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INTEGRATING CLIMATE CHANGE RISKS AND UNCERTAINTY IN INFRASTRUCTURE DEVELOPMENT TO ENSURE A CLIMATE RESILIENT IRELAND

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Key Research Findings & Observations

Climate risk consideration is fragmented and inconsistently embedded Climate risk consideration across Ireland's critical infrastructure is improving but remains fragmented and insufficiently embedded in the processes, regulations and structures governing infrastructure development and management across both public and private sectors. The critical entities identified within the Critical Entities Resilience (CER) Regulations may require additional coordination, institutional capability and alignment across adaptation, regulatory and governance structures to ensure climate risk and adaptation are consistently embedded.

Observation 1: Establish a universal statutory requirement for climate risk assessment across all critical infrastructure

Economic regulation does not incentivise climate resilience investment Climate resilience is not explicitly required or incentivised as a distinct category in economic regulation, leaving operators with weaker incentives to invest proactively in adaptation compared to other areas of network performance.

Observation 2: Introduce dedicated climate resilience metrics into regulatory price reviews

The planning and consenting system is inadequately equipped to scrutinise climate risk The EIA process is not designed to function as a comprehensive, decision-grade climate risk assessment, and climate risk considerations arrive too late in the project lifecycle. Current EIA processes also have limited capability to assess indirect and cascading societal impacts arising from infrastructure disruption, including downstream public health implications.

Observation 3: Develop national practitioner guidance for climate risk in EIA and advance its consideration to earlier lifecycle stages

Treatment of climate uncertainty is weak and inconsistent Few infrastructure projects demonstrate any structured approach to climate projection uncertainty. Multi-scenario stress testing is rare, projections are often outdated, and different operators are stress-testing against inconsistent climate futures due to the absence of a nationally agreed scenario baseline.

Observation 4: Establish a nationally agreed climate scenario baseline for infrastructure stress testing

Cascading and interdependent risks are not systematically assessed Climate risk assessments consistently treat infrastructure sectors in isolation despite deep interdependencies. The cascading failures during Storm Éowyn in January 2025, where simultaneous outages across electricity, water, transport and telecommunications compounded one another, are a direct consequence of this siloed approach.

Infrastructure disruption can also generate significant downstream societal and public health impacts, including impacts arising from prolonged outages, service disruption and cascading failures. Future climate risk assessment approaches should progressively incorporate consideration of wider societal vulnerabilities and impacts.

Observation 5: Mandate cross-sectoral interdependency assessment and establish a cross-sectoral climate risk coordination body

Existing infrastructure carries a significant unquantified climate risk A large proportion of Ireland's operational critical infrastructure was designed to standards that did not contemplate future climate conditions, yet no systematic, network-wide climate vulnerability assessment exists for any major sector.

Observation 6: Commission systematic network-wide climate vulnerability assessments for all major critical infrastructure sectors

Short-term emergency preparedness has improved but longer-term adaptation planning remains in its infancy Emergency coordination and response have strengthened in recent years, but long-term climate resilience planning for critical infrastructure remains underdeveloped, with no clear requirement for asset-level climate risk assessment or adaptation pathway development by owners and operators. Adaptation pathways approaches support long-term adaptation planning by enabling infrastructure risks, thresholds and adaptation options to be assessed under multiple future climate scenarios over time. This allows infrastructure operators and decision-makers to identify vulnerabilities earlier, prepare for a range of plausible future conditions, and reduce the risk of maladaptive or reactive responses to climate-related disruption events. Adaptation planning should also remain iterative and flexible, allowing learning from climate events and disruption incidents to inform future adaptation planning cycles and adaptation measures.

Observation 7: Embed long-term climate resilience requirements in the current National Development Plan investment cycle

Infrastructure disruption can generate significant downstream societal impacts which remain insufficiently integrated into current climate risk assessment approaches

While this study focused primarily on transport, energy, water and ICT as foundational infrastructure networks, disruption to these systems can generate significant downstream impacts across wider societal systems, including health, housing and food systems. Future climate risk assessment approaches should progressively incorporate consideration of cascading societal impacts and vulnerabilities arising from infrastructure disruption. In tandem, sectors such as health, food and housing also manage significant physical assets and infrastructure portfolios which may require climate risk assessment at asset, portfolio and entity level.

Observation 8: Integrate societal impacts into infrastructure climate risk assessment

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Executive Summary

Critical Infrastructure (CI), including transport, energy, water and communication, underpins a well-functioning society and a resilient economy. These interconnected networks provide important services, including mobility and trade, power for homes and businesses, safe water and wastewater services, digital connectivity and emergency response. When CI performs reliably, it supports public health, social wellbeing, productivity and national competitiveness. When it fails, cascading disruption can quickly affect essential services and citizens' daily lives and has severe impacts on the environment and economy.

Ireland has a recognised infrastructure deficit, with national analysis highlighting underinvestment and underdevelopment in key areas including transport and electricity (Conroy & Timoney, 2024). In response, the Irish Government has published the Accelerating Infrastructure Report and Action Plan, setting out time-bound actions intended to remove barriers and speed up delivery of major infrastructure across multiple sectors and agencies (Department of Public Expenditure, Infrastructure, Public Service Reform and Digitalisation, 2025). This policy momentum creates an important opportunity as Ireland invests to close the gap; it can ensure new assets are not only delivered faster but are also fit for a changing climate.

Ireland's climate adaptation governance framework has also evolved significantly in recent years through the National Adaptation Framework (NAF), Sectoral Adaptation Plans (SAPs), the National Climate Change Risk Assessment (NCCRA), and the transposition of the Critical Entities Resilience (CER) Directive through the European Union (Resilience of Critical Entities) Regulations 2024. Together, these frameworks increasingly recognise the importance of climate risk assessment, continuity of essential services and protection of wider societal functions.

