the distribution network between 1974 and 2025 including the type of weather event and the peak number of customers without supply (where recorded data was available). The information in Table 1 comes from ESB Networks' records and Met Éireann wind measurements. This data is separate to the ERA5 wind data reviewed in section 3.

Table 1: Summary of Extreme Weather Events on Distribution Network 1974-2025

Year	Date	Storm Name	Event Description	Max Recorded Gust (km/hr)	Peak No. of Customers Off Supply
1974	11th January	-	Lightning & Wind	174	241,000
1974	27th-28th January	-	Lightning & Wind	177	91,000
1976	2nd January	-	Wind	161	148,000
1978	18th-19th February	-	Snow & Wind	113	67,000
1981	13th-14th December	-	Snow, Lightning & Wind	145	120,000
1982	8th January	-	Snow & Wind	55-113	178,000
1984	All January	-	Wind	166	613,000
1985	25th-26th July	-	Lightning & Heavy Rain	-	295,000
1986	26th-29th July	-	Lightning	-	215,000
1988	1st-9th February	-	Wind & Rain	172	-
1990/91	24th December-7th January	-	Snow, Rain, Lightning & Wind	153	70,000
1993	8th-9th December	-	Wind	154	140,000
1997/98	24th December-4th January	-	Lightning & Wind	166	355,000
1998	26th December	-	Wind	179	185,000
2014	12th February	Darwin	Wind	159	260,000
2017	16th October	Ophelia	Wind	156	360,000
2018	19th September	Ali	Wind	147	186,000
2018	28th February-4th March	Emma	Snow & Ice	-	117,000
2021	7th-8th December	Barra	Wind, Snow & Rain	135	59,000
2024	21st-22nd January	Isha	Wind	137	235,000
2024	6th-7th December	Darragh	Wind	141	395,000
2025	23rd-24th January	Éowyn	Wind	184	768,000

Figure 5 shows the peak number of customers without supply for each of the major storms shown in table 1. This shows that extreme wind events have typically been the most impactful to the network in terms of the number of customers without supply resulting from a storm. It is noted that the National Climate Change Risk Assessment (NCCRA), published in June 2025, highlights the impact of extreme winds on energy infrastructure as one of its key risks.

Figure 5: Major Weather Events 1974-2025 Peak No. Customers Off Supply



3 Historical Weather Data Analysis

As discussed in section 1.4.1, the overhead network details have been mapped and linked with 40 years of weather data (1st March 1985 to 28th February 2025) from the Copernicus ERA5 reanalysis dataset.

3.1 Historical Data on High Wind Events

The ERA5 historical weather data has been analysed in relation to high wind events in order to determine several areas of interest, including:

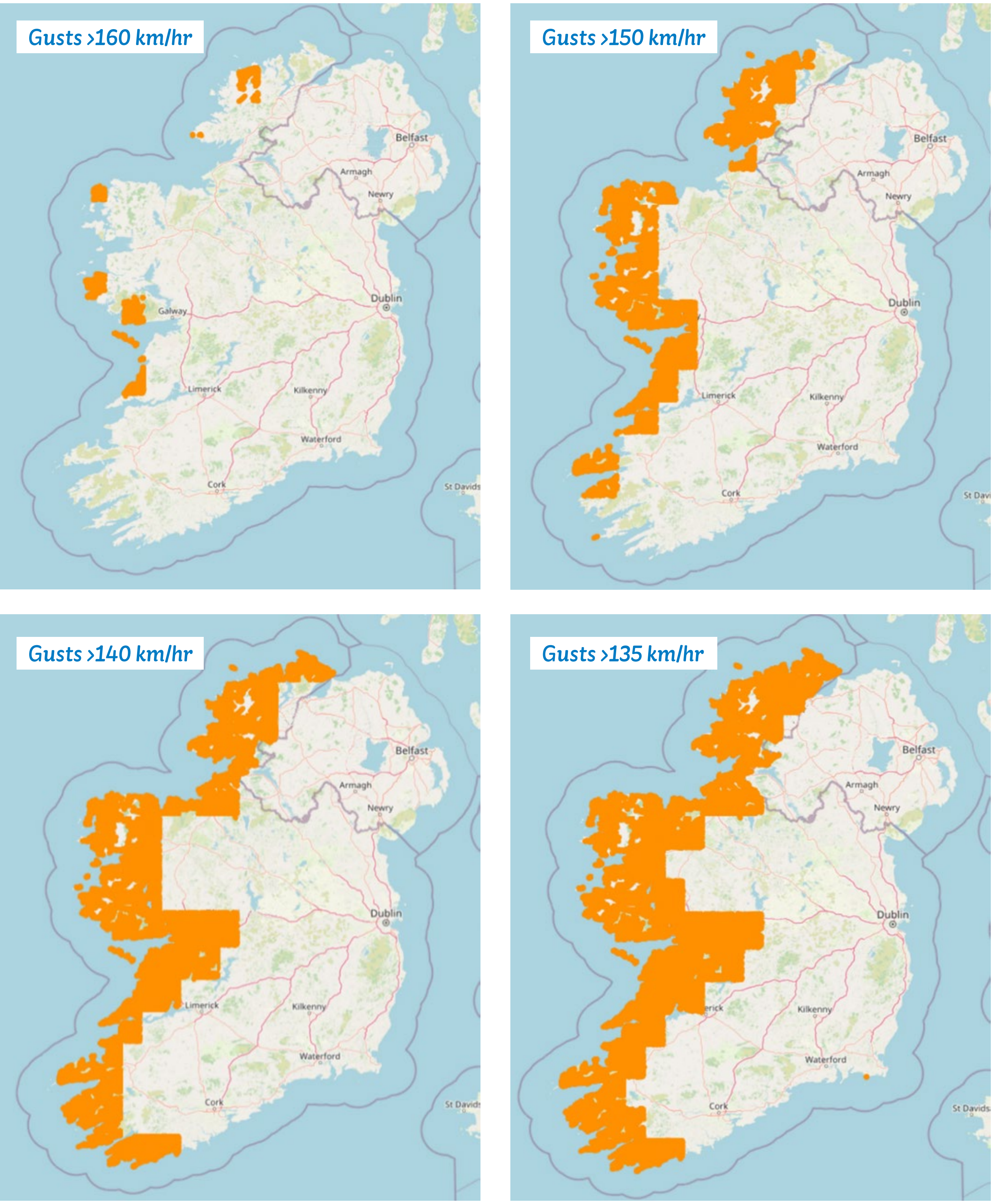
1. **Network most impacted by high wind events**
2. **Trends in the frequency of high wind events**
3. **Trends in the intensity of high wind events**

The gust wind data assessed has a resolution of 30 km, meaning that the gust wind speeds reported are the average gusts observed over a 30 km grid. This will mean that, in a given square on the grid, there will be locations which will have locally higher gust wind speeds and other locations where gusts will be lower. Some underestimation of gust wind speed is possible in the Copernicus ERA5 data and hence when looking to determine the percentage of network which has experienced an absolute limit it is sensible to consider the amount of network which has experienced a lower threshold to allow for this. This is discussed in greater detail in section 7 in relation to the consideration of design wind speeds. The gust wind speeds reported in the section 3.2 and section 3.3 are three-second gusts at 10 metres above ground level.

3.2 Network Impacted by Historical Wind Events

Figure 6 shows maps of Ireland with a highlight of the network which has seen the highest wind speeds over the 40-year period since 1985 based on the Copernicus ERA5 data.

Figure 6: ESB Networks overhead lines experiencing highest gust wind speeds 1985-2025 from Copernicus ERA5 data



Gusts >160 km/hr

Gusts >150 km/hr

Gusts >140 km/hr

Gusts >135 km/hr

3.3 Trends in Historical Wind Data

In order to assess the standards for distribution overhead lines it is important to consider trends in the frequency and intensity of high wind events on the network. From the 40 years of historical weather data (1st March 1985 to 28th February 2025) from Copernicus ERA5 which has been mapped against the network, data has been generated looking at the total count of hours the overhead MV network has experienced at different gust wind speed thresholds. The MV network is considered due to its geographic spread. Data has also been generated on the number of high wind events which have been observed each year on the most impacted assets.

The graphs shown in Figure 8 and Figure 9 illustrate the total hours where gust wind speeds impacting MV poles (combined total) reached a particular threshold. The count of hours is a combined total meaning that each hour for each pole is counted as a separate hour. The total hours of gust wind speeds reported in Figure 8 and Figure 9 are presented based on the thresholds outlined below:

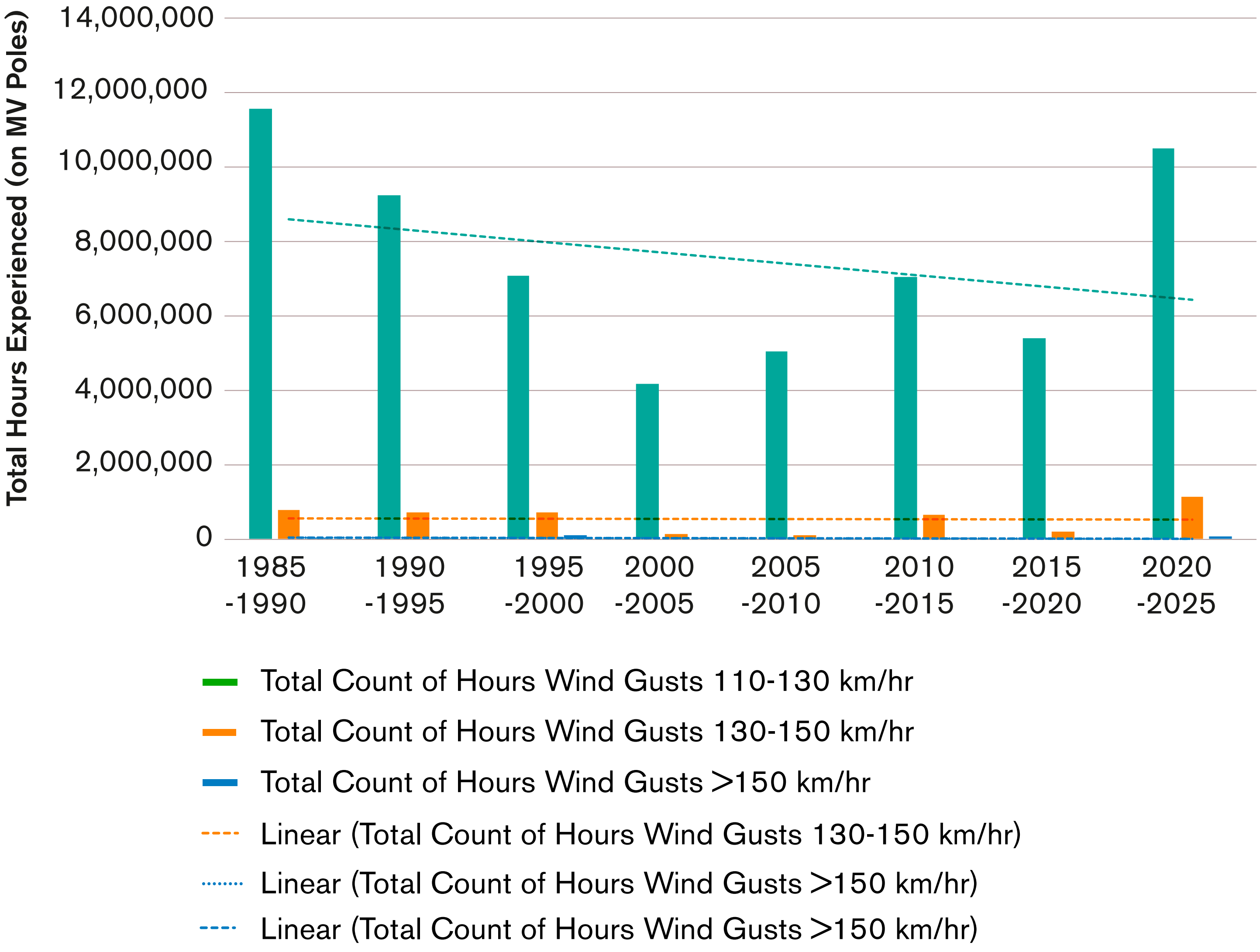
1. **Gusts between 110-130 km/hr (Orange Wind Warning)**
2. **Gusts between 130-150 km/hr (Red Wind Warning)**
3. **Gusts exceeding 150 km/hr (Red Wind Warning)**

To give these bandings more context, the Met Éireann Weather Warning System's criteria for yellow, orange and red wind warnings are shown in figure 7.

Figure 7: Met Éireann wind warning thresholds

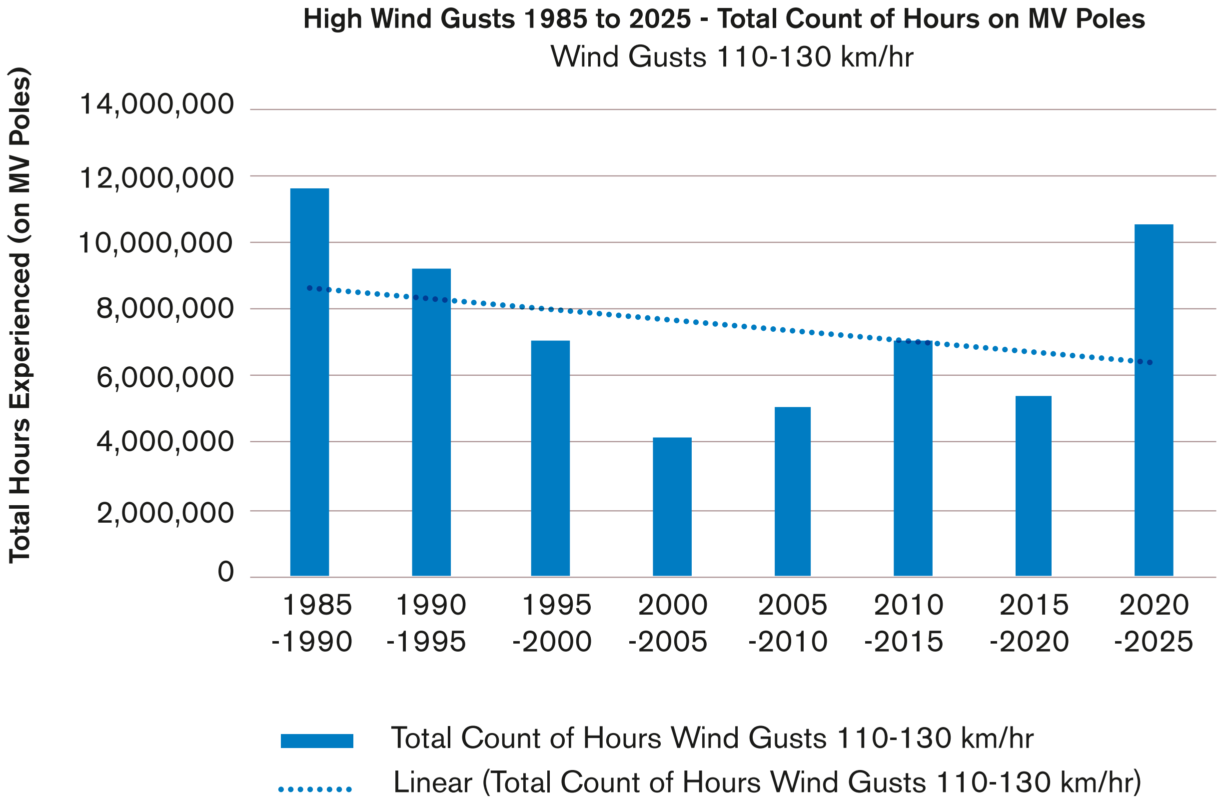
Status Yellow	Status Orange	Status Red
Weather that does not pose a threat to the general population but is potentially dangerous on a localised scale.	***Infrequent and dangerous weather conditions which may pose a threat to life and property.***	***Rare and very dangerous weather conditions from intense meteorological phenomena.***
Be aware about meteorological conditions and check if you are exposed to danger by nature of your activity or your specific location. Do not take any avoidable risks.	**Prepare** yourself in an appropriate way depending on location and activity. All people and property in the affected areas can be significantly impacted.	**Take action** to protect yourself and your property.
	Check your activity/event and delay or cancel as appropriate.	**Follow instructions** and advice given by the authorities under all circumstances and be prepared for exceptional measures.
Wind (mean speed: 10 minute)	**Wind** (mean speed: 10 minute)	**Wind** (mean speed: 10 minute)
• Widespread mean speeds between **50** and **65km/h**	• Widespread mean speeds between **65** and **80km/h**	• Widespread mean speeds in excess of **80km/h**
• Widespread gusts between **90** and **110km/h**	• Widespread gusts between **110** and **130km/h**	• Widespread gusts in excess of **130km/h**

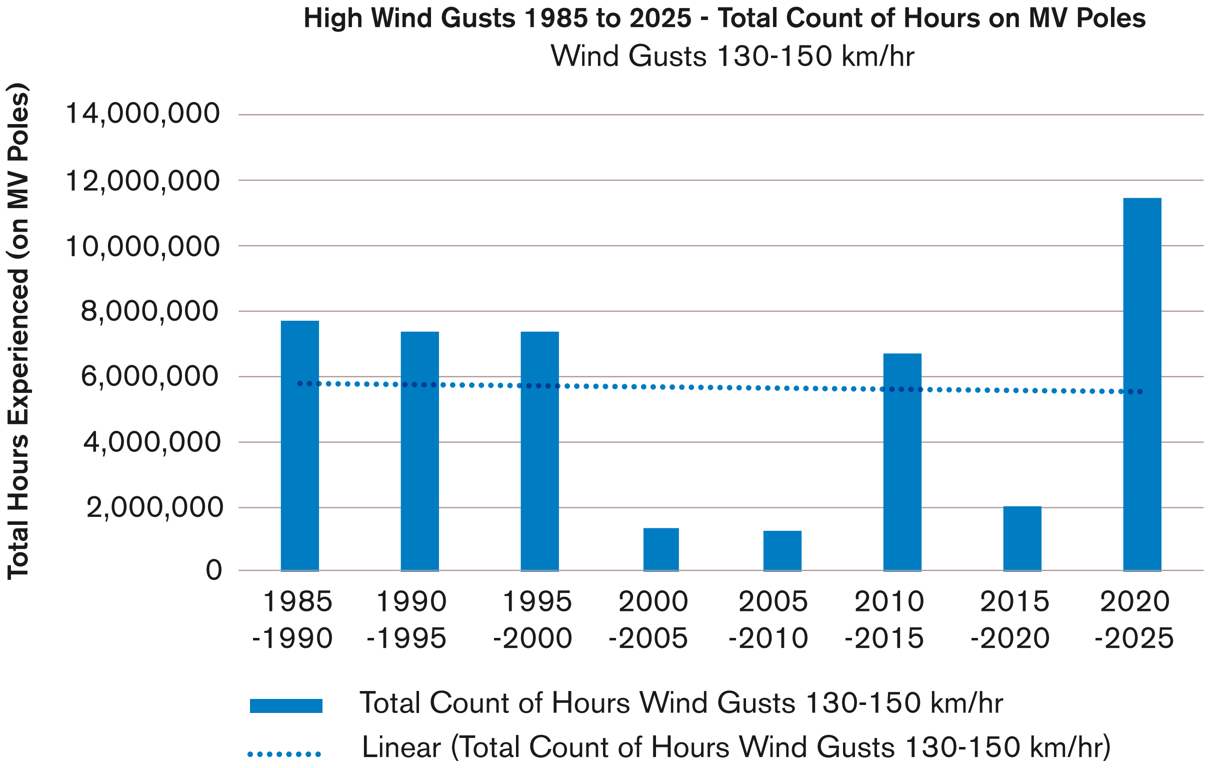
Figure 8: Analysis of high wind events on ESB Networks infrastructure 1985-2025 – total hours on all MV Poles from Copernicus ERA5 data

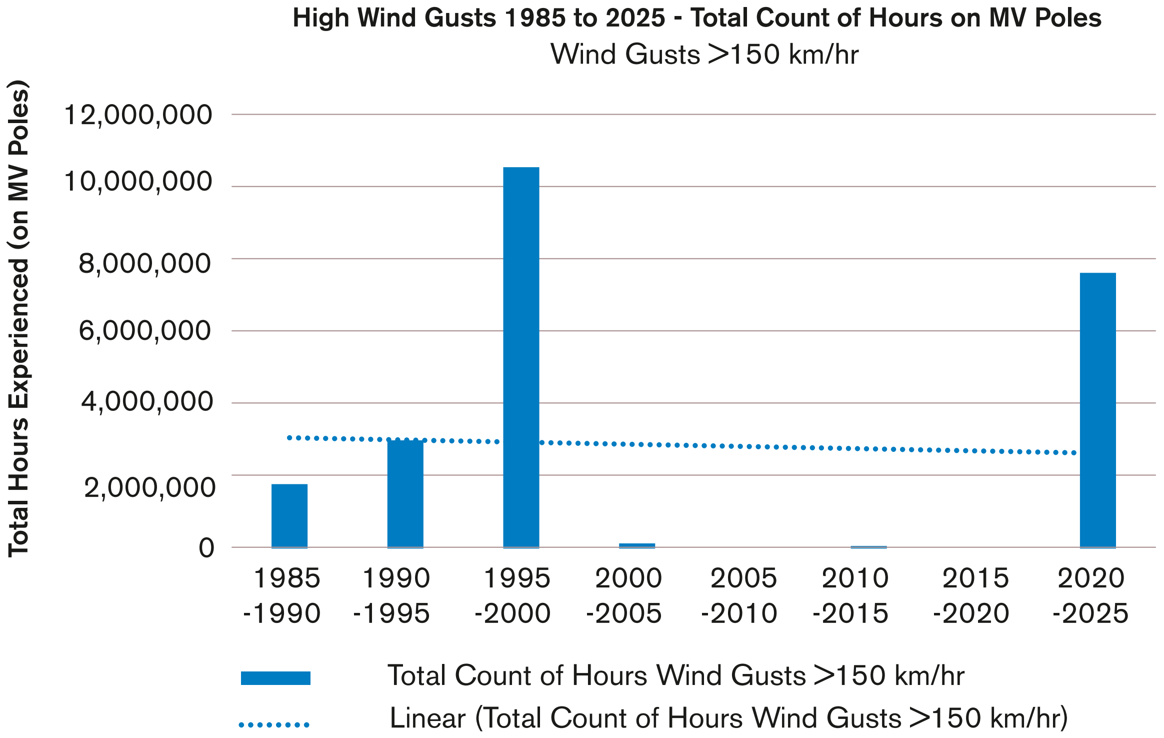


Note: Shown above are the combined total hours where gust wind speeds impacting MV poles reached a particular threshold. The count of hours is a combined total meaning that each hour for each pole is counted as a separate hour.'