Designing and managing infrastructure for Ireland's future climate is now essential. Observed and projected changes, such as more intense rainfall, heightened flood risk, and more frequent disruptive extreme events can undermine asset performance, shorten design life and increase maintenance burdens if not explicitly addressed in planning, design standards, and operational decision-making. Flood risk, extreme storm events, prolonged dry periods, sea level rise and coastal erosion are some of the climate hazards that are a growing concern in Ireland with direct consequences for communities, infrastructure operations and the wider economy. Beyond physical damage, extreme events can sever CI networks (e.g. power outages disrupting telecoms, flooded transport corridors impeding emergency access), with knock-on impacts for citizens, businesses and public services. Ireland's National Climate Change Risk Assessment (NCCRA) has highlighted risks in critical systems such as electricity, water and communications (Environmental Protection Agency, 2025), reinforcing the need for stronger preparedness and resilience measures.

At the same time, resilience is not only a 'new build' challenge. The reliability of Ireland's existing CI depends on sustained maintenance, targeted upgrades, and systematic management of climate-related risk across the full asset lifecycle. Without proactive adaptation, ageing infrastructure can become increasingly sensitive to extremes, increasing the likelihood of service disruption, escalating costs, and compounding socio-economic impacts.

International guidance strongly supports this shift. The OECD have highlighted that climate resilience should be mainstreamed into infrastructure planning and decision-making so that assets can withstand future climate-related risks (OECD, 2024). More specifically, the OECD have emphasised the need for whole-of-government coordination, improved data and risk understanding, and enabling regulatory and financing conditions that make resilience standard practice rather than an add-on. Similarly, the EU Technical Guidance Paper on Climate Proofing provides a high-level overview of all relevant legislation, directives, example projects and funding mechanisms that apply to critical infrastructure (European Commission, 2021). Recommendations include integrating climate vulnerability and risk assessment as part of the project screening and design integration and a regular review of the climate risk assessment is expected. This is to provide the broadest range of possibilities for selecting the optimal adaptation options against identified climate hazards.

This research project assesses how climate physical risks and associated uncertainty are currently considered and integrated in (1) the development of new critical infrastructure and (2) the management of existing critical infrastructure in Ireland. The study focuses primarily on transport, energy, water and ICT as foundational infrastructure networks underpinning wider societal systems and essential services. However, the outcomes are applicable to other infrastructure, such as the entities and/or assets within the health, housing and food systems.

The study combines a structured desk-based review with stakeholder engagement to understand current practices, decision points, data use, governance arrangements, and barriers to implementation. The central aim is to identify gaps and to provide evidence-informed insights to support policy and practice, ensuring that Ireland's infrastructure investment programme delivers assets that are not only timely and cost-effective, but resilient to Ireland's changing climate.

1 Introduction

1.1 Scope of Engagement

Climate Matters Ltd (CML) was engaged by Ireland's Climate Change Advisory Council to complete research entitled 'Integrating Climate Change Risks and Uncertainty in Infrastructure Development to Ensure a Climate Resilient Ireland', which commenced in November 2025 and was ongoing for a period of 6 months.

1.2 Objectives

Ireland's Critical Infrastructure networks are increasingly exposed to the impacts of climate change, including extreme weather events, such as flooding, windstorms, intense precipitation, heatwaves, as well as long-termer chronic hazards, such as sea level rise and rising temperatures. Recent extreme weather events, such as Storm Chandra and Storm Éowyn have demonstrated the vulnerability of CI systems to flooding, high winds, and prolonged service disruptions, with cascading consequences for communities and the economy. At the same time, the National Development Plan (NDP) in Ireland has set out unprecedented levels of investment in new infrastructure over the coming decades (Government of Ireland, 2025), creating both an opportunity and an obligation to embed resilience at the heart of infrastructure planning and delivery. International best practice, including guidance from the European Union, OECD, and the IPCC, emphasises the importance of integrating climate risk and uncertainty into infrastructure decision-making (European Commission, 2021; Intergovernmental Panel on Climate Change, 2023; OECD, 2024).

Critical Infrastructure (CI) refers to the essential systems, services, and assets that enable societies to function effectively. The IPCC define physical infrastructure as energy, transport, communications (including digital), built form, water and sanitation, and solid waste management (Intergovernmental Panel on Climate Change, 2023). The IPCC also highlight that physical infrastructure is costly to repair and has significant impacts on people's health and well-being. Meanwhile the EU have defined CI as 'an asset or system which is essential for the maintenance of vital societal functions' (Council of the European Union, 2008). While CI sectors differ between countries, Ireland's network typically consists of transport, energy, water and communications technology (ICT). For the purposes of this study, the assessment focuses primarily on these foundational infrastructure networks, which underpin wider societal systems and essential services. These interconnected systems provide the foundation for everyday life by delivering public services, supporting economic activity, and enhancing overall quality of life. However, their interdependent nature also creates systemic vulnerabilities. Disruption amongst one sector can extend across others, resulting in cascading failures that amplify the consequences of events.

The objective of this research was to establish best practice in relation to climate risk for existing and new CI networks in Ireland. To do so, Climate Matters have conducted a desk study in relation to current consideration of climate physical risk for existing and new CI in Ireland. In addition, a gap analysis has been conducted, which has led to the proposal of a climate risk framework for CI in Ireland, along with recommendations for improved consideration of climate risk and uncertainty in infrastructure development. The desk study has been complimented by substantial stakeholder engagement with infrastructure owners and operators from the transport, energy, water and telecommunications sectors, as well as government departments and other national authorities.

2 Stakeholder Engagement

To support the desktop research, stakeholder engagement was conducted with many of Ireland's critical infrastructure owners, operators, regulators and decision-makers. Due to the limited number of infrastructure owners in Ireland and the majority under government ownership, Climate Matters reached out to other sectors, which are typically investor owned and market facing, to understand differences between government owned infrastructure and privately owned.

2.1 Approach to Stakeholder Engagement

Climate Matters' team has been involved across energy, water, transport, engineering and the built environment over many years across infrastructure design, development, construction and through to operations and maintenance. From this network, contacts were selected to get a sense of how climate risk assessments are being carried out, what is being asked for by insurers, investors and lenders, and what are the expectations from a "good" climate risk assessment. To carry this out, Climate Matters contacted companies directly, industry bodies, government departments and agencies across the following stakeholder types:

- Approving bodies & investors in infrastructure projects,
- Insurance, reinsurance, brokers,
- Infrastructure owners and operators,
- Real estate owners and operators,
- Experts in energy, water, transport, communications,
- Regulators,
- Government departments & groups with responsibility for infrastructure,
- Project developers,
- Engineering consultancies with responsibility for carrying out climate risk assessment,
- Climate data providers.

2.2 Interview focused topics

The engagement focused on how climate risk and uncertainty are currently considered in infrastructure planning and operations in Ireland, and what the current regulations / drivers are in relation to consideration of climate risk and uncertainty. The engagement consisted of a series of meetings that comprised semi-structured interviews centred around the following questions:

- Does climate risk influence decision-making, reporting, and prioritisation of investment?
- What methodology is used for new investments and existing assets?
- Has your company assessed the commercial impacts of climate change (e.g. customers, contracts, insurance, regulator penalties, etc.)?
- What gaps exist in understanding your company's exposure, vulnerability, and adaptive capacity?
- What adaptation measures have been implemented to date?
- How does your company handle uncertainty?
- Have you any case studies you would like to support during this research?

Table 1 in Appendix 2 outlines the organisations that the project team met with during this research. The list is by no means exhaustive but represents a good portion of stakeholders relevant to this research project. Insights from these discussions were used to guide the desk research and to inform the case studies selected in this project.

2.3 Summary of Engagement

The discussions with stakeholders have influenced the direction of the research and following chapters contain further insight. There were several themes arising from the engagement:

- Private sector owners of CI are mandated by investors to provide detailed information on quantitative climate risk assessments and are required to use high resolution hazard data and consider multiple climate scenarios. They are also required to upload vulnerability details and existing adaptation measures. These can be to private platforms, where investors can compare risks across their portfolios, and are shared in public domains also. Real estate tends to dominate but infrastructure is also present and growing.
- Climate risk reporting takes place through CSRD reporting, where applicable.
- Commercial semi-states, which include some CI owners, report to the Climate Action Framework. Reporting qualitatively on climate adaptation is part of the current reporting process.
- In other jurisdictions, there is a growing requirement from insurers and financing partners for the developer and/or owner of new infrastructure to provide a quantitative climate risk assessment.

3 An Analysis of National and EU Requirements, Reporting Obligations, Gaps and Opportunities

The governance landscape for climate resilience of critical infrastructure in Ireland operates across three interlocking levels: 1) national transposing legislation, strategies and plans, 2) EU legislative and policy frameworks that set minimum binding requirements, and 3) sector-specific regulatory and appraisal regimes that determine how requirements are operationalised by infrastructure owners and operators. These three levels do not always align. This review maps each layer, identifies what is required of owners and operators in the transport, energy, water and telecommunications sectors, and identifies key gaps, opportunities and areas for alignment.

3.1 National Policy Frameworks

3.1.1 Climate Action and Low Carbon Development (Amendment) Act 2021

The Climate Action and Low Carbon Development (Amendment) Act 2021 (No 32 of 2021)) is the primary enabling legislation for climate governance in Ireland. It establishes legally binding economy-wide carbon budgets and sectoral emissions ceilings, mandates annual Climate Action Plans, and requires the National Adaptation Framework and Sectoral Adaptation Plans. It also established the Climate Change Advisory Council (CCAC) as the independent oversight body.

3.1.2 National Adaptation Framework (NAF) 2024

Ireland's second statutory National Adaptation Framework was published on 5 June 2024 (DECC, 2024). It identifies 14 priority sectors under 7 lead departments that are required to prepare sectoral adaptation plans under the Climate Act. The 2024 NAF moves towards an outcomes-based strategy to better monitor and evaluate progress in enhancing the resilience of infrastructure, ecosystems, and society at large against climate change.

The 14 sectors identified for SAPs include infrastructure-relevant categories within the Built Environment and Infrastructure theme, covering transport, energy/electricity and gas networks, communications, flood risk management, built environment and planning and water services infrastructure. The second iteration of SAPs, required under the NAF, resulted in 10 SAPs being published in 2025 (DECC, 2025). A review of the SAPs by the Climate Change Advisory Council found that while some sectors show ambition in their proposed measures, most have not clearly identified which specific policies or strategies will mainstream adaptation, and clear outcome-based indicators are still lacking (CCAC, 2025).

Notably, the Built Environment and Planning sector, newly added under the 2024 NAF, remains without a full Sectoral Adaptation Plan. While the Department of Housing, Local Government and Heritage (DHLGH) has confirmed a scoping exercise as an agreed action under the NAF, there is as yet no commitment to a full SAP for this sector (CCAC, 2024). This gap is of particular significance in the context of critical infrastructure. The built environment and planning system is the primary gateway through which new infrastructure assets are appraised, consented and delivered. Without a dedicated SAP setting out how climate risk and adaptation are to be systematically embedded in planning policy, development management and building standards, there is no overarching policy framework to drive climate resilience upstream, at the point where design decisions are made and where the cost of incorporating adaptation is lowest. The absence of this plan also means there is no formal mechanism to coordinate adaptation requirements across the infrastructure sectors that depend on the planning system to give effect to their own resilience objectives.