Figure 9: Analysis of high wind events on ESB Networks infrastructure 1985-2025 – total hours on all MV Poles from Copernicus ERA5 data (separated graphs)

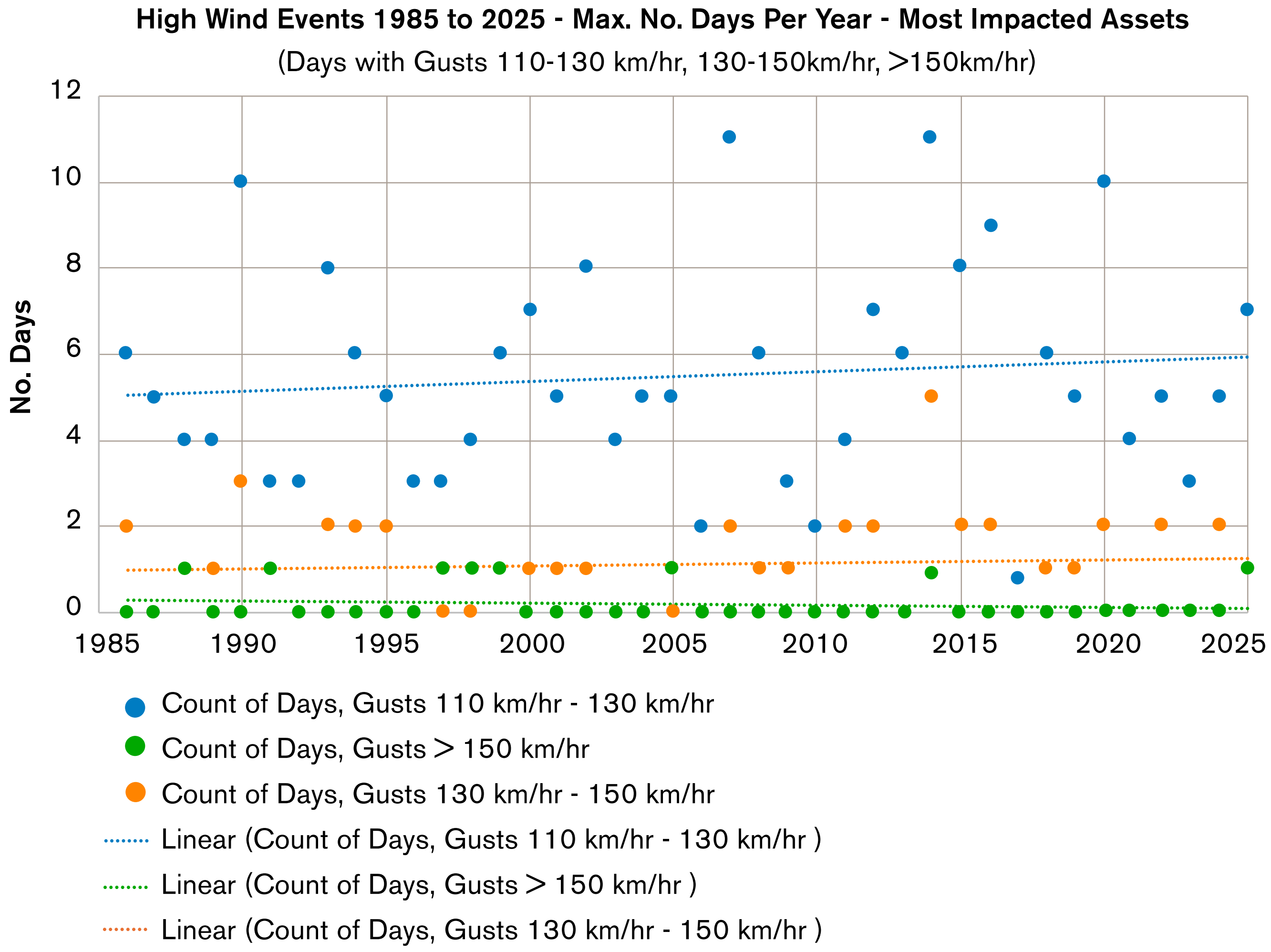






The graph shown in Figure 10 illustrates the count of days (for the most impacted assets) when gust wind speeds impacting the network reached the thresholds previously highlighted.

Figure 10: Analysis of high wind days on ESB Networks infrastructure – number of days on most impacted assets from Copernicus ERA5 data



The graph shown in figure 10 represents the most impacted assets, meaning that for a given year the figures shown represent the number of days in which a particular wind threshold was met on a particular distribution overhead network asset (with the highest number of repeat observations in the given year). This means that trending of this data relates to the most impacted assets.

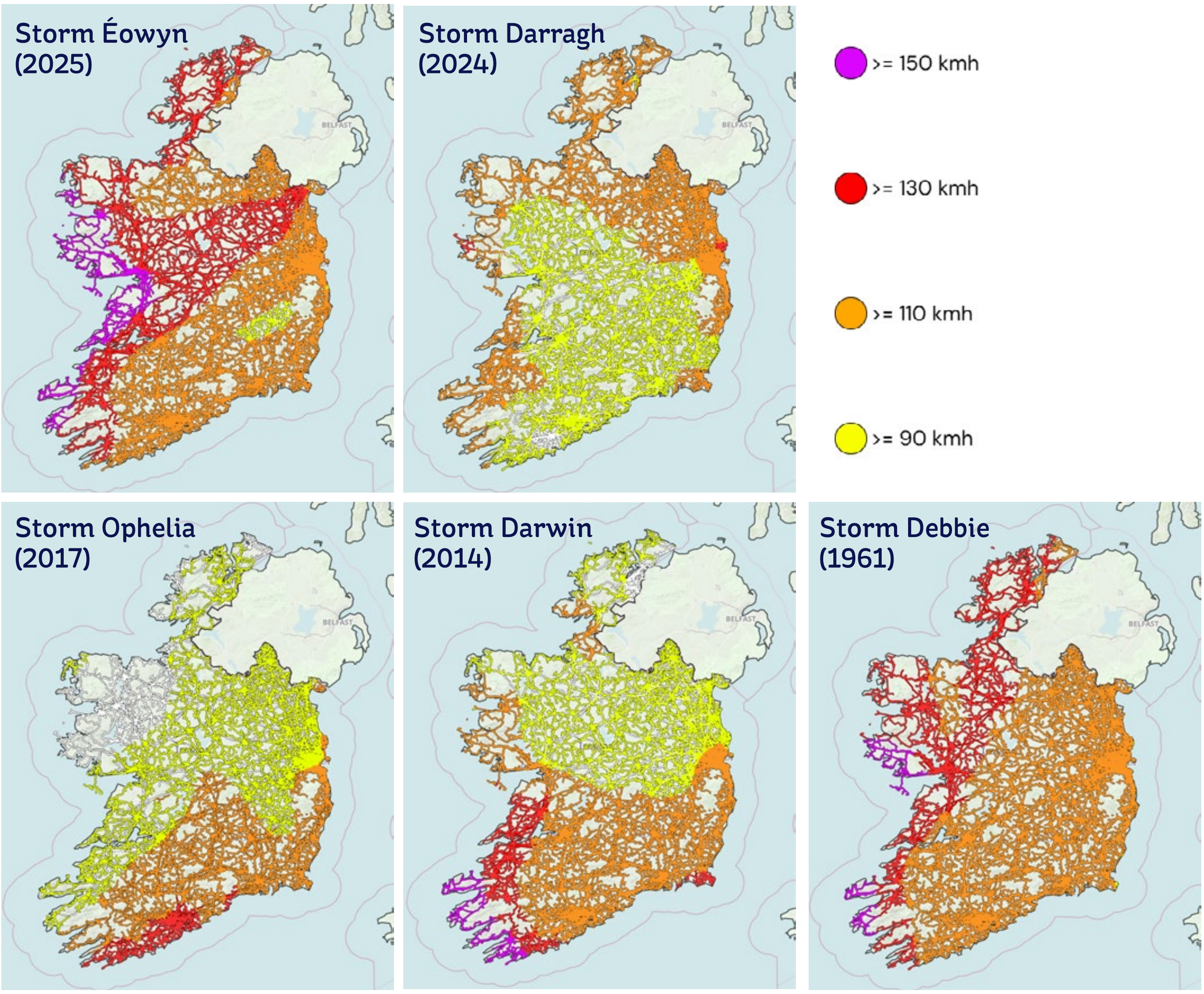
Examining the Copernicus ERA5 data presented in figure 8, figure 9 and figure 10, the following observations are noted:

1. Over the 40-year period examined there was a total of eight events in which wind gusts in the ERA5 data exceeded 150 km/hr. The trend in the data shows a decline in the frequency of these more severe windstorms, with six such events occurring in the 20 years between 1985 and 2005 and only two events occurring in the 20 years between 2005 and 2025. However, the rarity of these events means that accuracy of trend estimation is limited. The total count of hours for the most severe events is similarly difficult to trend, noting that for a 20-year period between 2000 and 2020, a low count of hours for these wind speeds was observed. It is noted that during this period there were a number of windstorms which had significant impacts on the network (most notably Storm Darwin and Storm Ophelia). This emphasises that windstorms at the lower thresholds illustrated are also important to consider. It is noted that Storm Éowyn, which occurred in January 2025, was one of the most severe windstorms experienced in Ireland in the last century. This is a reminder that trending of these rare events can be challenging.
2. The occurrence of storms in which the average gust wind speed reached 130-150 km/hr demonstrated a slight increasing trend over the period 1985 to 2025 when examining the number of days on the most impacted assets. However, the total hours across the entirety of the network demonstrated a slight decreasing trend.
3. The occurrence of storms in which the average gust wind speed reached 110-130 km/hr demonstrated an increasing trend over the period 1985 to 2025 when examining the number of days on the most impacted assets. However, the total hours across the entirety of the network demonstrated a decreasing trend.

The National Climate Change Risk Assessment (NCCRA), published in June 2025, highlights the impacts of extreme wind on energy infrastructure as a key risk. The report states that *'while climate projections show potentially limited changes in extreme wind events in the future, there is a high degree of uncertainty associated with the projections. Extreme events over recent years have shown however, that Ireland has high exposure to the impacts of extreme wind in these sectors. The current level of impact experienced means that the consequence is therefore assessed as Critical now and in the future'.*

The graphics shown in figure 11 show the intensity of wind on the network during a number of notable extreme storms (Éowyn 2025, Darragh 2024, Ophelia 2017, Darwin 2014 and Debbie 1961). These graphics indicate the peak wind speeds experienced on the network over the course of the storms based on ERA5 weather data. The maps shown in figure 11, indicate that the wind speeds observed during Storm Éowyn in 2025 were more severe and widespread than even the most impactful storms experienced in the last 75 years.

Figure 11: Storm wind intensity on ESB Networks infrastructure ERA5 wind gust data for Storms Éowyn, Darragh, Ophelia, Darwin and Debbie



4 Future Weather Data Analysis

The overhead network details have been mapped and linked with 20 years of future modelled weather data (1st January 2031 to 31st December 2050). The future modelled weather data considers the following two climate scenarios:

- RCP4.5 – Moderate mitigation resulting in intermediate emissions. Global mean temperature increase approximately 2.4°C.
- RCP8.5– No mitigation ('business as usual') resulting in high emissions. Global mean temperature increase is over 4.0°C.

These climate scenarios are linked to the level of mitigations implemented globally to reduce the emission of greenhouse gases, known as Representative Concentration Pathways (RCPs). RCP 4.5 and RCP 8.5 have also been adopted for the assessment completed in the National Climate Change Risk Assessment (NCCRA) published in June 2025. The modelled future weather wind gust data is taken from the Meteorological Research Institute Earth System Model Version 2.0 (MRI-ESM2.0), which is part of the globally recognised Coupled Model Intercomparison Project Phase 6 (CMIP6). This data is looked at as part of the review at this time as the downscaled Met Éireann TRANSLATE weather models for wind gusts in Ireland are not currently available. The TRANSLATE data (or similar) for wind gusts will be reviewed once available.

The future modelled weather data is examined to establish predicted trends in windstorms.

4.1 Future Modelled Data on High Wind Events

The future modelled weather data has been analysed in relation to high wind events for the two climate scenarios in order to determine several areas of interest, including:

1. **Possible changes to network most impacted by high wind events under RCP 4.5 and RCP 8.5 climate scenarios.**
2. **Trends in the frequency of high wind events under RCP 4.5 and RCP 8.5 climate scenarios.**
3. **Trends in the intensity of high wind event under RCP 4.5 and RCP 8.5 climate scenarios.**

The RCP 4.5 and 8.5 scenarios are considered in this review for consistency with the National Climate Change Risk Assessment (NCCRA) published in June 2025.

When using future modelled data caution should be taken when comparing absolute values versus historical data. Examining the modelled future weather wind gust data in detail, it is observed that the values reported for wind gusts (duration and intensity) typically report somewhere in the region of 20 km/hr less than the Copernicus ERA5 historical weather data. For example, in the ERA5 historical wind data at gust wind speeds of 130-150 km/hr, the number of hours across all MV poles was 565,154 hours on average, in each five-year period from 1985 to 2025. Examining the MRI-ESM2.0 future modelled wind gust data for RCP 8.5 and RCP 4.5 reports five-year averages of 489,187 hours and 344,285 hours respectively, based on gust wind speeds of 110-130 km/hr. (As noted in section 3.3, the count of hours referred to is a combined total meaning that each hour for each pole is counted as a separate hour. These total counts account for between 3 to 5 hours approximately on average per impacted MV pole over a five-year period, depending on the number of poles impacted in each case). This cannot be seen as a prediction of decreasing wind speeds, but rather that there is a degree of inherent data bias between the global modelled data over Ireland and the observed Irish data. Focus should instead be on comparing trends for each climate scenario and comparing relative changes with regards to RCP 4.5 and RCP 8.5 outcomes.

Met Éireann are currently expanding their TRANSLATE climate prediction data to include wind gusts. One of the aims of this work is to generate climate prediction data specific for Ireland that has a much lower inherent bias than global modelled data, and this will be reviewed once available.

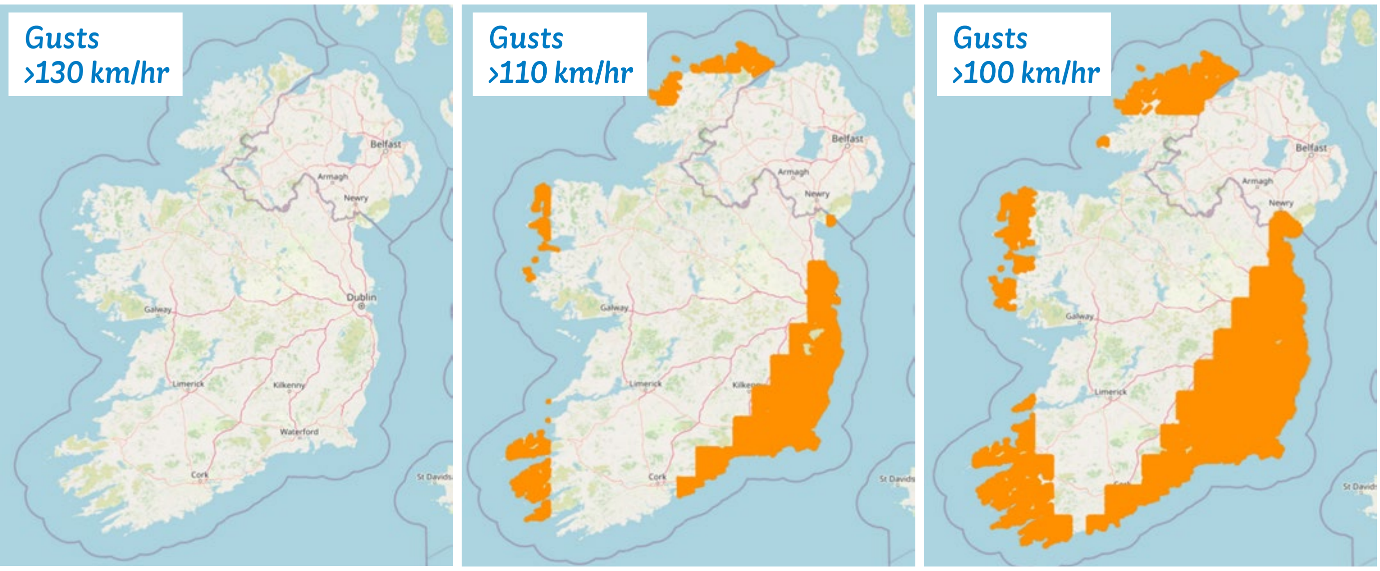
The gust wind speeds reported in section 4.2 and section 4.3 are three-second gusts at 10 metres above ground level.

4.2 Network Impacted in Modelled Future High Wind Events

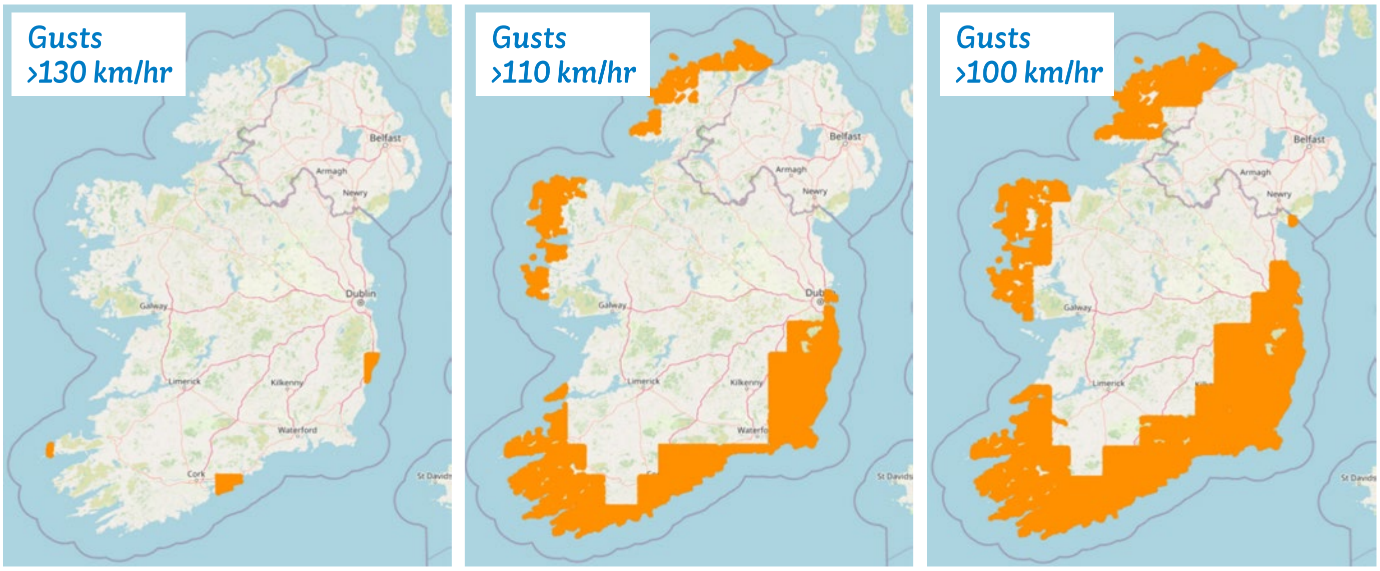
Copernicus ERA5 historical wind data from 1985 to 2025 shows the seaboard on the western side of the country (including north-west and south-west) as the area most exposed to high winds, as shown in Figure 6. The MRI-ESM2.0 future modelled weather data for both RCP 4.5 and RCP 8.5 indicates that areas bordering the south coast and south-east coast may also be vulnerable to severe wind events, as shown in Figure 12.

Figure 12: RCP 4.5 and RCP 8.5 future modelled wind gusts – impacted network from MRI-ESM2.0 data

RCP 4.5 Model Wind gusts: Impacted Network 2031-2050



RCP 8.5 Model Wind gusts: Impacted Network 2031-2050



4.3 Trends in Future Wind Data

In order to assess the standards for distribution overhead lines it is important to consider possible future trends in the frequency and intensity of high wind events on the network. Standards which may have met needs in the past may not continue to do so in the future. From the MRI-ESM2.0 future modelled weather data examined (1st January 2031 to 31st December 2050), data has been generated on the total count of hours the overhead MV network has experienced at different gust wind speed thresholds. As previously highlighted, the MV network is considered due to its geographic spread.

The graphs shown in Figure 13 and Figure 14 illustrate the total hours where gust wind speeds impacting MV poles (combined total) are predicted to reach a particular threshold. The count of hours is a combined total meaning that each hour for each pole is counted as a separate hour. As noted in section 4.1, it is observed that the values reported for wind gusts (duration and intensity) typically report somewhere in the region of 20 km/hr less than the Copernicus ERA5 historical weather data. For this reason, the total hours of gust wind speeds reported in Figure 13 and Figure 14 are presented based on thresholds which are 20 km/hr lower than those presented in section 3.3, as follows:

1. **Gusts between 90-110 km/hr**
2. **Gusts between 110-130 km/hr**
3. **Gusts exceeding 130 km/hr**

In section 3.3, it is noted that based on the Copernicus ERA5 data the most severe wind events (where average gusts exceed 150 km/hr) are rare, with six such events occurring in the 20 years between 1985 and 2005 and only two events occurring in the 20 years between 2005 and 2025.

Figure 13: RCP 8.5 future modelled wind gusts 2031-2050 – total hours on all MV poles from MRI-ESM2.0 data

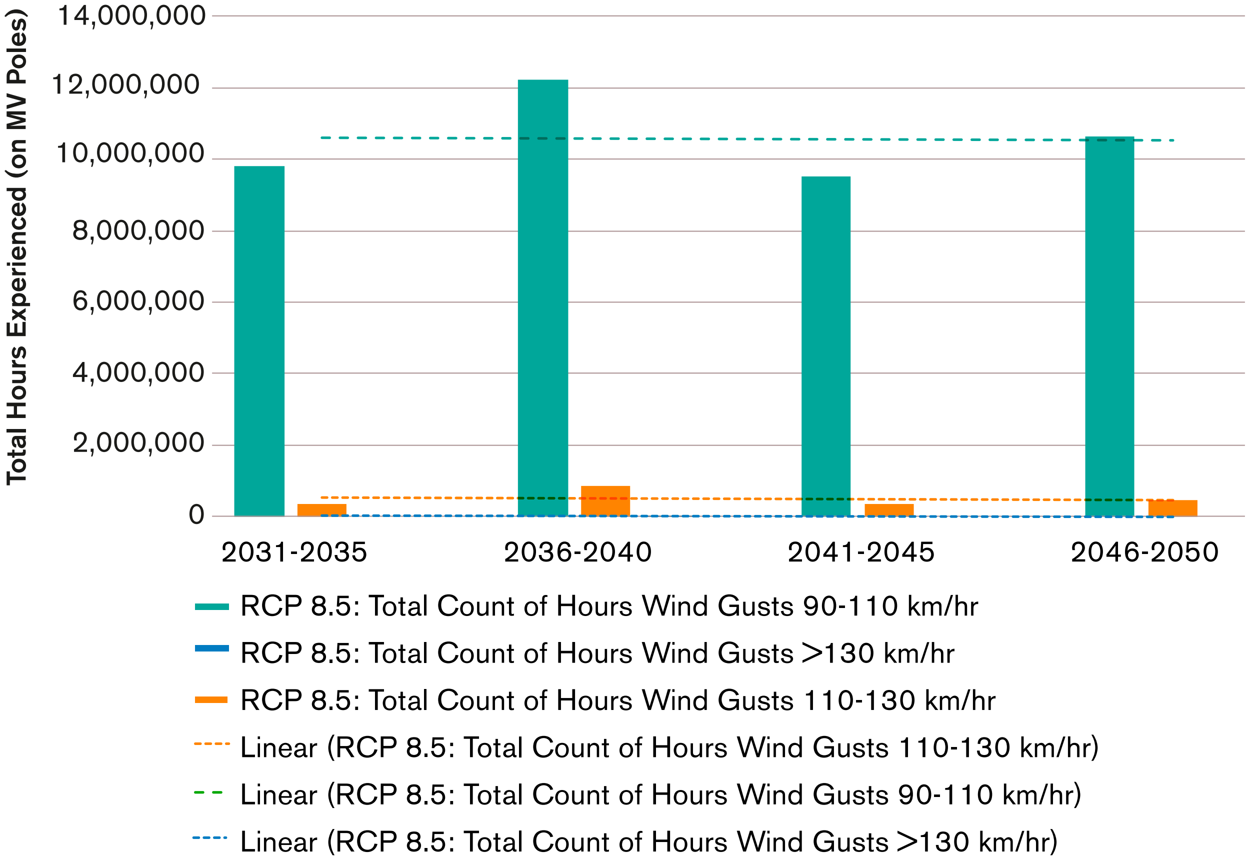
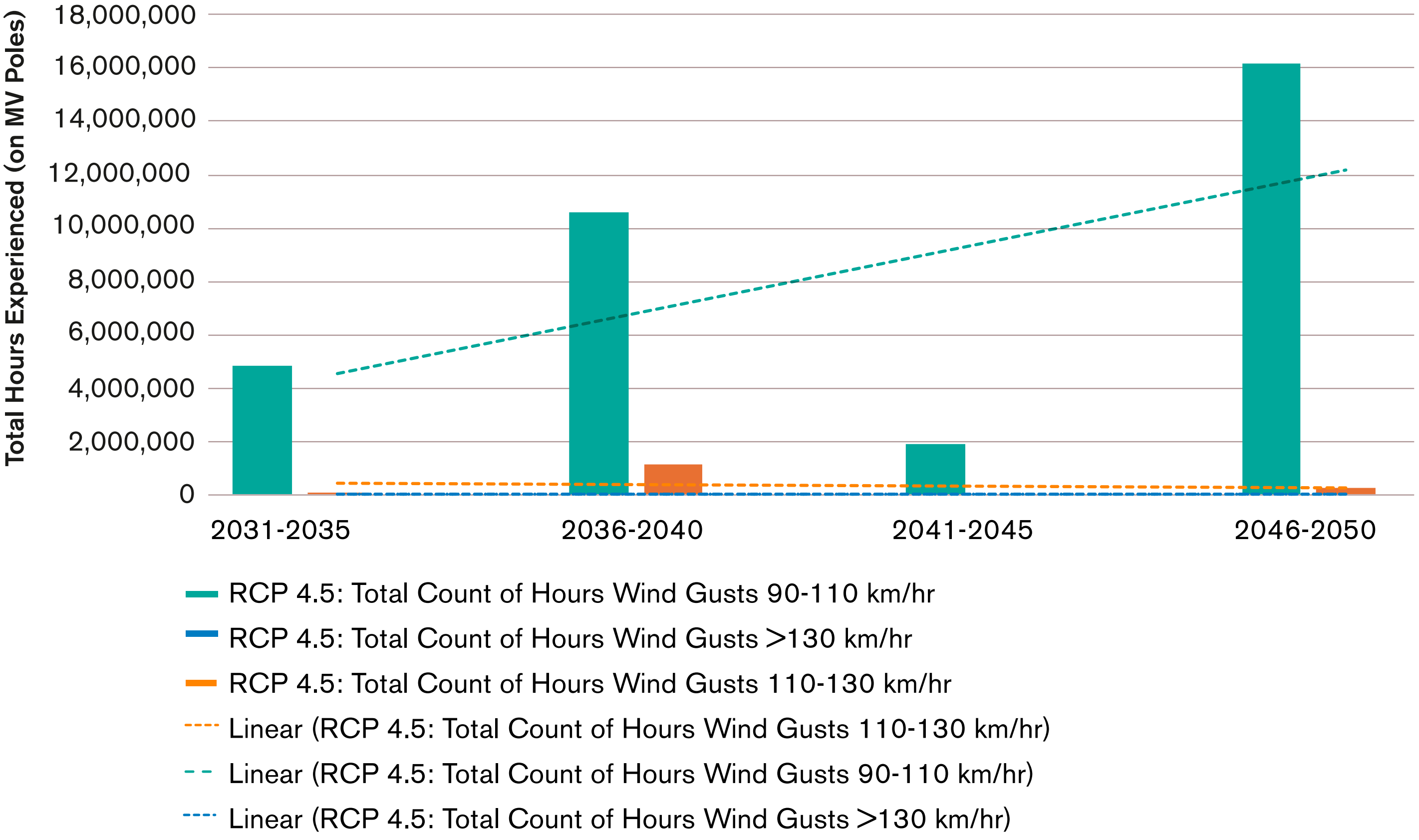


Figure 14: RCP 4.5 future modelled wind gusts 2031-2050 – total hours on all MV poles from MRI-ESM2.0 data



Examining the graphs presented in figure 13 and figure 14 alongside the underlying data, the following observations are noted:

1. Comparing modelled wind data to the end of 2050 from both RCP 4.5 and RCP 8.5, the RCP 8.5 scenario indicates increased total wind hours on the network at all high wind speed intervals considered. The RCP 8.5 modelled wind gust data shows a 26% increase in wind hours on the network at wind speeds 90-110 km/hr and a 46% increase in wind hours on the network at wind speeds 110-130 km/hr when compared with the RCP 4.5 modelled wind gust data. It is noted that for wind speeds in excess of 130 km/hr, the scarcity of these events in the modelled data may mean that there is not a reliable statistical basis upon which to draw a conclusion regarding an increase for the most severe windstorms.
2. Although the RCP 8.5 scenario reports more wind hours on the network compared to the RCP 4.5 scenario, the trends over the 20 years of data for RCP 8.5 indicate a static trend over the period up to the end of 2050.
3. The RCP 4.5 scenario indicates a static or slightly decreasing trend for wind hours on the network at wind speeds of 110-130 km/hr. At wind speeds of 90-110 km/hr the RCP 4.5 modelled data indicates a possible increasing trend of wind hours on the network. However, this may be normalised if considering a longer period within the modelled data.
4. Based on comparison of the total wind hours from RCP 4.5 and RCP 8.5 models up to 2050, the data indicates that with increased global warming there may be an increase in the amount of wind experienced on the network. However, the Sectoral Adaptation Plan (SAP) for electricity and gas networks[1] published in 2025 identifies a number of future wind projections which show potential decreases in the number of days for some wind speed thresholds.

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[1] *Sectoral Adaptation Plan (SAP) for Electricity and Gas Networks published in 2025*

The NCCRA Technical report[1] published in June 2025, emphasises that for Ireland, confidence in projection of extreme wind speeds is considered very low due to the limited availability of global, regional and national projections, with further investigation required. In the NCCRA, European scale projections (EURO-CORDEX) have been employed to assess future changes in exposure with a minor reduction in extreme wind days projected, for both RCP 4.5 and RCP 8.5 scenarios. By 2100, a decrease is projected in both scenarios of -0.47 days (RCP 4.5) and -0.44 days (RCP 8.5).

The Environmental Protection Agency (EPA) reports 339[2] and 471[3] which focus on high resolution climate projections for Ireland, use national scale projections which project a 10% reduction in the frequency of less intense storms affecting Ireland, aligning with projections employed through the NCCRA. The study also suggests an increase in more severe windstorms. However, the severe storms considered as part of this study are considered as rare events, and as a result, the authors state that the storm projections should be considered with a high level of caution. Among the recommendations of EPA report 471 it states:

"Future work will assess the impact of climate change on North Atlantic storms. As extreme storm events are rare, this work will require analysing a very large ensemble, thus allowing a robust statistical analysis of extreme storm track projections".

ESB Networks will continue to be guided by expert analysis included in the NCCRA and the research which informs this risk assessment.

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[1] *National Climate Change Risk Assessment (NCCRA) Technical Report published by the Environmental Protection Agency (EPA) in June 2025*

[2] *Report 339: High-resolution Climate Projections for Ireland – A Multi-model Ensemble Approach published by the Environmental Protection Agency (EPA) in 2020*

[3] *Report 471: Updated High-resolution Climate Projections for Ireland published by the Environmental Protection Agency (EPA) in 2024*

5 Independent Review of Wind and Storms in Ireland

In 2025, ESB Networks also commissioned an independent report to gain better understanding of storm and wind gust patterns across Ireland. This report was prepared by a weather data provider and consultancy called 'Meteomatics'. This work drew on recent meteorological data and insights from literature. The findings of this independent report are outlined below.

1. Storm Activity is a Climatic Norm for Ireland

Ireland frequently experiences strong Atlantic storms, a result of its position beneath the North Atlantic jet stream and along the primary Atlantic storm track. This geographical setting exposes the region to a higher storm incidence than many neighbouring areas, including much of the United Kingdom (UK) and western European DSO regions (e.g. Brittany, the Netherlands).

2. Seasonal Shifts in Moderate Wind Gusts

Wind events reaching speeds of approximately 75 km/h have shown a distinct seasonal reconfiguration since 1980. In autumn and winter, the frequency of such gusts has diminished. In contrast, summer seasons now exhibit a relative increase, coinciding with rising thunderstorm activity likely driven by a warmer atmosphere with higher convective potential.

3. Directional Changes in Extreme Gusts

Extreme gusts, defined in the report as wind speeds exceeding 110 km/h, have not become more frequent in aggregate. However, the dominant wind direction during these events has shifted. Historically arriving from the west, such gusts now more often originate from the southwest. This subtle shift may reflect changes in synoptic-scale pressure systems and storm tracks under a warming climate regime.

4. Regional Relevance of UK Climate Findings

Although centred on the UK, the State of the UK Climate 2024[1] report offers valuable insights for Ireland too. Given the close climatic links between the two countries, particularly across western regions, many of its conclusions can reasonably be extended to Irish conditions; heat and rainfall extremes are increasing markedly and are now a regular feature. In contrast, storm trends are less clear; the report does not conclude that storms have become more intense or frequent overall

Climate models suggest a weakening of pressure gradients across the North Atlantic, likely contributing to a continued decline in the overall number of storms. However, this does not equate to lower risk. Warmer sea surface temperatures increase the availability of latent energy, heightening the potential for explosive cyclogenesis and intense wind gusts. Moreover, ex-tropical cyclones may persist longer into the mid-latitudes, possibly raising the frequency of impactful storm events in future autumns.

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[1] *State of the UK Climate Report 2024 published in July 2025*

Ireland's storm and wind-gust landscape is undergoing measurable change. While certain risks appear to be moderating—such as the overall number of strong gusts in winter—others may intensify, especially in summer and autumn months. Planning for the future will require a nuanced understanding of these evolving patterns.

It is noted that in this report an overall trend towards higher peak wind gusts was observed based on a linear regression of annual peak wind gusts since 1980. This would be consistent with the NCCRA which highlight the potential for fewer but stronger windstorms.

6 Strength of Overhead Distribution Network

6.1 Background of Overhead Line Standards

Overhead line standards in Ireland have evolved over time, originating with the German VDE standard which was introduced by Siemens during the Ardnacrusha hydroelectric scheme in the late 1920s and subsequent expansion of rural electrification. Standards have been improved where necessary in order to respond to the impact experienced on the network. An example of this relates to icing conditions experienced in the early 1940s which were used in updating the 38 kV overhead line design standard.

The strength of overhead network to current standards relates to component/material design and rationalisation as well as the underlying principles applied in designs. Standards for overhead lines specify the environmental conditions (e.g. wind speed or ice weight) for which different network must be designed but also include design parameters such as factors of safety and material strengths to be adopted in the design. The mechanical strength of the overhead network is also affected by design spans which may be limited to ensure that required ground clearance is achieved and to avoid conductor clashing. Furthermore, the rationalisation of material components (e.g. limiting the number of different poles, stays, crossarms) can result in increasing the mechanical strength in some configurations of the overhead network.

6.2 Mechanical Strength of Overhead Distribution Network

The analysis and results presented in this report are based on standard designs for components (e.g. poles, crossarms, stays, conductors) which have not deteriorated in condition and which have been constructed and maintained in line with the relevant standards.

LV and MV overhead network have been assessed based on the target spans set out in ESB Networks' standards. 38 kV network has been assessed based on existing network line designs as this network follows a different design and planning process to LV and MV overhead network. Mean wood pole strength is considered for LV and MV standard designs. Mean wood pole strength is the average strength achieved by wood poles based on mechanical testing. Wind loading is considered acting at the most onerous direction relative to the overhead line (typically perpendicular to the line).

6.2.1 Mechanical strength of LV overhead network standard

Finite element computer models were developed for a variety of network configurations in order to determine the mechanical strength for each configuration under wind loading. A simulated circuit was modelled in order to include all structure types (i.e. end poles, double end poles, branch poles, light angle poles, medium angle poles, heavy angle poles and intermediate poles). The configurations were modelled for both single-phase and three-phase network with different conductor sizes. Wind loading was applied in the model and the withstand capacity of the network was recorded.

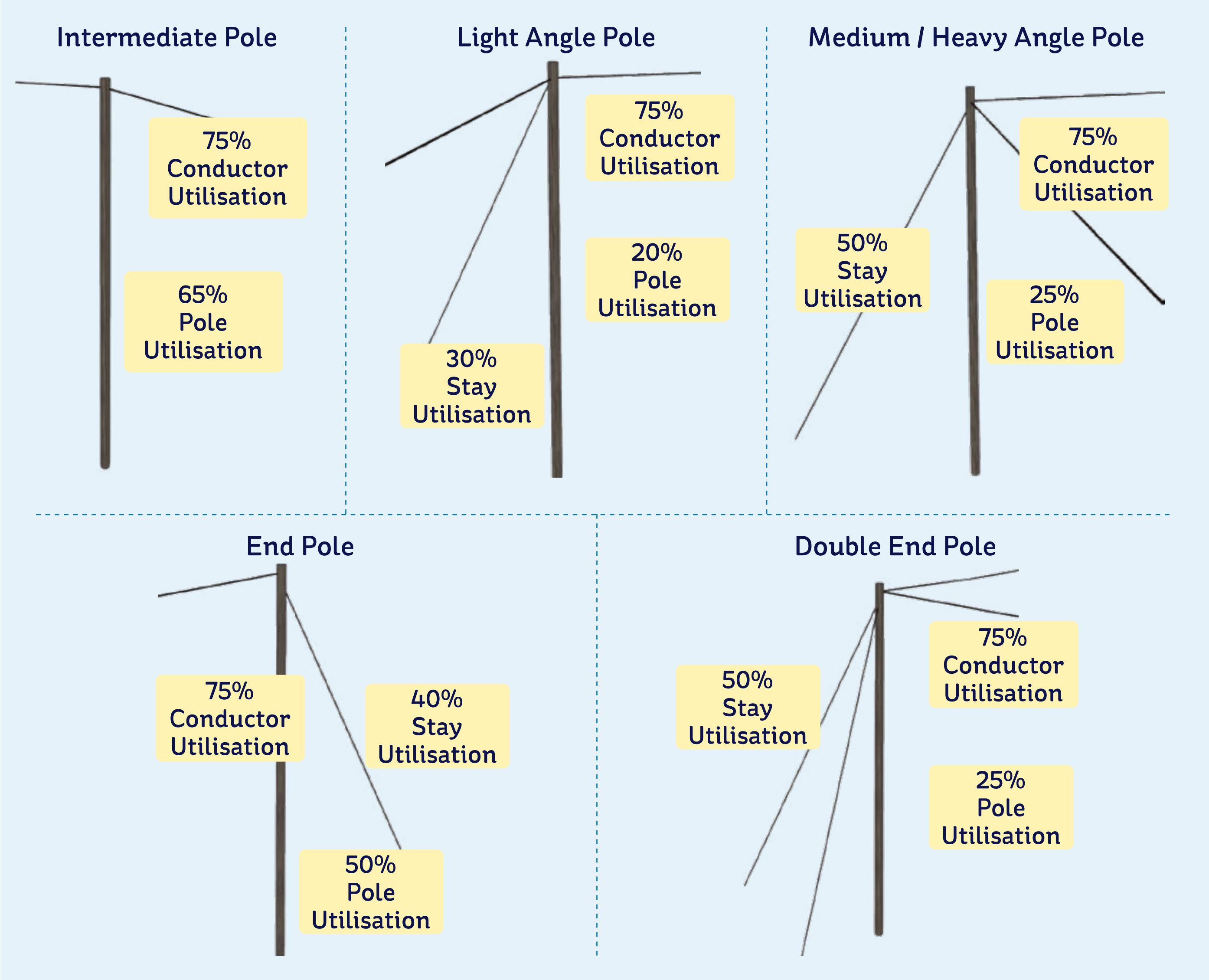
The LV overhead network consists of a mixture of historical bare (uninsulated) network where conductors are attached to poles/crossarms at a certain spacing to isolate phases, and more modern Aerial Bundle Conductor (ABC) in which several insulated wires are twisted together in a bundle which is strung between structures. Current GIS records show that 60% of the LV overhead network consists of ABC network. All new LV overhead construction uses ABC, with bare conductor only being used on the LV network for repair work where necessary. The majority of LV overhead lines constructed with ABC consist of single-phase or three-phase network with 50 mm^2 or 95 mm^2 conductors.