The 2024 NAF also requires all local authorities to prepare Local Authority Climate Action Plans (LACAPs), building on the statutory obligation established under the (Climate Action and Low Carbon Development (Amendment) Act 2021 (No 32 of 2021). All 31 local authorities completed their first LACAPs by Q1 2024, each valid for five years and incorporating both mitigation and adaptation measures, with collectively almost 4,000 actions set out across all plans. A subsequent analysis by the Climate Action Regional Offices (CAROs) found that of the 3,935 actions adopted, only 13% are classified exclusively as adaptation actions, while 49% address both mitigation and adaptation (CARO, 2024) suggesting that dedicated adaptation activity at local level remains limited relative to the scale of the challenge. Local authorities are currently in the implementation phase of their first LACAPs, with the next iteration due to be developed in advance of 2029.

3.1.3 Climate Action Plan

The annual Climate Action Plan set out both mitigation and adaptation actions. The adaptation chapter of Climate Action Plan 2024 is process-based, with key actions including the development of SAPs (Government of Ireland, 2024). The Climate Action Plan 2025 states that adaptation is mainstreamed across the plan as a whole and that relevant actions are incorporated in an adaptation section as well as under different sections of the plan (Government of Ireland, 2025a). Climate Action Plan 2026 was not yet published at the time of this publication (The Irish Times, 2026).

3.1.4 National Climate Change Risk Assessment (NCCRA)

The EPA published Ireland's first National Climate Change Risk Assessment in June 2025. This provides the prioritised national risk register that underpins SAP development and should inform designations under the CER Regulations, as described in Section 3.2.1. The NCCRA and some recent Sectoral Adaptation Plans have increasingly recognised cascading and cross-sectoral climate risks; however, the extent to which these risks are systematically incorporated into infrastructure planning, appraisal and operational decision-making remains inconsistent across sectors.

3.2 EU Legislative and Policy Frameworks

3.2.1 Directive (EU) 2022/2557 - Critical Entities Resilience (CER) Directive

The CER Directive 2022/2557 is the foundational EU instrument. It replaces the European Critical Infrastructure Directive of 2008 (Council Directive 2008/114/EC), which only applied to the energy and transport sectors, and widens the scope to eleven sectors, including banking, financial market infrastructure, health, digital infrastructure, and the production, processing, and distribution of food. The Directive establishes an all-hazards approach, explicitly including natural hazards, climate change, terrorist attacks, sabotage and public health emergencies. Climate adaptation is explicitly embedded in the resilience measures required. Designated entities must prevent incidents from occurring, duly considering disaster risk reduction and climate adaptation measures. This is a legally binding requirement, not guidance.

In October 2024, the Minister for Defence signed the European Union (Resilience of Critical Entities) Regulations 2024 (S.I. No. 559 of 2024), transposing Directive (EU) 2022/2557. The regulations apply to the following sectors: energy, transport, banking, financial market infrastructure, health, drinking water, wastewater, digital infrastructure, public administration, space, and large-scale food production, processing, and distribution.

Ireland has allocated supervisory and enforcement responsibilities to regulatory bodies across a number of sectors. This means existing sectoral regulators, rather than a single new body, act as competent authorities under the Regulations. The competent authorities for the Critical Infrastructure sectors examined in this research are outlined in Table 2.

Table 1 - Competent Authorities for Critical Infrastructure Sectors in Ireland under S.I. No. 559 of 2024

Sector	Competent Authority
Energy (electricity, gas)	Commission for Regulation of Utilities (CRU)
Drinking water / Wastewater	Commission for Regulation of Utilities (CRU)
Digital infrastructure / Telecommunications	Commission for Communications Regulation (ComReg)
Transport	Department of Transport

Competent authorities must decide which entities they supervise should be counted as critical entities within 21 months of the entry into force of the Regulations (i.e., by July 2026), and those entities will be notified of their designation within one month.

Once notified of designation, critical entities in Ireland must, within ten months:

1. Conduct a risk assessment — covering all relevant hazards including climate and natural hazards, with updates every four years or following significant changes.
2. Prepare and implement a resilience plan — a documented policy setting out how the entity will prevent, resist, mitigate and recover from incidents. The entity shall review and where necessary update its resilience plan following each risk assessment or significant change.

3. Implement physical and operational resilience measures — including physical security, crisis response procedures, business continuity, supply chain risk management, and personnel security.
4. Notify incidents — without undue delay — to the competent authority where incidents significantly disrupt or could significantly disrupt essential services.
5. Cooperate with competent authorities, including during inspections and advisory missions.

The climate adaptation obligation is embedded in point 1 and 2 - risk assessments must consider natural hazard and climate risks, and resilience plans must address prevention of incidents through climate adaptation measures. Given that the CER framework is concerned with all hazards, there is a risk that climate risk assessment is treated as a secondary consideration within what is primarily a national security framework, rather than being accorded equal standing with natural hazard risk.

3.2.2 Additional EU Policy Instruments

Several additional EU instruments bear directly on climate resilience of infrastructure:

- **European Green Deal (COM(2019) 640 final) and Fit for 55 Package (COM(2021) 550 final):** Creates the decarbonisation context within which resilience planning must operate, particularly relevant for energy and transport.
- **EU Taxonomy Regulation (2020/852)**: Requires "Do No Significant Harm" (DNSH) assessments and climate resilience screening for infrastructure investment accessing EU sustainable finance.
- **EU Adaptation Strategy (2021)**: Commits the EU to smarter, faster and more systemic adaptation, with infrastructure as a key sector.

The European Commission has also announced plans to develop an integrated European framework for climate resilience, expected in 2026, which aims to strengthen harmonised climate risk assessment, resilience-by-design approaches and cross-sectoral climate preparedness across Member States.

3.3 Sector-Specific Regulatory and Appraisal Regimes

3.3.1 Guidance for Semi-State Bodies: NewERA Climate Action Framework

The NewERA Climate Action Framework establishes the overarching requirements for how Commercial State Bodies (CSBs) are expected to identify, assess and respond to climate risk (National Treasury Management Agency, 2022). The 2025 Implementation Update reflects a growing recognition that adaptation has received comparatively less attention than mitigation across the semi-state sector, and that this gap must be addressed as climate-related physical risks to critical infrastructure intensify.

The core requirement of the Framework is that climate risks must be identified, assessed and integrated into each CSB's risk management process. As of the 2025 update, 25 of the 26 CSBs have completed this step. Organisations are expected to apply a standard physical climate risk methodology encompassing the identification of relevant hazards, exposure and vulnerability assessment. Official climate data sources are to be used alongside national risk assessments and sectoral adaptation plans to ensure that individual risk assessments are both evidence-based and nationally aligned. Climate objectives must be board approved and embedded within investment strategies, with investment appraisal incorporating the monetisation of climate impacts. Flooding is identified as the most prominent hazard across the sector.

Notwithstanding progress on risk identification, adaptation planning across the semi-state sector remains less mature, less formalised and less consistently implemented than mitigation-focused activity. Of the 26 CSBs, 10 have climate action objectives related to adaptation, 4 have published adaptation plans, and 19 have assessed their exposure to climate hazards, of which 20 have drawn on official data sources. Six CSBs have not completed any assessment of climate exposure. A key challenge is that adaptation does not lend itself to the universal targets and measurable metrics that characterise mitigation policy, making consistent implementation and performance monitoring more difficult.

The 2025 update acknowledges structural gaps in the broader enabling environment, including the absence of adaptation indicators and a climate damage risk register at national level, and highlights financing gaps for adaptation investment in Ireland. The publication of recent sectoral adaptation plans and the operational impact of Storm Eowyn are expected to prompt CSBs to revisit their investment plans and sharpen their adaptation objectives.

CSBs report their progress on climate action to NewERA through two channels. First, by specifying capital investments and projects included in their corporate plans that relate to climate action, in addition to reporting on emissions, emissions reduction and energy efficiency initiatives. Second, through the Climate Action Framework submission, which requires organisations to provide statements on their adaptation objectives, confirm whether a board-approved adaptation plan is in place, document the climate risk and vulnerability assessments undertaken, identify the hazards to which they are exposed, specify the climate information sources used, and declare any barriers to completing the above.

This submission process functions as a progress indicator, enabling NewERA to track how consistently and rigorously CSBs are advancing their adaptation planning. For critical infrastructure operators within the semi-state sector, the Framework sets a clear direction of travel: organisations are expected to evolve from basic risk identification towards defined adaptation objectives, formal adaptation plans, explicit resilience measures, and scenario-based modelling aligned with national adaptation policy.

3.3.2 Transport

The Department of Transport's Transport Appraisal Framework (TAF) (DoT, 2023) and TII's Project Appraisal Guidelines (PAG) (TII, 2024) are the primary instruments governing how climate risk is considered in transport infrastructure planning and investment decisions.

Climate change is one of seven appraisal criteria in the TAF/PAG Multi-Criteria Analysis framework. An options score under the climate change sub-criteria should reflect its ability to promote travel patterns which reduce the carbon footprint of transport users. The criterion also aims to capture an option's potential ability to deliver infrastructure or services which are resilient to climate change induced events such as higher rainfalls and sea levels. The PAG requires that the assessment should include the impact of the proposal on greenhouse gas emissions and the resilience of the proposal to the impacts of climate change, information on the incorporation of climate impacts into the economic appraisal, and the output of the Climate Change Impact and Local Environment Impact assessments from the Transport and Accessibility Appraisal (TAA) for the scheme. This reflects both climate mitigation and climate adaptation impacts. Despite the inclusion of climate adaptation as a qualitative MCA criterion, the depth of treatment is largely discretionary and not standardised. There is no explicit requirement to conduct formal scenario-based climate risk assessment or apply Decision Making under Deep Uncertainty (DMDU) methods.

From the outset of a project, the Project/Programme Outline Document (POD) should outline if the proposal is aligned with national and local climate adaptation strategies such as the National Adaptation Framework, Sectoral Adaptation Plan and Local Authority Climate Action Plans. As such, this link is formal but light-touch.

TII has also published a Climate Adaptation Strategy, committing to proactively managing climate change impacts on the national road and light rail networks, including heatwaves which can cause damage and service disruptions, with TII aiming to manage climate change impacts proactively to avoid the worst of these impacts and costly reactive measures.

3.3.3 Energy

The CRU is Ireland's independent energy and water economic utility regulator, licensing and monitoring electricity generators, setting allowed revenue/tariffs for transmission and distribution, and approving connection policy. Through its revenue-setting (price review) process, the CRU approves network operators' capital and operating expenditure, including resilience investment.

The CRU's 2025 strategic plan (CRU, 2025 explicitly frames its work around "regulating energy and water for a changing climate," but the specific mandated requirements for climate risk assessment within the revenue-setting process remain largely at the discretion of the regulated entities (ESB Networks, EirGrid, Gas Networks Ireland, Uisce Éireann). The Climate Change Advisory Council identified information gaps presenting barriers to achieving climate resilience and noted governance, coordination and cross-cutting issues as key challenges for the energy sector (CCAC, 2025a).

Public sector projects are required to demonstrate how they will result in increased resilience to the impacts of climate change, offering opportunities for improving the climate risk stress testing of critical infrastructure projects and identifying potential failure points, adaptation options and cascading risks.