The details and analysis results are as follows:

- Single-phase 50 mm² ABC constitutes ~28% of LV overhead network constructed with ABC. Standard designs for this network configuration have the mechanical strength to withstand wind speeds in excess of 180 km/hr. The conductor breaking strength is the governing component in the design.

Figure 15 provides an overview of structural utilisations for single-phase 50 mm² ABC overhead network based on current standards under loading resulting from 180 km/hr wind speeds. In this context the term 'utilisation' refers to the degree to which a component such as a pole, steel crossarm, stay or conductor is utilised for a given applied load relative to its structural capacity. For example, a component at 100% utilisation for a particular loading condition has reached its maximum capacity. If the load is increased further it will exceed its rated strength.

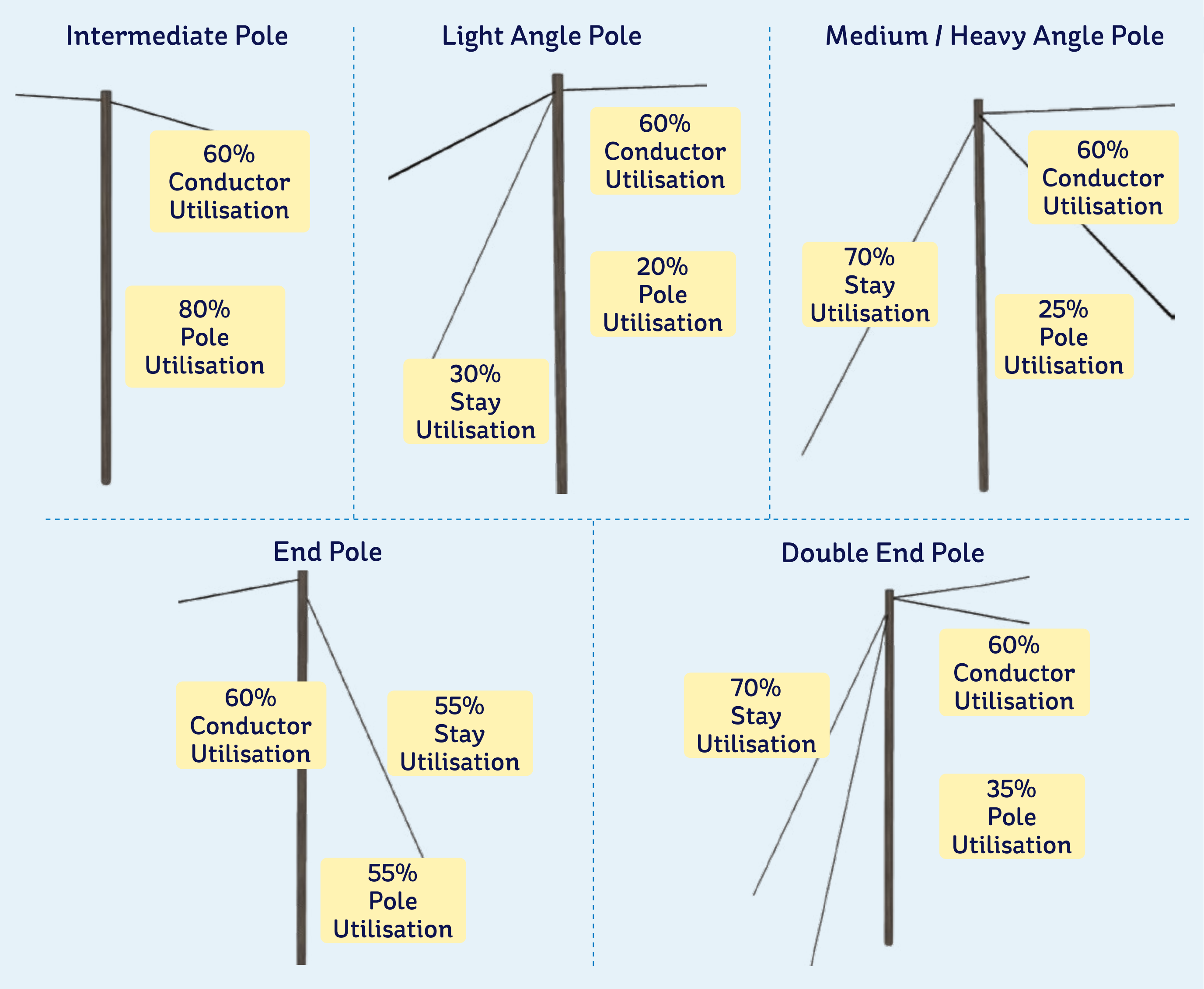
Figure 15: Single-phase 50 mm² ABC overhead network – structural utilisations for 180 km/hr wind



- Single-phase 95 mm² ABC constitutes ~61% of LV overhead network constructed with ABC. Standard designs for this network configuration have the mechanical strength to withstand wind speeds in excess of 180 km/hr. The wood pole on intermediate structures is the governing component in the design.

Figure 16 provides an overview of structural utilisations for single-phase 95 mm² ABC overhead network based on current standards under loading resulting from 180 km/hr wind speeds.

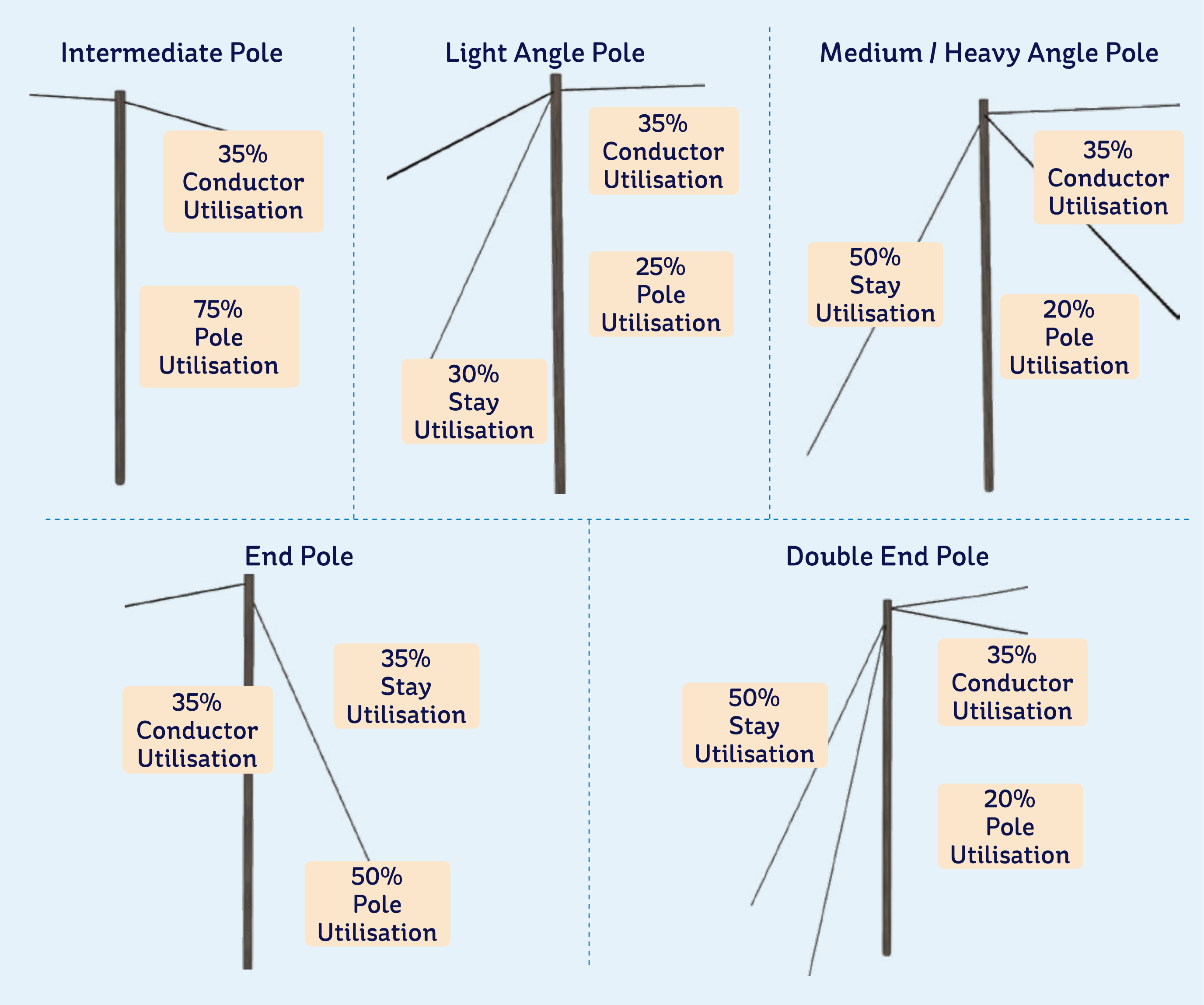
Figure 16: Single-phase 95 mm² ABC overhead network – structural utilisations for 180 km/hr wind



- Three-phase 50 mm² ABC constitutes ~3% of LV overhead network constructed with ABC. Standard designs for this network configuration have the mechanical strength to withstand wind speeds in excess of 180 km/hr. The wood pole on intermediate structures is the governing component in the design.

Figure 17 provides an overview of structural utilisations for three-phase 50 mm² ABC overhead network based on current standards under loading resulting from 180 km/hr wind speeds.

Figure 17: Three-phase 50 mm² ABC overhead network – structural utilisations for 180 km/hr wind



- Three-phase 95 mm² ABC constitutes ~7% of LV overhead network constructed with ABC. Standard designs for this network configuration have the mechanical strength to withstand wind speeds in excess of 180 km/hr. The wood pole on intermediate structures is the governing component in the design.

Figure 18 provides an overview of structural utilisations for three-phase 95 mm² ABC overhead network based on current standards under loading resulting from 180 km/hr wind speeds.

Figure 18: Three-phase 95 mm² ABC overhead network – structural utilisations for 180 km/hr wind

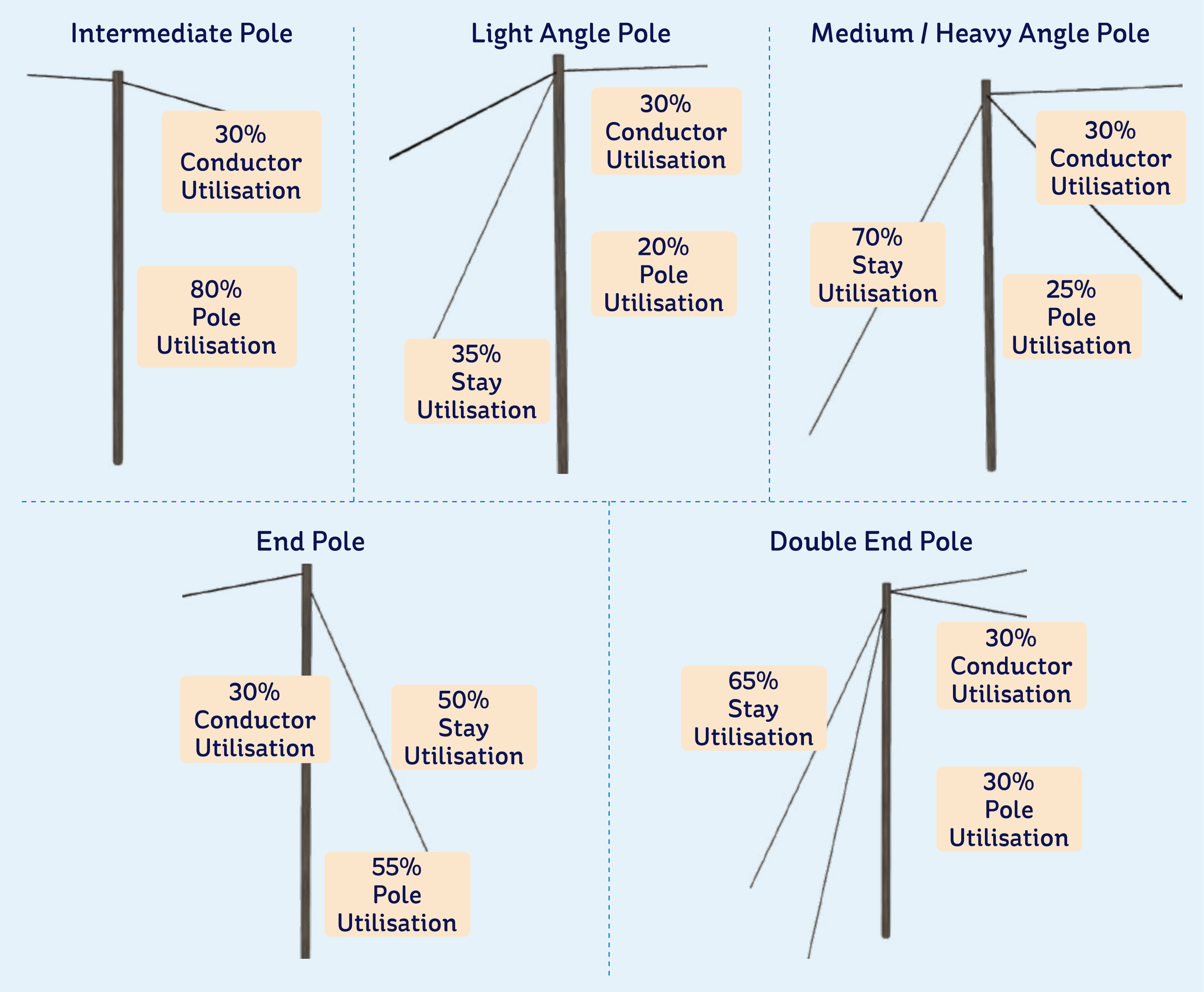


Table 2 summarises the strength for different LV overhead network configurations based on the current standards.

Table 2: Strength of standard designs for LV overhead network (summarised)

LV Overhead Network Configuration	Strength of Standard Network Designs to Wind Gust Speed (km/hr)
2 x 50 mm² ABC (single-phase)	>180 km/hr
2 x 95 mm² ABC (single-phase)	>180 km/hr
4 x 50 mm² ABC (three-phase)	>180 km/hr
4 x 95 mm² ABC (three-phase)	>180 km/hr

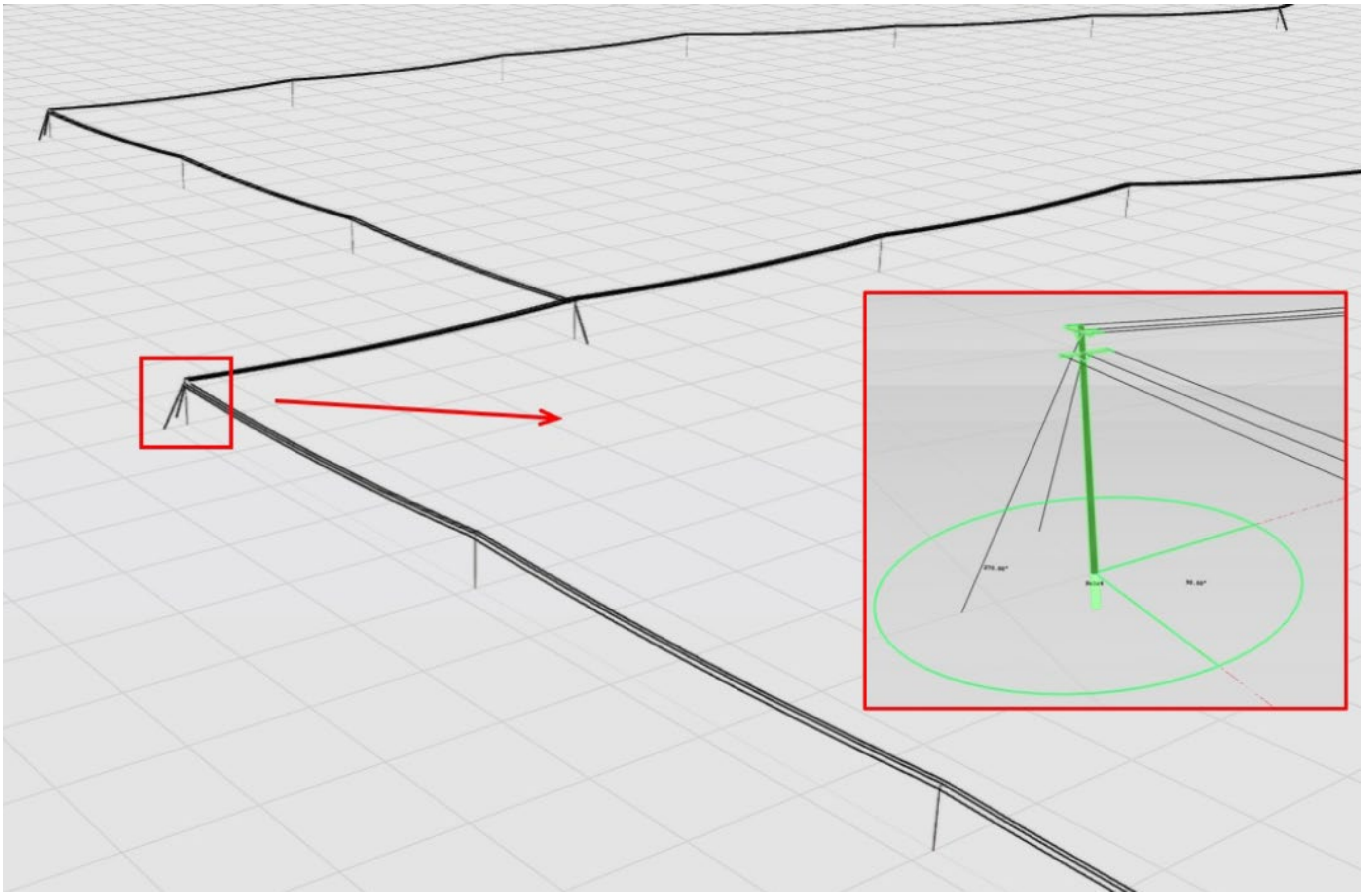
Bare LV overhead lines are no longer constructed on the network. The existing bare LV overhead network predominantly consists of overhead line with 25 mm² or 50 mm² conductors, with a similar construction and mechanical strength as the MV overhead network at these conductor sizes, as highlighted in section 6.2.2.

6.2.2 Mechanical strength of MV overhead network standard

To determine the mechanical strength of the MV overhead network standard, the same methodology was used as for the LV overhead network standard, developing finite element models for a variety of network configurations in order to determine the mechanical strength for each configuration under wind loading. A simulated circuit was modelled in order to include all structure types (i.e. end poles, double end poles, branch poles, light angle poles, medium angle poles, heavy angle poles and intermediate poles). The configurations were modelled for both single-phase and three-phase network with a variety of different conductor sizes (from 25 mm^2 ACSR up to 150 mm^2 AAAC). Wind loading was applied in the model and the withstand capacity of the network was recorded.

Figure 19 shows an example of the network model which was analysed under increasing wind speeds to determine the mechanical strength of the network.

Figure 19: Example of MV overhead network finite element model

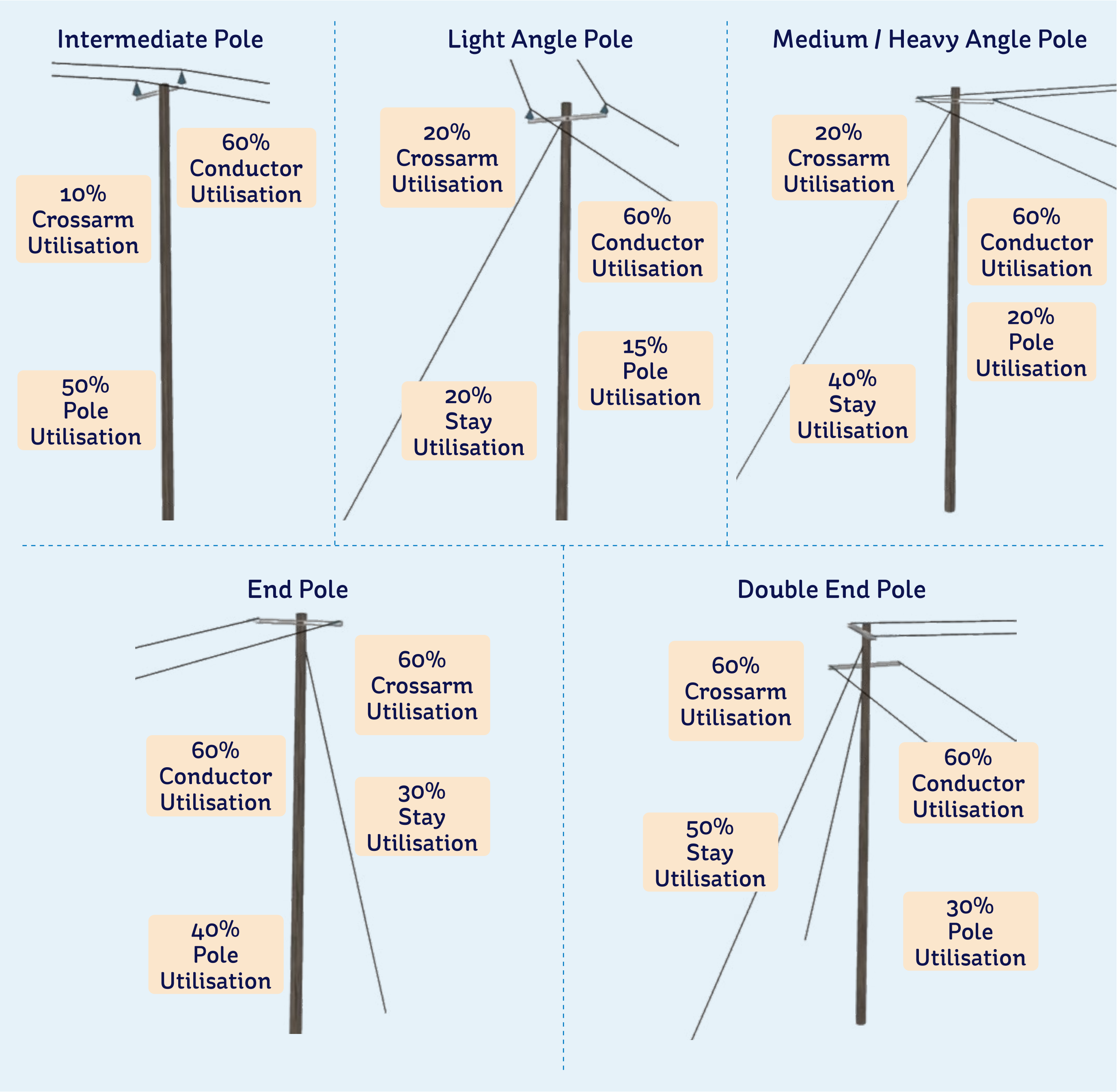


The details and analysis results are as follows:

- 25 mm^2 ACSR conductor is no longer constructed on the network as a new conductor (but may be used for local repair of existing network). However, approximately one third of the total MV overhead network consists of single-phase 25 mm^2 ACSR construction. 50 mm^2 AAAC is now used to replace this conductor as a minimum standard. Standard designs for this network configuration have the mechanical strength to withstand wind speeds in excess of 180 km/hr. The conductor breaking strength and crossarms on end poles and branch poles are the governing components in the design.

Figure 20 provides an overview of structural utilisations for single-phase 25 mm^2 ACSR overhead network based on current standards under loading resulting from 180 km/hr wind speeds.

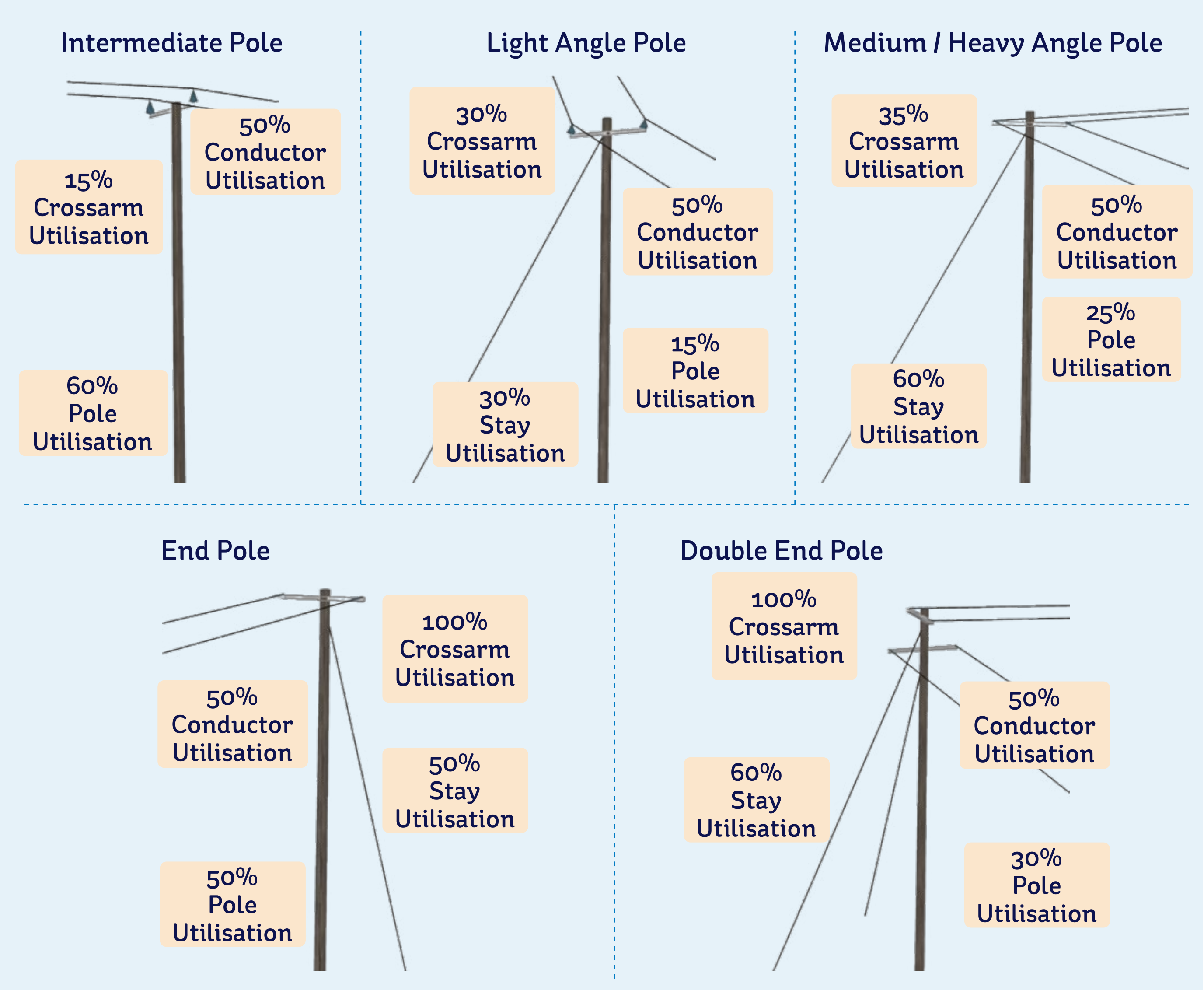
Figure 20: Single-phase 25 mm^2 ACSR overhead network – structural utilisations for 180 km/hr wind



- The remaining MV single-phase overhead network (other than 25 mm^2 ACSR) constitutes approximately one third of the total MV overhead network. This is mostly comprised of single-phase 50 mm^2 ACSR (~18%), 25 mm^2 Copper (~10%) and 50 mm^2 AAAC (~4%). Single-phase 25 mm^2 Copper overhead network exhibits results similar to that presented for 25 mm^2 ACSR network, noting slightly higher utilisations (~5% higher) for some components. On single-phase overhead network with 50 mm^2 ACSR or AAAC conductors, this network has greater conductor strengths however the higher tensions of these conductors increase the utilisations of components such as stays and termination crossarms. Standard designs for this network configuration can accommodate wind speeds up to 180 km/hr at which point the analysis indicates that termination crossarms at end poles and branch poles begin to exceed their structural capacity. It is noted that other components of the line design (poles, conductors, stays and non-termination crossarms) are still within their capacity limits at these wind speeds provided adequate condition and installation.

Figure 21 provides an overview of structural utilisations for single-phase 50 mm^2 ACSR and 50 mm^2 AAAC overhead network based on current standards under loading resulting from 180 km/hr wind speeds for the analysis completed.

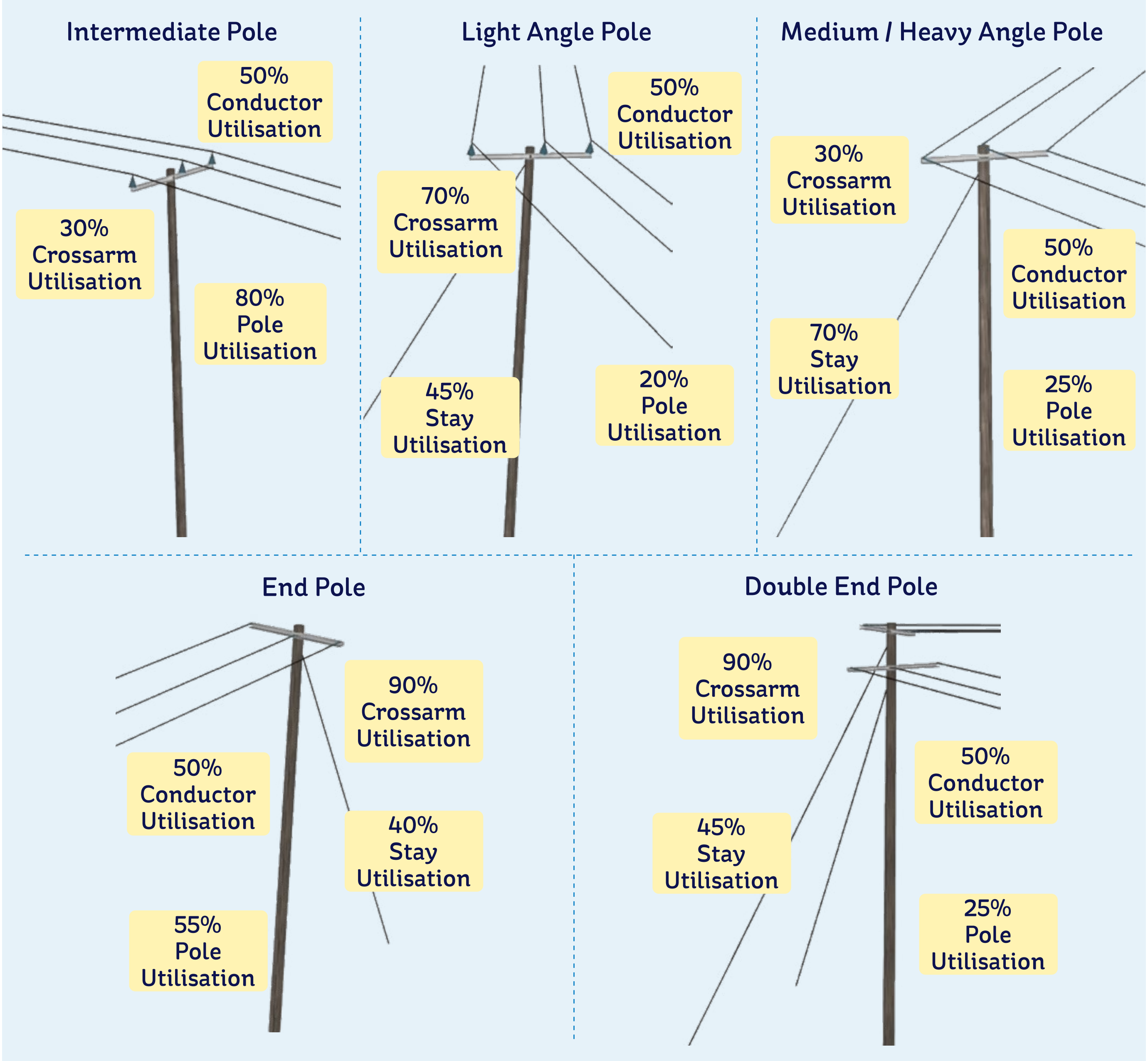
Figure 21: Single-phase 50 mm^2 ACSR/AAAC overhead network – structural utilisations for 180 km/hr wind



- Three-phase overhead network constitutes the remaining one third of the total MV overhead network. The majority of this network configuration is comprised of three-phase 50 mm^2 ACSR (~12%), 25 mm^2 ACSR (~7%), 25 mm^2 Copper (~7%), 92 mm^2 ACSR (~3%), 50 mm^2 AAAC (~2%), 50 mm^2 Copper (~2%) and 150 mm^2 AAAC (~1%).
- On three-phase overhead network with 50 mm^2 ACSR or AAAC conductors, standard designs for this network have the mechanical strength to withstand wind speeds in excess of 180 km/hr, provided adequate condition and installation. Crossarms on end poles and branch poles are the governing components in the design.

Figure 22 provides an overview of structural utilisations for three-phase 50 mm^2 ACSR and 50 mm^2 AAAC overhead network based on current standards under loading resulting from 180 km/hr wind speeds.

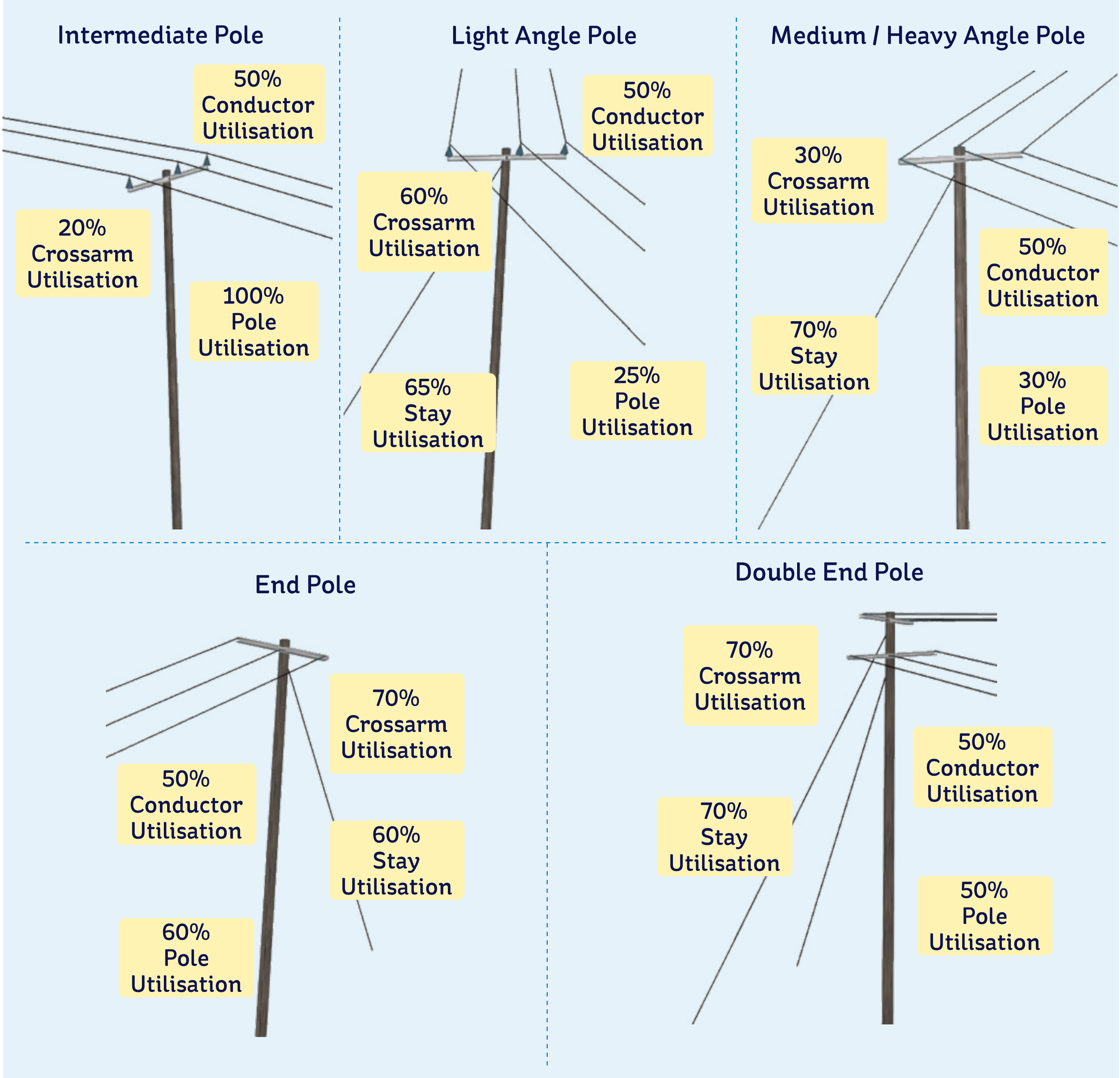
Figure 22: Three-phase 50 mm^2 ACSR/AAAC overhead network – structural utilisations for 180 km/hr wind



- On three-phase overhead network with 92 mm² ACSR conductor, standard designs for this network configuration have the mechanical strength to withstand wind speeds up to 180 km/hr, at which point the analysis indicates that poles on intermediate structures begin to exceed their structural capacity. In situations where the pole has a high utilisation for a given applied load, the site ground conditions may become a limiting factor in the design capacity of the structure.

Figure 23 provides an overview of structural utilisations for three-phase 92 mm² ACSR overhead network based on current standards under loading resulting from 180 km/hr wind speeds.

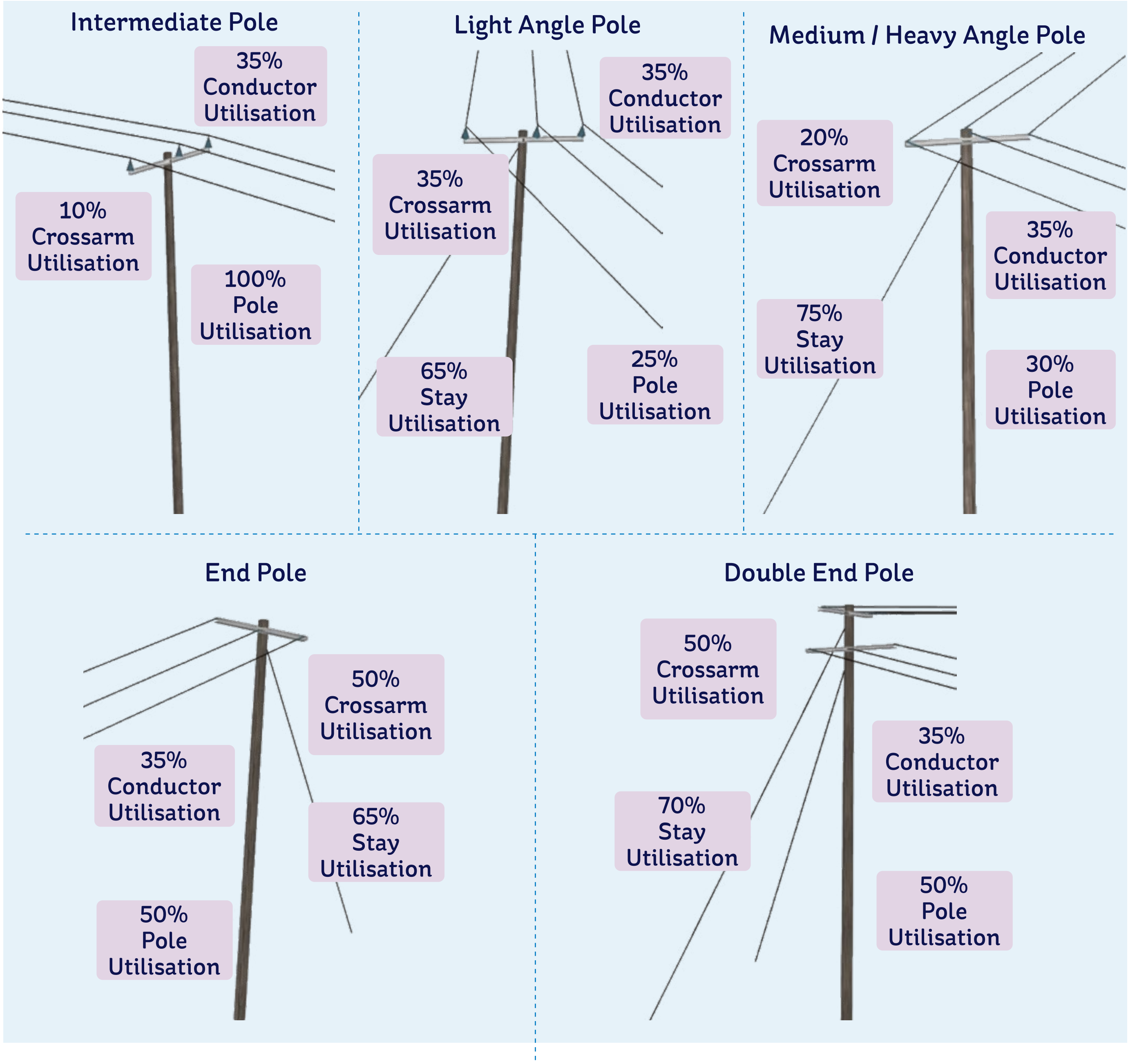
Figure 23: Three-phase 92 mm² ACSR overhead network – structural utilisations for 180 km/hr wind



- On three-phase overhead network with 150 mm² AAAC conductor, standard designs for this network configuration have the mechanical strength to withstand wind speeds up to 160 km/hr, at which point the analysis indicates that poles on intermediate structures begin to exceed their structural capacity. In situations where the pole has a high utilisation for a given applied load, the site ground conditions may become a limiting factor in the design capacity of the structure. As noted previously, three-phase network with 150 mm² AAAC conductor accounts for only ~1% of the total MV overhead network. .