3.3.4 Water

The CRU is Uisce Éireann's economic regulator. It has a role in revenue setting, performance reporting (Uisce Éireann must report to the CRU on its performance every six months), customer service, and approval of policy and charges.

Uisce Éireann, as a designated critical entity in both the drinking water and wastewater sectors under S.I. 559/2024, will be subject to the full suite of CER obligations. Climate resilience of water infrastructure is also addressed under the relevant SAP and is referenced in CAP 2025 (Action AD/25/1 on improving the resilience of water infrastructure through nature-based solutions).

3.3.5 Telecommunications

The Commission for Communications Regulation (ComReg) has been designated as the competent authority in the State for the resilience of critical entities in the Digital Infrastructure sector. ComReg's formal regulatory instruments have not yet embedded climate risk assessment requirements into operator obligations. ComReg's new strategy for 2025–2027 (ComReg, 2025) sets out that as competent authority under the CER Directive, ComReg will have regard to the National Strategy for the Resilience of Critical Entities which the Department of Defence Office of Emergency Planning will deliver in Q1 2026.

3.4 Relevant National Research Activities

Two EPA-funded research projects, CIViC: Critical Infrastructure Vulnerability to Climate Change (Ryan et al. , 2021) and INFRALINC: Infrastructure Climate Change Risk Considering Interdependencies and Cascading Hazards (Bernardini et al. 2023), provide useful good-practice references for climate-proofing Irish critical infrastructure. CIViC developed a climate-risk analysis framework for Irish critical infrastructure, using the IPCC framing of risk as a function of hazard, exposure and vulnerability, and applied it first through high-level GIS-based screening across transport, energy, water and ICT, before moving to a more detailed quantitative assessment for the energy sector. The report's key implication is that screening is valuable for identifying potential hotspots but is not sufficient on its own to support adaptation investment decisions; more detailed quantitative assessment is required where assets or networks are flagged as exposed or vulnerable.

INFRALINC complements this by focusing specifically on interdependencies and cascading hazards across critical infrastructure systems. It frames climate risk as a system-of-systems issue, where failures in one infrastructure network can propagate through others, and where extreme weather hazards such as storms, landslides, river flooding and coastal events can have wider societal and environmental consequences. The project highlights practical barriers to robust cross-sector risk assessment in Ireland, particularly inconsistent risk methodologies, gaps in data availability, limited data sharing, data-security concerns and the absence of common cross-sector metrics. Its recommendations point towards the need for shared governance arrangements, secure data-sharing protocols, monitoring regimes and common minimum datasets to enable meaningful cross-sector climate risk assessment.

3.5 Identified Gaps and Opportunities

3.5.1 Alignment between CER Risk Assessments, the NCCRA and SAPs

Three distinct risk assessment processes currently apply to critical infrastructure in Ireland: 1) the CER national risk assessment (under S.I. 559/2024); 2) the National Climate Change Risk Assessment (EPA, 2025); and 3) the SAP risk assessment process. These have been developed on parallel tracks with limited explicit integration. Without alignment, there is a risk that infrastructure sectors produce multiple, inconsistent risk assessments that do not cross-fertilise.

The recently published National Climate Change Risk Assessment (EPA, June 2025) provides a natural common foundation for CER risk assessments. A policy requirement that critical entities designate their sector's relevant risk categories from the NCCRA as the baseline, to be supplemented by entity-level assessment, would ensure consistency and enable aggregation. Furthermore, the SAP process and the CER designation and compliance process currently run in parallel with limited cross-reference. There is an opportunity to align these.

A practical method for aligning the NCCRA, Sectoral Adaptation Plans and Critical Entities Resilience designation would be to establish a common climate-risk alignment framework for critical infrastructure. This would use the NCCRA as the national reference taxonomy for climate risks, while allowing Sectoral Adaptation Plans and CER risk assessments to add sector- and entity-specific detail. The NCCRA is well placed to perform this role because it identifies Ireland's priority climate risks and is intended to support national, sectoral and local adaptation planning. For example, each infrastructure-related SAP could map its sectoral risks and adaptation actions to the relevant NCCRA risk categories, including the hazard, exposed assets or services, vulnerability factors, interdependencies and decision urgency. Next, CER competent authorities should use this mapped SAP/NCCRA risk set when identifying and designating critical entities, so that designation reflects not only current service criticality but also exposure to material climate risks.

3.5.2 No Standardised Climate Scenario Methodology for Infrastructure

While Met Éireann's TRANSLATE project has produced Ireland's first standardised national climate scenarios, there is no equivalent standardised requirement for critical entities conducting risk assessments under the CER regulations. Entities conducting risk assessments may use different climate scenarios, making comparison and aggregation at national and EU level difficult and potentially producing inconsistent results.

3.5.3 Limited Depth of Treatment in Project Appraisal Frameworks

The TII PAG treats climate change as one of seven qualitative sub-criteria in the Multi-Criteria Analysis. There is no requirement for formal climate risk scenario testing, no use of DMDU methods, and no alignment requirement with the design life of the asset. For long-lived infrastructure (roads, rail, bridges) with design lives of 50–100 years, this represents a significant methodological gap relative to best practice.

3.5.4 Strengthening Climate Resilience in CRU Revenue Setting

The CRU price review process approves capital and operating expenditure for regulated utilities, but there is no explicit statutory requirement for climate resilience investment to be quantified and justified through formal risk assessment methodology. The inclusion of climate resilience capex is currently at the discretion of the regulated entity and the judgment of the CRU, rather than being driven by a standardised risk-based framework.

The CRU's price review determinations for ESB Networks, EirGrid, Gas Networks Ireland and Uisce Éireann represent the primary mechanism through which capital investment in resilience is funded. Formalising a requirement for regulated entities to submit climate risk assessments, using standardised climate scenarios and a DMDU-aligned methodology, as part of their price review submissions would create a direct pathway from climate science to funded investment.