Figure 24 provides an overview of structural utilisations for three-phase 150 mm² AAAC overhead network based on current standards under loading resulting from 160 km/hr wind speeds.

Figure 24: Three-phase 150 mm² AAAC overhead network – structural utilisations for 160 km/hr wind



By increasing the size of the intermediate pole up one pole class on three-phase overhead network with 150 mm² AAAC conductor, the withstand capacity of this network would increase to 180 km/hr wind speed.

Table 3 summarises the strength for different MV overhead network configurations based on the current standards.

Table 3: Strength of standard designs for MV overhead network (summarised)

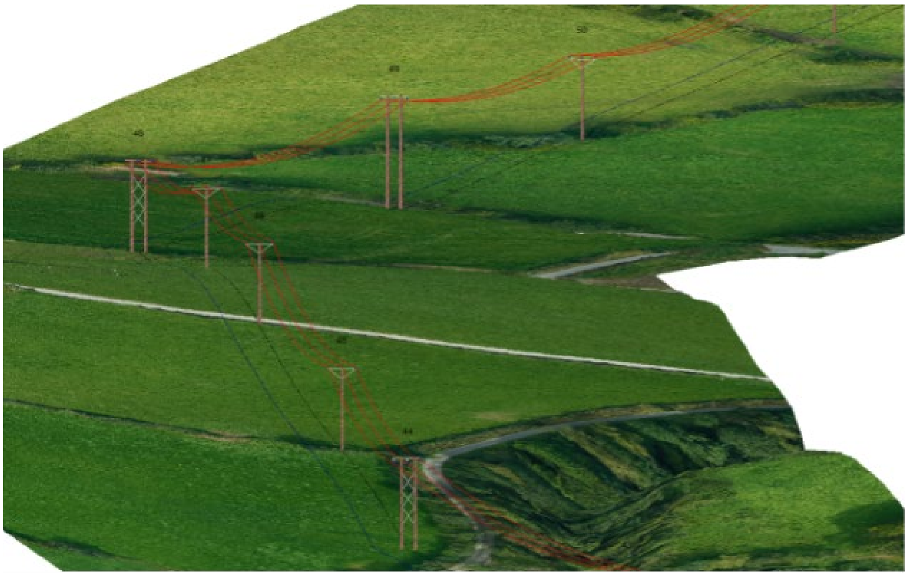
MV Overhead Network Configuration	Strength of Standard Network Designs to Wind Gust Speed (km/hr)
2 x 25 mm² ACSR / CU	>180 km/hr
2 x 50 mm² ACSR / AAAC	~180 km/hr
3 x 50 mm² ACSR / AAAC	>180 km/hr
3 x 92 mm² ACSR / AAAC	~180 km/hr
3 x 150 mm² AAAC	~160 km/hr

6.2.3 Mechanical strength of 38 kV overhead network standard

38 kV design follows a different process than LV or MV overhead network. For some configurations of LV and MV network, the design spans may often be limited by considerations such as ground clearance or conductor clashing. For 38 kV overhead lines which deploy typically larger conductors, components of the design are often more highly utilised for the same loading when compared with LV or MV overhead network.

Analysis was completed using a typical 38 kV line with 100 mm² ACSR (~100 structures) which has been modelled with finite element software. An image from this computer model is shown in figure 25. The analysis shows that single-pole structures are the most heavily utilised components in the 38 kV line design when analysed for high wind conditions, with the wood pole being the limiting component of the design. The standard combined wind and ice loading condition was the governing loading condition, with utilisations on average 18% above those for the high wind loading condition for the most utilised structures on the line design. Considering mean wood pole strength, the analysis showed that the line could withstand wind speeds up to 180 km/hr, at which point the analysis indicates that some wood poles on single-pole intermediate structures on longer spans begin to exceed their structural capacity. This analysis was expanded upon as detailed below.

Figure 25: Example of finite element model of typical 38 kV overhead line



The span data for all single-pole spans on 38 kV overhead lines on the network with 100 mm^2 ACSR/AAAC conductor and 150 mm^2 AAAC conductor is presented in table 4 and table 5. Models were built for each of these span configurations with the relevant conductor sizes. The models were analysed to determine the maximum wind speed which could be applied before the withstand capacity of the wood pole was reached. The tables show the maximum wind speeds (rounded to nearest 5 km/hr) which could be withstood at each span, considering mean wood pole strength

Table 4: 38 kV Single-pole construction with 100 mm^2 ACSR/AAAC conductor - maximum wind speeds by wind span

Percentile of Wind Span	Strength of Network Designs to Wind Gust Speed (km/hr)
99th percentile	165 km/hr
95th percentile	170 km/hr
90th percentile	175 km/hr
80th percentile	180 km/hr

Table 5: 38 kV Single-pole construction with 150 mm^2 AAAC conductor - maximum wind speeds by wind span

Percentile of Wind Span	Strength of Network Designs to Wind Gust Speed (km/hr)
99th percentile	160 km/hr
95th percentile	165 km/hr
90th percentile	165 km/hr
80th percentile	170 km/hr

38 kV single-pole construction with 100 mm^2 and 150 mm^2 conductor represents approximately 23% of structures on the 38 kV overhead network. The 38 kV 'portal' structure which comprises two poles and a steel crossarm joining the poles has greater mechanical strength than the single-pole configuration. The span data for all intermediate portal structure spans on 38 kV overhead lines on the network with 100 mm^2 ACSR/AAAC conductor and 150 mm^2 AAAC conductor is presented in table 6 and table 7. 38 kV portal structures are the most prevalent structure type on the 38 kV overhead network.

Table 6: 38 kV Portal construction with 100 mm^2 ACSR/AAAC conductor - maximum wind speeds by wind span

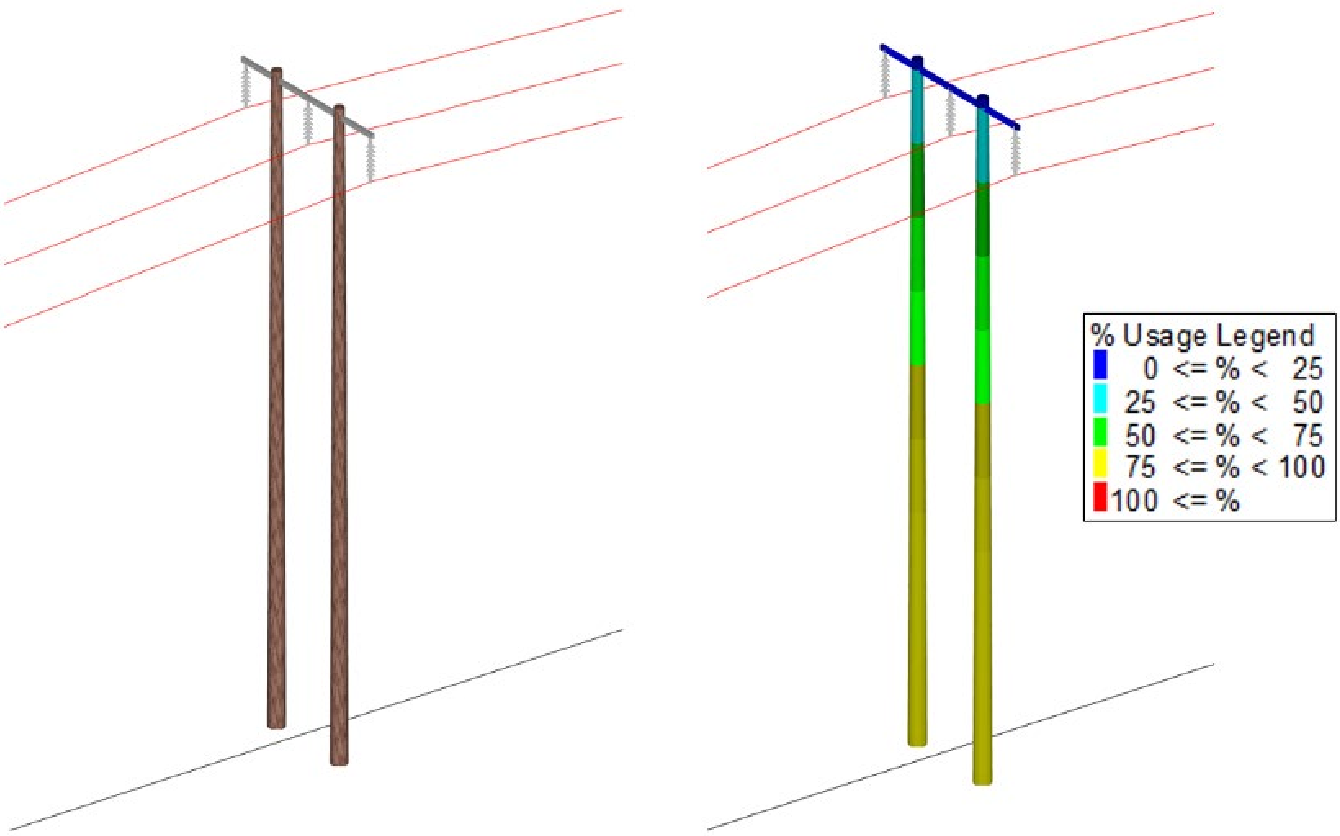
Percentile of Wind Span	Strength of Network Designs to Wind Gust Speed (km/hr)
99th percentile	>180 km/hr
95th percentile	> 180 km/hr
90th percentile	> 180 km/hr
80th percentile	>180 km/hr

Table 7: 38 kV Portal construction with 150 mm² AAAC conductor - maximum wind speeds by wind span

Percentile of Wind Span	Strength of Network Designs to Wind Gust Speed (km/hr)
99th percentile	>180 km/hr
95th percentile	> 180 km/hr
90th percentile	> 180 km/hr
80th percentile	>180 km/hr

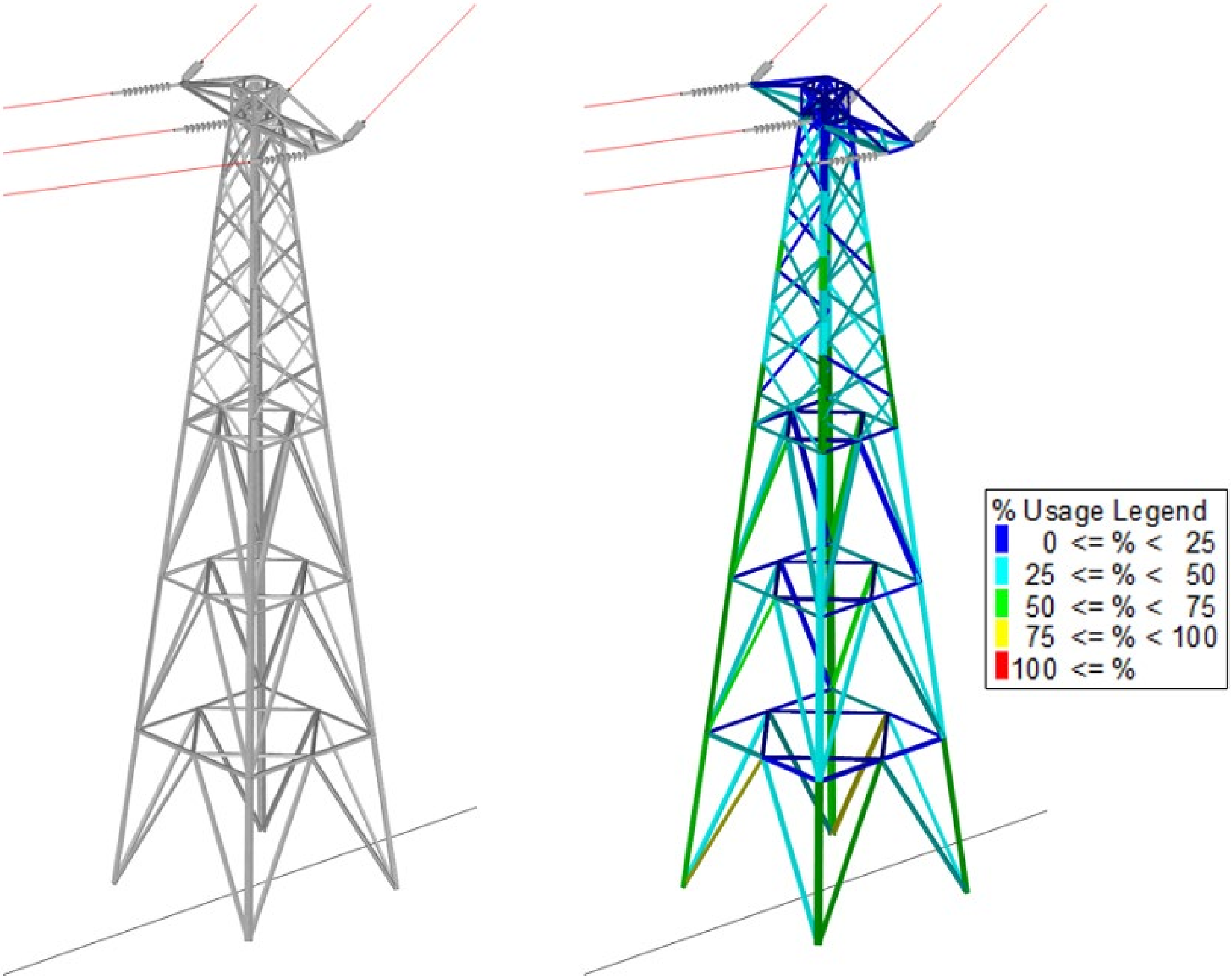
Figure 26 shows an example of the finite element computer analysis completed for the 38 kV portal structure, with the image showing the utilisation of the portal structure under a 180 km/hr wind speed.

Figure 26: Example of finite element analysis completed for 38 kV portal structures



Analysis was also completed on the current 38 kV single circuit tower designs. Figure 27 shows an example of the finite element computer analysis completed for the current 38 kV single circuit tower, with the image showing the utilisation of the tower members under a 180 km/hr wind speed. These towers are used for a variety of different functions, for example as the termination point at the end of an overhead line or at positions where the direction of the line changes. The analysis showed these towers have the mechanical strength to withstand wind speeds in excess of 180 km/hr.

Figure 27: Example of finite element analysis completed for 38 kV tower structures



6.3 Comparison of International Design Standards

The governing loading conditions which affect the design of an overhead line are variable depending on the weather parameters which are possible for a particular region/country. For this reason, the basis for the design of overhead lines varies depending on the location of the network. Some areas may account for much higher potential ice loads (e.g. Nordic countries) while others may have higher or lower wind exposure depending on geographic location.

There is a common standard for the design of overhead lines in Europe, EN 50341 ('Overhead electrical lines exceeding AC 1 kV'). European countries, as members of CENELEC ('Comité Européen de Normalisation Électrotechnique'), adopt the EN 50341 standard and develop their own National Normative Aspects (NNA) which tailor the main standard to national needs such as locally determined parameters, including weather-based loading conditions to be considered in the design of overhead lines. Comparisons are therefore only relevant to make with the design of distribution overhead lines with other regions which are geographically similar. In this context, the United Kingdom is useful for comparison as there is a shared experience of weather events and similar network construction types.

The National Normative Aspects for the UK (EN 50341-2-9) set out the nationally determined parameters to be applied in the design of overhead lines in Great Britain and Northern Ireland. This document sets out that "for overhead lines supported on timber poles, the project specification shall specify either Design Approach 3 or 1". These two design approaches represent different design philosophies with the main differences being:

- Design Approach 3 is an empirical approach based on practical experience and observation over time.
- Design Approach 1 is a probabilistic approach which incorporates variability in loads, material properties and environmental conditions using probability/statistics.

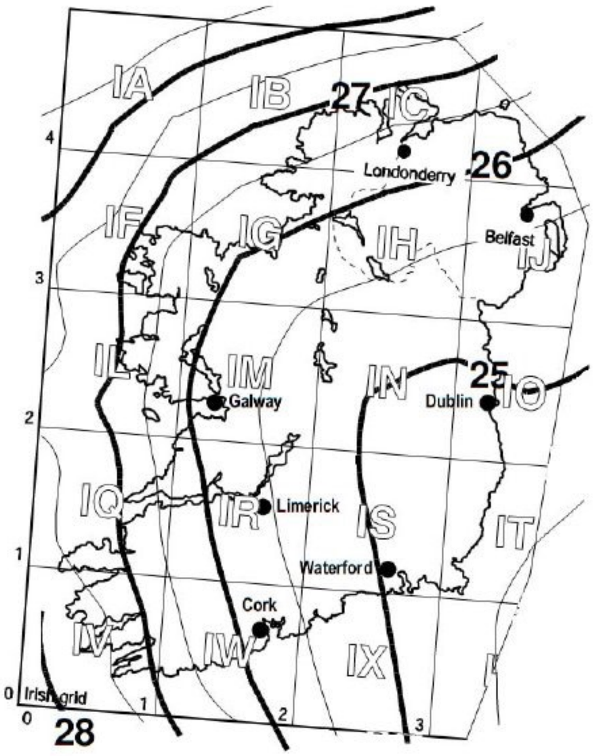
Table 4.4.1/GB.1 of EN 50341-2-9 sets out the wind pressures which should be considered for Design Approach 3. The high wind loading condition sets out that a wind pressure of 1740 N/m^2 shall be considered in designs with a partial factor of 1.1 applied for this load case. This corresponds to a peak design wind speed of 175 km/hr with no partial factor applied, and 183 km/hr with the partial factor applied. Design Approach 3 in the UK adopts mean wood pole strength for designs.

Considering the wind speeds from Design Approach 3 in the UK with those outlined in Table 2 in section 6.2.1 and Table 3 of section 6.2.2, it can be seen that the strength of standard designs for LV and MV overhead network in Ireland compare well with Design Approach 3 in EN 50341-2-9. When comparing with the limiting capacities for 38 kV single-pole construction in Table 4 and Table 5 in section 6.2.3, it can be seen that the UK Design Approach 3 yields slightly stronger designs. The strength of standard designs for 38 kV portal structures and towers outlined in section 6.2.3 compare favourably with 'Design Approach 3' in EN 50341-2-9.

The Energy Networks Association (ENA) Technical Specification 43-40, 'Specification for single circuit overhead pole lines for use at high voltage up to and including 33 kV' notes that the relevant British Standards Institution (BSi) committee has confirmed that the empirical design approach (Design Approach 3) is to be adopted for the design of distribution wood pole overhead lines in the UK. It is therefore this design approach which is most relevant for comparison in this review.

Further details on a probabilistic design approach are included here for information purposes. To provide a comparison with Design Approach 1 (probabilistic design) in the UK, the Eurocode wind map for Ireland given in the National Annex to standard EN 1994-1-4 ('Actions on structures – Part 1-4: General actions – Wind actions') is adopted. This wind map sets out the basic wind velocity to be considered in design (in metres per second) before altitude correction is applied. A number of other parameters also affect the peak wind pressure which is derived from this basic wind velocity including the terrain category, orography and the height above ground of the component being considered. The Eurocode wind map for Ireland is shown in Figure 28.

Figure 28: Irish wind map, basic wind velocity (m/s) – National Annex to EN 1994-1-4



Considering the most conservative basic wind velocity of 27.5 m/s for Ireland (contour which contacts parts of the South-West) with the following parameters:

- Reliability Level 1 (return period of 50 years)
- Terrain category II ('Area with low vegetation such as grass and isolated obstacles [trees, buildings] with separations of at least 20 times obstacle heights')
- Site altitude taken as 50 metres above sea level
- Height above ground taken as 10 metres
- Orography factor (related to land gradient/slope) = 1.0
- Drag factor = 1.0
- Factors including directional factor and seasonal factor as per recommended value of 1.0

This yields a peak design wind speed of ~147 km/hr. Considering the same parameters but instead adopting terrain category I ('Sea or coastal area exposed to the open sea') would yield a peak design wind speed of ~165 km/hr. It is more challenging to make a direct comparison with the probabilistic design approach. As can be seen from the example given, the design wind speeds (147 km/hr or 165 km/hr) are below the maximum wind speeds which can be resisted in the majority of standard designs covered in section 6. However, the probabilistic based design adopts more conservative parameters on wood pole strength. When these parameters are included, this would yield stronger designs (for the wood pole) than some of those set out in section 6. As previously noted, for wood pole overhead lines on the distribution network in the UK, the empirical Design Approach 3 is still applied and hence comparison with this approach is considered to be most relevant for this review.

Focusing strictly on the wind speeds, it is noted that a 180 km/hr gust wind represents an extremely rare storm event. Based on the Eurocode wind map for design in Ireland and the EN 50341 design standard for overhead lines, for a lower altitude site without significant local orography impacts, this equates to a 1 in 150 year return period for an exposed coastal location on the West coast of Ireland and a 1 in 500 year return period for an inland rural location.