4 A Review of Climate Risk and Uncertainty in Recent Irish Infrastructure Planning

The preceding sections have examined the EU and national policy, legal and governance frameworks that set out requirements for infrastructure owners and operators in Ireland. A key question that follows from both reviews is the extent to which these frameworks are reflected in practice, specifically, whether and how climate risk and uncertainty are being considered in the planning and appraisal of infrastructure projects as they move through Ireland's development consent process. This section addresses that question through an examination of a selection of recent infrastructure planning applications and decisions across the transport, energy, water and telecommunications sectors. For each project, the analysis considers 1) the nature and extent of climate risk assessment undertaken, 2) the methods used to characterise and communicate uncertainty, 3) the degree to which assessments are aligned with national climate scenarios and adaptation policy, and 4) any observations made by An Bord Pleanála or other decision-making bodies on the adequacy of climate risk treatment. The aim is not to provide a comprehensive audit of planning practice, but to identify patterns, strengths and recurring gaps that can inform recommendations for improving how climate risk and uncertainty are handled across the project lifecycle, from appraisal and consent through to design, construction and operation.

4.1 New Critical Infrastructure Development

Integration of climate risk and uncertainty considerations into new infrastructure development is critically important given the planned substantial investment planned in the coming decades. The National Development Plan commits to the largest ever investment in the state's history of €275.4 billion between 2026 and 2035. A large portion of this investment relates to critical infrastructure as follows:

- €102.4 billion allocated for 2026–2030 across Government Departments
- An extra €34 billion compared to the previous National Development Plan, including €10 billion equity funding for major energy, water, and transport projects
- Over €40.4 billion for housing and critical infrastructure from 2026–2030
- €35.9 billion for housing and infrastructure
- €4.5 billion for Uisce Éireann to support water services

To highlight the scale of this investment, for the electricity sector for example, the CRU's PR6 enables up to €18.9 billion of investment in Ireland's electricity transmission and distribution networks between 2026 and 2030 (CRU, 2025). To support this programme, the Government has also approved €3.5 billion in equity investment in ESB and EirGrid. While not a direct comparison, in 2024, EirGrid Group's total assets were valued at approximately €1.35 billion and ESB Networks Regulated asset base valued at circa €11bn. Hence, the level of investment in electricity infrastructure is transformational. The dependency on electricity for heat and transport is growing rapidly and encouraged through government supports.

The following sections outline the existing requirements for considering climate risk and uncertainty for new infrastructure in Ireland.

4.1.1 Infrastructure Guidelines

For Exchequer-funded capital investment, the Infrastructure Guidelines (IG) embed climate considerations within the business case process (Department of Public Expenditure, NDP Delivery and Reform, 2023). In particular, the IG's Strategic Assessment / Preliminary Business Case guidance requires a dedicated section on "Climate and Environmental Performance", including assessment of the project's resilience to climate change impacts. Although the IG introduces an explicit requirement to assess climate resilience, it does not explicitly adopt or reference the OECD's Ireland-tailored methodology for integrating climate risk and uncertainty across planning, appraisal and subsequent lifecycle phases (OECD, 2023), despite that methodology having been developed in collaboration with Irish Government stakeholders as technical support to strengthen decision-making.

The OECD proposes a structured approach to assessing climate resilience in infrastructure appraisal built around three linked steps: vulnerability analysis, impact analysis, and adaptation strategies. Vulnerability analysis is used to identify and prioritise the climate and environmental hazards most relevant to an investment. It does this by assessing (i) the project's sensitivity, including on-site assets, inputs and outputs, and dependencies such as access and transport links, and (ii) the project's exposure to specific climate hazards. Impact analysis then focuses on the hazards assessed as presenting high to medium vulnerability. It evaluates (1) the likelihood of those events occurring and (2) the severity of impacts if they occur, considering multiple impact categories such as asset damage, safety and health, environmental effects, cultural heritage, social impacts, financial impacts, and reputational impacts. These likelihood and impact judgements are combined in a risk matrix to classify overall risk as low, medium, high, or extreme. Where risks fall from medium to extreme, the methodology requires the identification of adaptation strategies and measures to reduce vulnerability and manage residual risk.

The IG signals the importance of climate resilience, but does not translate that requirement into a consistent, mandatory analytical approach. Given the availability of an Ireland-specific OECD methodology developed with Government involvement, the absence of a prescribed framework in the IG can be seen as a missed opportunity to standardise practice across sectors and improve comparability.

4.1.2 Sector-Specific Project Appraisal Guidance

In the absence of a prescriptive cross-government method, some sectors have begun to develop their own sector-specific guidance and practices to operationalise climate resilience in appraisal and delivery. This has the benefit of tailoring to sectoral hazards, asset types and decision contexts, but it also risks fragmentation and uneven maturity across sectors.

In Ireland's transport sector, the Department of Transport's Transport Appraisal Framework (TAF) explicitly requires consideration of climate adaptation and resilience within project appraisal and business case development. At Preliminary Business Case stage, a dedicated "Climate and Environmental Performance" section must be included that addresses the resilience of the project to the impacts of climate change, and may additionally document the climate-related risks the project is exposed to and the adaptation and resilience impacts of the proposal (with qualitative treatment permitted where quantification is not feasible). In detailed appraisal, the TAF defines the "climate adaptation" dimension in terms of improving robustness (avoiding closure of critical links during extreme weather) and resilience (maintaining network function when some links fail), and embeds adaptation within the Transport and Accessibility Appraisal (TAA) as an assessment of vulnerability to climate impacts and likelihood of impact, drawing on climate hazard assessment and requiring that any qualitative scoring is grounded in a robust evidence base.