7 Network Exposure

As discussed in section 3.1, the gust wind data assessed has a resolution of 30 km, meaning that the gust wind speeds reported are the average gusts observed over a 30 km grid. This will mean that, in a given square on the grid, there will be locations which will have locally higher gust wind speeds and other locations where gusts may be lower. ERA5 is known to smooth out the most extreme peak gusts. In practice, bursts such as those driven by small scale convection, sharp terrain accelerations, or very localised downbursts are averaged together and may not reach the same magnitude as an instantaneous observation. As a result, the highest extremes in ERA5 tend to be underestimated, sometimes by 10–20 % compared to well exposed anemometer readings during severe storms.

From the recent example of Storm Éowyn it is noted that a wind speed of 184 km/hr was recorded at the Met Éireann weather station in Mace Head, compared with a maximum wind speed 160-170 km/hr reported in the ERA5 data which is reported at 30 km resolution. This illustrates that locally there may be higher gust wind speeds which impact the network. It is reasonable to assess that a very small percentage of the overhead network has experienced wind speeds up to and marginally in excess of 180 km/hr. A comparison of wind gust measurements from 23 Met Éireann weather stations during Storm Éowyn with the ERA5 wind gust data for this period showed that at 7 locations the ERA5 wind gusts were below the local measurements (by an average of 10%) and at 16 locations the ERA5 wind gusts were above the local measurements (by an average of 12%). Locations where the Storm Éowyn wind gust measurements were underestimated by the ERA5 data tended to be the locations where the highest extremes were observed. As underestimation of gust wind speed is possible in the Copernicus ERA5 data, when looking to determine the percentage of network which has experienced an absolute limit it is sensible to consider the amount of network which has experienced a lower threshold to allow for this. For instance, when considering what percentage of the network has experienced wind gusts up to 160 km/hr, also considering the proportion of the network which has experienced wind speeds in excess of 150 km/hr (or 140 km/hr) to account for locally higher wind speeds. Table 9 is reported with bandings of wind speed for this reason.

7.1 LV Overhead Network Exposure

Table 8 summarises the mechanical strength of the LV overhead network standard relating to high wind as determined in section 6. It also shows the proportion of the LV overhead network which has observed differing levels of wind speed over the 40 years of ERA5 wind gust data as determined using the analytics platform.

Table 8: Strength of LV network standard (wind gust) compared to exposure over 40 Years of ERA5 historical wind data (1985-2025)

LV Overhead Network Configuration	Strength of Network Configuration to Wind Gust Speed (km/hr)	% of LV Overhead Network Exposed to 170-180 km/hr Wind Gusts (1985-2025)	% of LV Overhead Network Exposed to 160-170 km/hr Wind Gusts (1985-2025)	% of LV Overhead Network Exposed to 150-160 km/hr Wind Gusts (1985-2025)	% of LV Overhead Network Exposed to 140-150 km/hr Wind Gusts (1985-2025)	% of LV Overhead Network Exposed to 130-140 km/hr Wind Gusts (1985-2025)
2 x 50 mm^2 ABC	>180 km/hr	0% to 0.01%	0.01% to 1.40%	1.40% to 11.61%	11.61% to 23.45%	23.45% to 55.81%
2 x 95 mm^2 ABC	>180 km/hr					
4 x 50 mm^2 ABC	>180 km/hr					
4 x 95 mm^2 ABC	>180 km/hr					

Table 8 shows that, for the LV network configurations highlighted, the strength of the standard designs typically exceeds the wind speeds observed over the 40-year period reviewed.

7.2 MV Overhead Network Exposure

Table 9 summarises the mechanical strength of the MV overhead network standard relating to high wind as determined in section 6. It also shows the proportion of the MV overhead network which has observed differing levels of wind speed over the 40 years of ERA5 wind gust data as determined using the analytics platform.

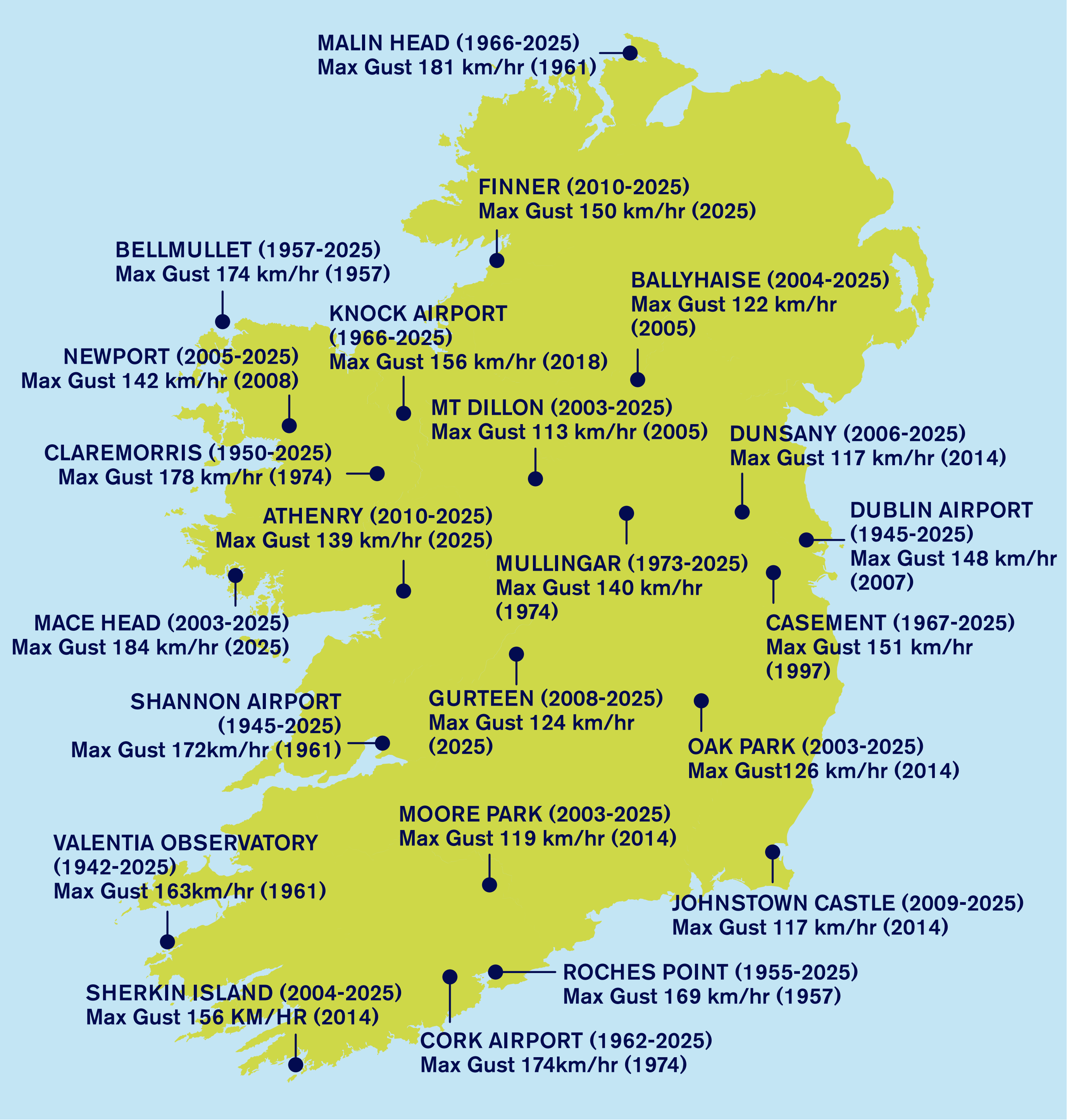
Table 9: Strength of MV network standard (wind gust) compared to exposure over 40 Years of ERA5 historical wind data (1985-2025)

MV Overhead Network Configuration	Strength of Network Configuration to Wind Gust Speed (km/hr)	% of MV Overhead Network Exposed to 170-180 km/hr Wind Gusts (1985-2025)	% of MV Overhead Network Exposed to 160-170 km/hr Wind Gusts (1985-2025)	% of MV Overhead Network Exposed to 150-160 km/hr Wind Gusts (1985-2025)	% of MV Overhead Network Exposed to 140-150 km/hr Wind Gusts (1985-2025)	% of MV Overhead Network Exposed to 130-140 km/hr Wind Gusts (1985-2025)
2 x 25 mm^2 ACSR / CU	>180 km/hr	0% to 0.02%	0.02% to 1.27%	1.27% to 10.4%	10.4% to 22.86%	22.86% to 48.71%
2 x 50 mm^2 ACSR / AAAC	~180 km/hr					
3 x 50 mm^2 ACSR / AAAC	>180 km/hr					
3 x 92 mm^2 ACSR / AAAC	~180 km/hr					
3 x 150 mm^2 AAAC	~160 km/hr					

Table 9 shows that, for most MV network configurations, the strength of the standard designs typically exceeds the wind speeds observed over the 40-year period reviewed. Three-phase 150 mm^2 AAAC network may be more vulnerable as the current standard designs may exceed capacity above 160 km/hr wind gusts – a threshold which has been observed on a proportion of the network.

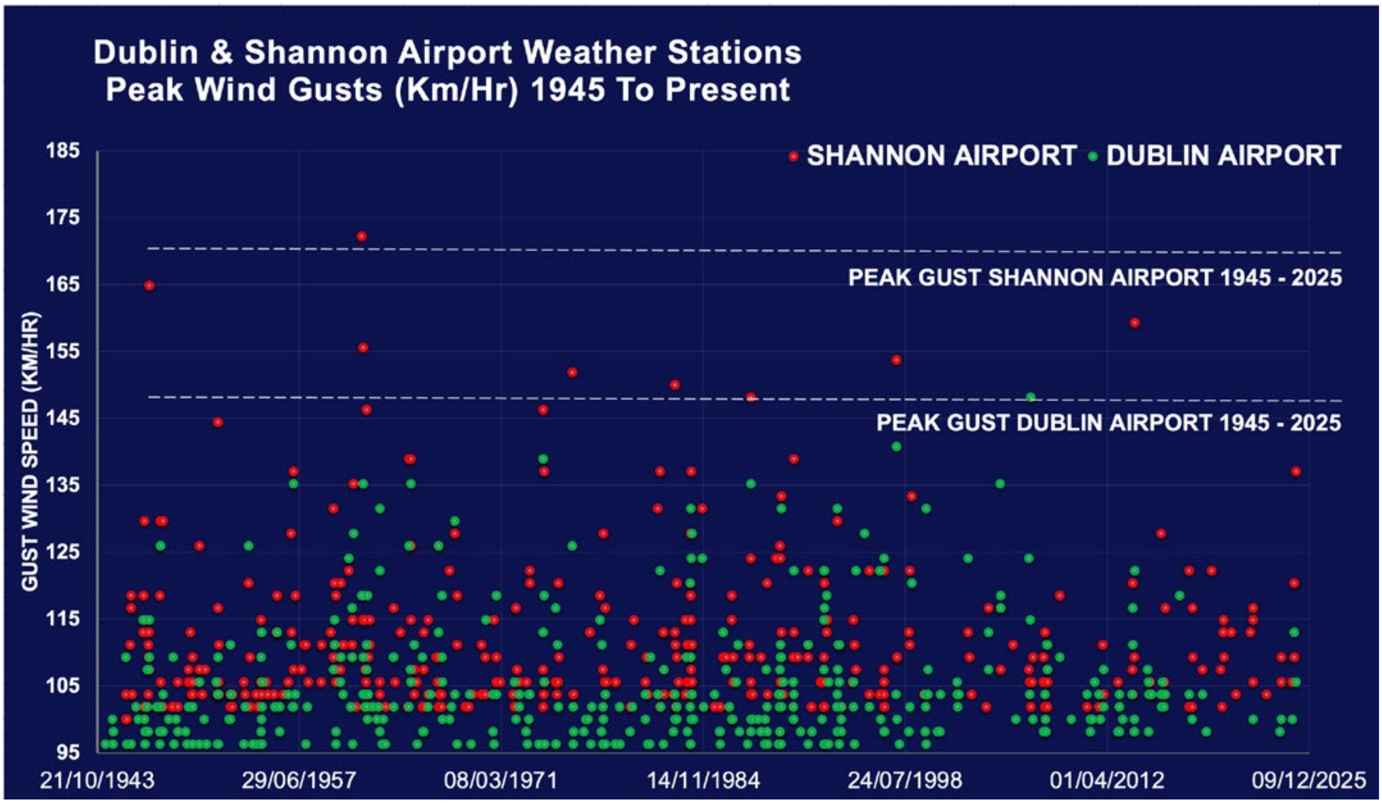
Figure 29 shows an illustration of all peak wind gust measurements on record from Met Éireann weather stations up to and including Storm Éowyn. This shows that, within the records available, weather stations on the Atlantic coast have experienced wind gusts up to and marginally exceeding 180 km/hr. The data presented in Figure 29 is extracted from publicly available Met Éireann weather station records. It is noted that Met Éireann have also reported some other notable measurements including a wind speed of 182 km/hr at Shannon Airport in 1945 and a wind speed of 178 km/hr in Rosslare in 1995.

Figure 29: Met Éireann weather station record peak wind gust measurements



The graph shown in Figure 30 illustrates the peak wind gust measurements from weather stations in Dublin Airport and Shannon Airport from 1945 to the present. This graph illustrates the peak wind speed recorded at Dublin Airport of 148 km/hr and the peak wind speed recorded at Shannon Airport of 172 km/hr. It can be seen from this graph that only twice in the 85-year period from 1945 to 2025 did wind speeds exceed 160 km/hr at the Shannon Airport weather station. The distribution of red and green markers in the graph for Shannon and Dublin respectively also provide a good visual illustration of the higher wind speeds experienced in the west of Ireland.

Figure 30: Dublin Airport and Shannon Airport peak wind gusts 1945-2025



7.3 38 kV Overhead Network Exposure

Table 10 summarises the mechanical strength of the 38 kV overhead network standard relating to high wind as determined in section 6. It also shows the proportion of the 38 kV overhead network which has observed differing levels of wind speed over the 40 years of ERA5 wind gust data as determined using the analytics platform.

Table 10: Strength of 38 kV network standard (wind gust) compared to exposure over 40 years of ERA5 historical wind data (1985–2025)

38 kV Overhead Network Configuration	Strength of Network Configuration to Wind Gust Speed (km/hr) considering 99th percentile span	% of 38 kV Overhead Network Exposed to 170-180 km/hr Wind Gusts (1985-2025)	% of 38 kV Overhead Network Exposed to 160-170 km/hr Wind Gusts (1985-2025)	% of 38 kV Overhead Network Exposed to 150-160 km/hr Wind Gusts (1985-2025)	% of 38 kV Overhead Network Exposed to 140-150 km/hr Wind Gusts (1985-2025)	% of 38 kV Overhead Network Exposed to 130-140 km/hr Wind Gusts (1985-2025)
Single-Pole 100 mm² ACSR/ AAAC	165 km/hr	0%	0% to 1.5%	1.5% to 11.3%	11.3% to 22.9 %	22.9% to 52.9%
Single-Pole 150 mm² AAAC	160 km/hr					
Portal 100 mm² ACSR/ AAAC	>180 km/hr					
Portal 150 mm² AAAC	>180 km/hr					
Towers All Conductor Sizes	>180 km/hr					

Designs for MV overhead network have traditionally balanced the scale of the network and the additional cost and difficulty in constructing the network with higher levels of reliability and security. Traditionally, 38 kV network is designed at a lower reliability level as overhead network at 110 kV and higher voltages. However, the design rationale for 38 kV network is more aligned to these higher voltage networks than MV overhead network. Table 10 shows that, for 38 kV portal structures and towers, the strength of the standard designs typically exceeds the wind speeds observed over the 40-year period reviewed. Table 10 also shows that there are proportions of the 38 kV overhead network where single-pole construction may have experienced wind speeds which have the potential to exceed the mechanical strength on certain spans in the same time period. There are a number of factors which contribute to reducing the probability of this occurrence which are discussed in section 7.4.

7.4 Vulnerability of Network

The current review has identified some areas where enhancing standards may be warranted as network development and renewal continues. However, it is important to provide further context on the potential vulnerability of these and other network configurations on the existing network.

When assessing the probability of a structural failure on the overhead distribution network due to wind loading exceeding the withstand capacity of the overhead distribution network, a number of factors must also be considered, as shown below (with examples provided for context):

- Percentage of overhead network configuration exposed to maximum strength wind speed during a storm event:
  - Only 7% of the MV overhead three-phase 150mm^2 has experienced wind gusts exceeding 150 km/hr between 1985 and 2025 from ERA5 data.
  - Only 9.7% of the 38 kV overhead 100/150 mm^2 has experienced wind gusts exceeding 150 km/hr between 1985 and 2025 from ERA5 data.
- Extent of a particular network type on the system:
  - 1.3% of the total MV overhead network is three-phase 150 mm^2 construction.
  - 75% of the total 38 kV overhead network is 100/150 mm^2 construction.
- Prevalence of the structure/component which represents the potentially vulnerable part of a given network type:
  - 64% of MV overhead three-phase 150 mm^2 are intermediate/suspension structures.
  - 30% of 38 kV overhead 100/150 mm^2 are single-pole structures.
- Percentage spans which are at or exceed the limits considered:
  - Less than 20% of the MV overhead three-phase 150 mm^2 are constructed up to the target span considered.
  - 38 kV span data as shown in section 6.2.3.
- Probability of wood pole material strength (or minimum pole dimensions) being below mean population value on the longer spans of an impacted overhead line.
- Probability that wind direction will be close to perpendicular to the line on the longer spans resulting in maximum transverse force of wind being applied to the structure.

- Duration of the gust wind speeds not being sufficient to apply full transverse loading to the structure. In order for the structure to experience the transverse loading from the wind, the conductors must be fully deflected into the horizontal position ('blown out'). It may require a gust duration greater than three-seconds for this to occur.
- Probability of an extreme wind event which reaches the design strength thresholds occurring in a given year or over a defined period of time.

It is estimated that the overhead network designs constructed on approximately 98-99% of the LV and MV network (by length) and approximately 95% of the 38 kV overhead network (by length) are capable of withstanding wind gusts of up to 180 km/hr or greater considering mean wood pole strength. When additional mitigating parameters such as network exposure are considered, the current level of vulnerability/exposure based on the mechanical strength of the distribution overhead line standard is considered to be low relative to storms experienced in the past (including Storm Éowyn).

Figure 31 shows all the three-phase MV overhead network on a map of Ireland. In this figure the three-phase 150 mm² overhead network which has experienced wind gusts exceeding 150 km/hr during the period 1985 to 2025 based on the ERA5 data is highlighted in orange. The modelled wind design strength of this network is determined to withstand sustained wind gusts of 160 km/hr.

Figure 31:
MV overhead network – three-phase 150 mm² AAAC network exposed to wind gusts exceeding 150 km/hr between 1985 and 2025 in ERA5 data highlighted in orange

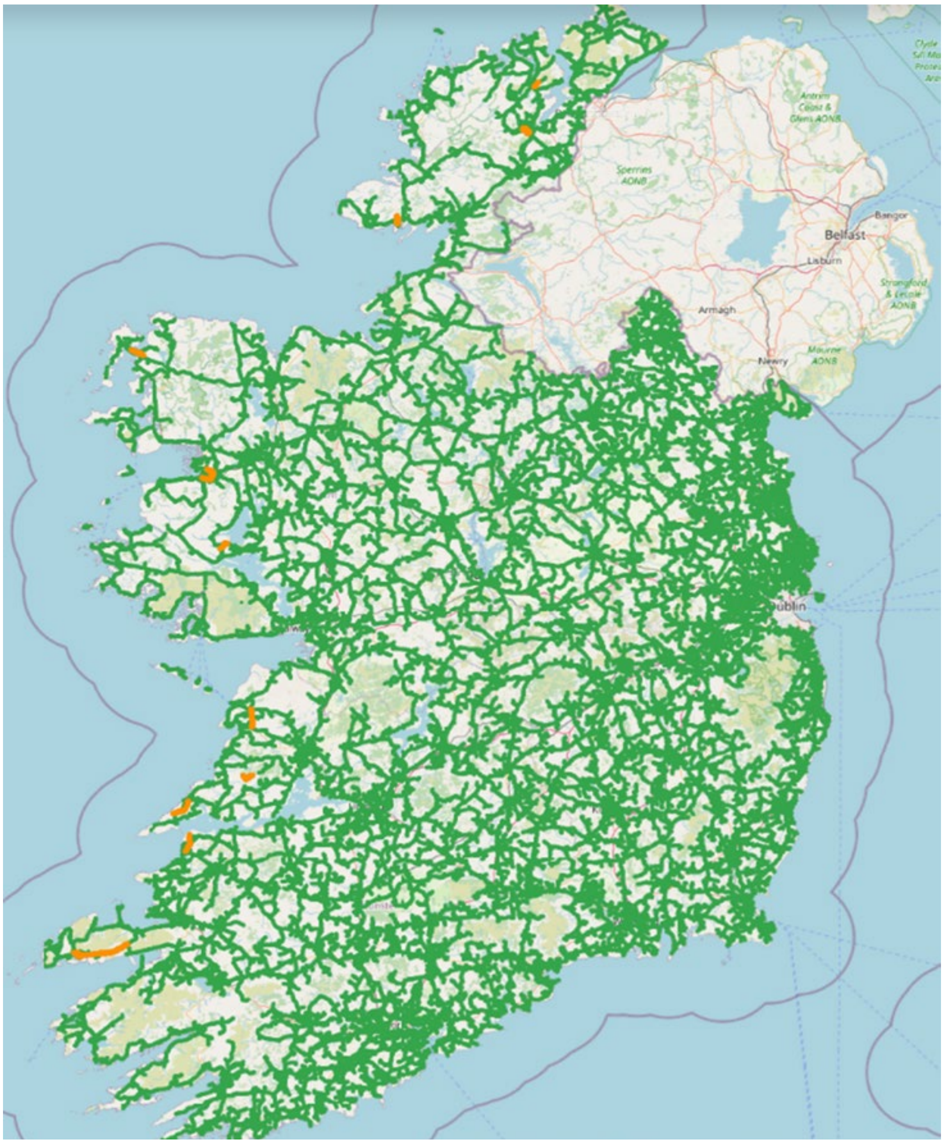
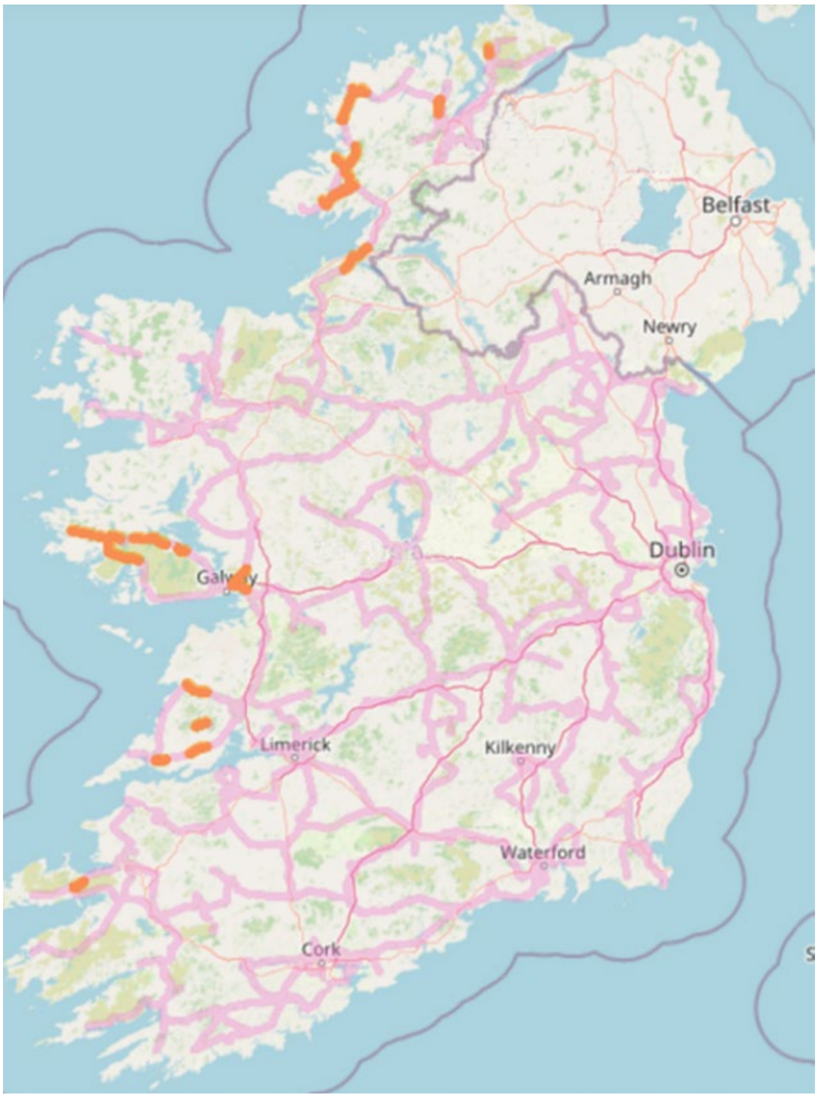


Figure 32 shows all the 38 kV overhead network on a map of Ireland. In this figure the single-pole network constructed with 100/150 mm² conductor which has experienced wind gusts exceeding 150 km/hr during the period 1985 to 2025 based on the ERA5 data is highlighted in orange. The modelled wind design strength of this network is determined to withstand sustained wind gusts of typically 160 to 180 km/hr or greater (depending on spans) based on mean wood pole strength.

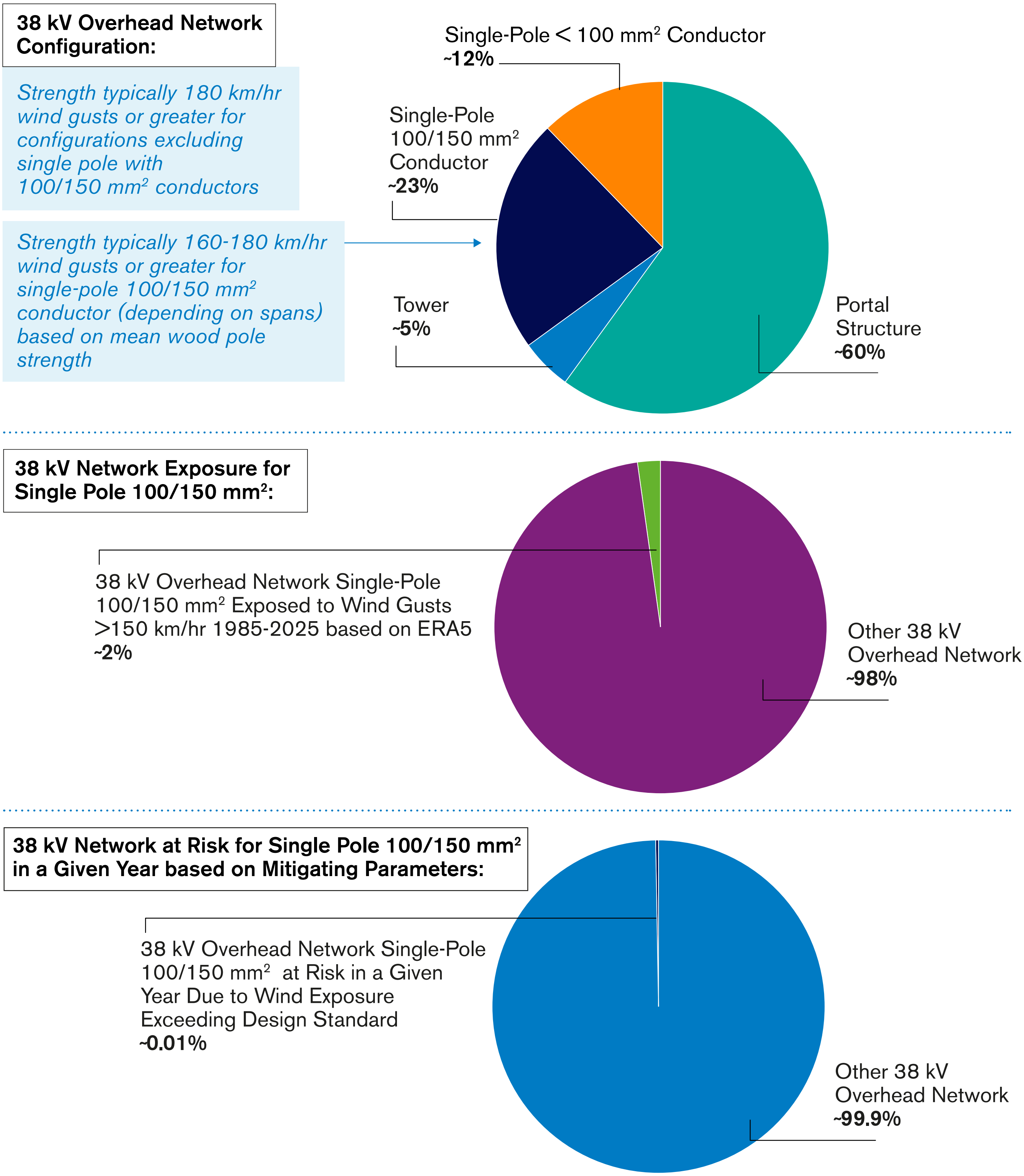
Figure 32: 38 kV overhead network – 100/150 mm² single-pole network exposed to wind gusts exceeding 150 km/hr between 1985-2025 in ERA5 data highlighted in orange



While the maps shown in Figure 31 and Figure 32 demonstrate that over a 40 year period (1985-2025) the exposure for these network types has been limited, it also demonstrates the exposed Atlantic coastal zone where enhancing the strength of the network could be of most benefit. The overhead lines which have been highlighted in Figure 31 and Figure 32 are currently undergoing an assessment to identify targeted strengthening measures which will be completed in order to increase overall resilience with regard to the mechanical strength of the network. In determining what overhead network should be prioritised for proactive strengthening measures a conservative banding of wind speeds from the ERA5 weather data has been adopted. In addition, areas of the network which may not have been identified with exposure in the ERA5 data back to 1985 but which may also be geographically exposed to Atlantic storms will also be reviewed for future interventions. The interventions envisaged arising from the interim review will involve strengthening specific isolated structures across ~900 km of MV overhead network and ~1400 km of 38 kV overhead network.

Figure 33 shows a number of graphs illustrating the structure configurations present on the 38 kV overhead network, the proportion of single-pole structures supporting 100/150 mm² conductor exposed to wind gusts exceeding 150 km/hr between 1985 and 2025 based on the ERA5 data and the percentage of single-pole structures supporting 100/150 mm² conductor which is at risk of exceeding the withstand capacity of the structures on an annual basis considering the mitigating factors previously outlined.

Figure 33: 38 kV Overhead Network Configurations & Potential Exposure/Vulnerability



38 kV Overhead Network Configuration:

Strength typically 180 km/hr wind gusts or greater for configurations excluding single pole with 100/150 mm² conductors

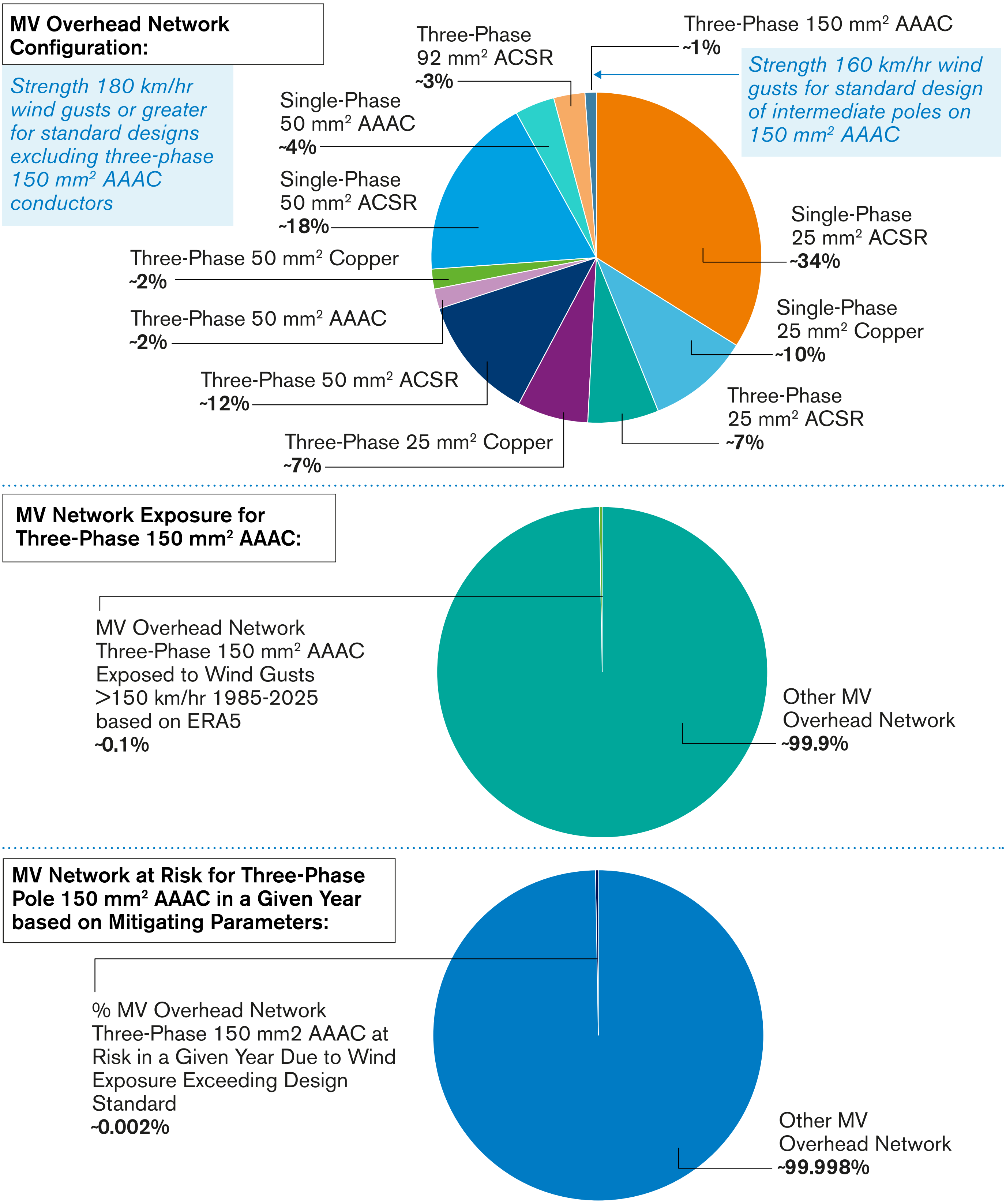
Strength typically 160-180 km/hr wind gusts or greater for single-pole 100/150 mm² conductor (depending on spans) based on mean wood pole strength

38 kV Network Exposure for Single Pole 100/150 mm²:

38 kV Network at Risk for Single Pole 100/150 mm² in a Given Year based on Mitigating Parameters:

Figure 34 shows a number of graphs illustrating the configurations present on the MV overhead network, the proportion of three-phase 150 mm² AAAC overhead network exposed to wind gusts exceeding 150 km/hr between 1985 and 2025 based on the ERA5 data and the percentage of three-phase 150 mm² AAAC overhead network which is at risk of exceeding the withstand capacity of the structures on an annual basis considering the mitigating factors previously outlined.

Figure 34: MV Overhead Network Configurations & Potential Exposure/Vulnerability



Degradation levels of overhead line components is important to manage in consideration to network vulnerability. ESB Networks has significant asset replacement programmes which are being completed under the current regulatory investment period known as Price Review 6 to manage the condition of the overhead line network. Details of this investment programme are contained in the Price Review 6 Business Plan Executive Summary[1] published by ESB Networks in 2025.

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[1] *Price Review 6 Business Plan Executive Summary Published by ESB Networks in April 2025*

8 Conclusions

8.1 Weather Data

There is much uncertainty linked to trending and predictions for windstorm activity. The data contained within this report and commentary provided does not contain definitive conclusions. The report sets out information which can inform discussions around the potential impacts of future windstorms on the electrical network. The uncertainty in future windstorm frequency and intensity is in itself an important factor to consider when assessing the standards applied to overhead lines.

The review of ERA5 historical weather data and the proportions of the network which have experienced various wind speed thresholds provides valuable insights into the exposure of the network to severe windstorms. The occurrence of storms in which the gust wind speeds reached either 110-130 km/hr or 130-150 km/hr demonstrated a slight increasing trend over the period 1985 to 2025 when examining the number of days on the most impacted assets. However, the total hours across the entirety of the network demonstrated a decreasing trend, particularly at wind speeds 110-130 km/hr. The ERA5 historical wind data shows that the most severe windstorms are rare and can therefore be difficult to trend and predict with a high degree of confidence. Over the 40-year period examined there was a total of eight events in which average wind gusts exceeded this threshold.

Modelled future wind data based on the RCP 4.5 and RCP 8.5 scenarios allows us to assess the possible impact of the changing climate as they relate to high winds in the coming years. This modelled data also allows us to consider other areas of the network that may be vulnerable to extreme wind events. Based on comparison of the total wind hours from RCP 4.5 and RCP 8.5 models, the data indicates that with increased global warming there may be an increase in the amount of wind experienced on the network.

The National Climate Change Risk Assessment (NCCRA) published in June 2025, highlights the challenges for confidently projecting extreme wind events and emphasises Ireland's exposure to such events.

In determining appropriate levels of reliability for overhead network standards, it is also important to consider that the context and importance of the network to society have changed over the last century. This may demand that higher levels of reliability, resilience and redundancy exist in network standards to cater for the most extreme wind events, such as that experienced in January 2025.

Met Éireann TRANSLATE weather models for wind gusts in Ireland are currently under development and should be reviewed once available.

8.2 LV and MV Overhead Line Standards

The analysis completed shows that the standard designs for LV and MV overhead network provide good levels of reliability in terms of mechanical strength to withstand windstorms provided the network is constructed in accordance with the relevant standards and the condition of the network is good. However, MV three-phase overhead network constructed with larger diameter conductors may be more vulnerable to severe wind events.

Experience has been that the LV and MV overhead network has performed well in terms of mechanical strength for wind events. Where failures have been observed this has typically been linked to factors such as poor condition, impact by trees or poor ground conditions.

8.3 38 kV Overhead Line Standards

The analysis completed shows that 38 kV portal structures which are the most common structure type at this network voltage offer high levels of mechanical strength. However, the 38 kV single-pole designs with larger diameter conductors may be more vulnerable to severe wind conditions than other overhead network standards. During Storm Éowyn, the limited number of failures which were documented on the 38 kV overhead network, which did not result from timber or forestry, were linked to degraded condition or inadequate foundations/staying leading to leaning of the poles. Notwithstanding this and despite mitigating factors as highlighted in section 7.4, on longer spans of 38 kV network with single-pole structures (particularly for 150 mm^2 AAAC conductor), some structures on this network may be exposed to overloading during the most extreme wind events.

9 Recommendations

The current review shows that generally the current standard designs for LV, MV and 38 kV overhead distribution network are resilient with regard to mechanical strength for windstorms experienced on the network to date. The greatest benefits to overall windstorm resilience may come from in areas such as forestry and vegetation management, asset replacement programmes and storm planning. In the example of Storm Éowyn, over 59% of damage assessments recorded hedgerow timber or forestry as the primary cause of damage. Notwithstanding this, enhancing standards to increase resilience is also an important intervention to make where it is beneficial and cost effective.

The recommendations stemming from this review are as follows:

1. **For MV overhead network, it is recommended to increase the minimum pole size up one pole class for intermediate structures on three-phase 150 mm^2 AAAC MV overhead network for new construction and as part of any asset replacement or upgrade works. This change would increase the resilience of this network, which is of particular importance as it is the most likely to be supplying electricity to large customer groups on the MV system.**
2. **For 38 kV network with 100/150 mm^2 conductor the single pole structure is identified as the least reliable component for high wind events. It is recommended to increase the strength of the pole on single-pole structures for new construction and as part of any asset replacement or upgrade works in order to achieve greater resilience to wind events across the 38 kV network as network development and renewal is undertaken.**
3. **This review has identified some specific network which has greater vulnerability due to the lower mechanical strength of the network and the historical exposure of this network to severe windstorms. ESB Networks plans to complete proactive interventions to increase the mechanical strength of this network over the course of the Price Review 6 period (2026 to 2030). The interventions envisaged will involve strengthening specific isolated structures across ~900 km of MV overhead network and ~1400 km of 38 kV overhead network. These interventions will be future-proofed to ensure the strength of these structures has capacity to withstand wind gusts in excess of 180 km/hr.**
4. **Documentation relating to mechanical design parameters, materials and standard designs should be reviewed and updated where necessary to ensure that the mechanical strength which is inherent in the combination of these standards is preserved to an appropriate level to meet the potential severity of windstorms impacting the overhead network. Enhancements to the 38 kV and MV standards as proposed above are to be included in these updates. The updates to this documentation will have no material change to the mechanical strength of the network as set out in this report apart from the enhancements stated, unless upon subsequent analysis decisions to enhance other areas of the standard are made. The updated standards should be reflected in a revised National Normative Aspects (NNA) to the European standard EN 50341.**
5. **The anticipated Met Éireann TRANSLATE weather models for wind gusts in Ireland will be reviewed once available and further trending of data will be completed up to the end of the century for the various climate change scenarios.**

The interim report has been developed largely in the context of Storm Éowyn, with initial findings that identify several aspects of overhead line standards that can be enhanced immediately.

The final report will be completed in the context of future climate risk, including the potential for Ireland to be affected by more extreme storms that further exceed all historical records. This work will incorporate continued guidance from the NCCRA and relevant expert reports, alongside further analysis of climate change impacts using Met Éireann data on future wind gusts, once available. The final report will also include considerations relating to severe windstorms experienced in other parts of Europe. Enhanced-strength overhead network designs are currently being developed, including the use of composite poles, which can be engineered to achieve significantly higher strengths than traditional timber poles. All of this work will inform the setting of long-term, future design parameters for the distribution overhead network and will be incorporated into the final report.

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