The OPW requires a Scheme Climate Change Adaptation Plan (SCCAP) to be prepared for all new OPW-funded flood relief schemes, as set out under the Climate Change Sectoral Adaptation Plan for Flood Risk Management (Government of Ireland, Prepared by the Office of Public Works, 2025). The SCCAP is intended to ensure that flood risk management interventions designed for present-day flood risk are also planned regarding potential future increases in flood risk due to climate change, and that the scheme is flexible and adaptable across possible future scenarios. The OPW's technical methodology sets out an Adaptation Pathway Process, aiming to embed climate resilience in a nationally consistent manner across the flood relief capital programme. Developing similar, sector-specific climate risk and resilience guidance for other critical infrastructure sectors would clarify expectations, support more consistent appraisal, and accelerate implementation, as well as helping to plan under conditions of uncertainty.

4.1.3 Environmental Impact Assessment

Environmental Impact Assessment (EIA) processes can capture aspects of climate resilience, including project vulnerability to climate change, but an EIA is not designed to function as a comprehensive, decision-grade climate risk assessment on its own. Dedicated practitioner guidance on how to assess climate change resilience and adaptation within EIA is available in the UK, which provides a structured framework for integrating climate risk and adaptation into EIA practice (IEMA, 2020). In Ireland, climate change is addressed within the national EIA guidance for planning authorities and the competent authority (Government of Ireland, 2018), but it is embedded as part of broader EIA guidance rather than being supported by a standalone, Ireland-specific practitioner 'how-to' guide focused on climate resilience/adaptation. This suggests an opportunity to strengthen consistency in practice by developing and/or formally adopting more detailed methodological guidance for climate risk and resilience within Irish EIA processes, particularly for long-lived critical infrastructure.

4.1.4 EU-funding Requirements

Where projects are supported by EU funding, requirements tend to be clearer and more operational, with well-established climate proofing guidance that sets out structured screening and escalation to more detailed analysis where warranted (European Commission, 2021).

4.1.5 Summary

A breakdown of climate risk requirements for new Critical Infrastructure development in Ireland is outlined in Table 3.

A preliminary review of Strategic Infrastructure Development (SID) applications in Ireland since 2018 was conducted, as outlined in Table 4. The objective was to understand where and the extent to which Climate Risk and Uncertainty is currently being considered for CI development in Ireland.

Table 2 - CRA Requirements for New CI Development in Ireland

Trigger / context	Guidance / Documentation	What is required (climate risk / resilience)	Who it applies to	Where in the project cycle
Exchequer-funded capital projects	Infrastructure Guidelines	Include a Climate and Environmental Performance section in the Preliminary Business Case (PBC), covering resilience to climate change impacts.	Public bodies / bodies receiving Exchequer capital funding	Strategic Assessment & Preliminary Business Case
EU-funded infrastructure	European Commission technical guidance	Climate proofing integrating adaptation, typically via screening and,	Projects seeking EU funds	Project preparation / appraisal;

	on climate proofing of infrastructure (2021/C 373/01)	where needed, detailed analysis (aligned with CPR and referenced for RRF).	(cohesion/CPR programmes, RRF-related investments, etc.)	supports investment decisions
Projects requiring Environmental Impact Assessment (EIA)	IEMA guide on EIA and climate change resilience & adaptation (2020)	Consider climate-related issues including vulnerability of the project to climate change and climate in the assessment scope (adaptation/resilience aspects).	Projects within EIA scope	Consenting / planning and environmental assessment stage
Sectoral delivery bodies with established climate guidance	e.g. TII climate guidance	Sector guidance may require climate screening and escalation to detailed climate risk assessment where material risks are identified.	Projects under that delivery body's remit	Design development / environmental assessment and asset decision stages

Table 3 - Review of Climate Risk & Uncertainty in Irish SID Applications since 2018

Sector	Project	Climate Risk Mentioned?	Quality / Depth of Assessment	Uncertainty in Projections	Adaptation Measures Proposed	Key Gaps / Observations
Transport	MetroLink	Yes — dedicated EIAR Chapter 11 (Climate)	Moderate. Climate addressed primarily as mitigation (GHG from construction, modal shift). Physical risk to assets covered qualitatively. Underground alignment presented as inherently resilient. Limited scenario-based stress testing.	No evidence of multi-scenario (RCP4.5/RCP8.5 or SSP) stress testing of design parameters. Sea level implications for Estuary terminus not prominently assessed.	Partial. Underground alignment reduces wind/storm exposure. No explicit adaptation measures listed for stations or surface infrastructure. No long-term asset resilience plan in public application documents.	Mitigation framing dominates. Flood risk to tunnel stations during extreme rainfall and sea level rise at coastal terminus were not prominent in the oral hearing record. Embodied carbon received more scrutiny than physical climate risk.
Transport	DART+ West (Maynoot	Yes — in EIAR and Inspector's Report	Flood risk assessment conducted for EIAR but site	Absent at project inception. Flood vulnerability of	Absent for depot. No adaptive design	Most significant planning failure of post-2018 SID transport

	h Line Upgrade + M3 Parkway)		with known flooding history selected as preferred depot location. Climate / flood risk appears not to have been applied as a filter at options appraisal stage.	preferred depot site was not identified as a fatal constraint until Inspector's review. Climate projections not used to screen sites at business case stage.	measures proposed to address flood vulnerability — site was refused rather than redesigned. Track upgrade did not include climate adaptation provisions in public record.	applications. Inspector stated the site 'should never have progressed to being the preferred site.' Demonstrates critical failure to embed climate/flood risk at site selection and Preliminary Business Case stage — before any planning application is lodged.
Transport	DART+ Coast North (Clongriffin–Balbriggan electrification)	Partial — climate referenced in strategic context and in TII Climate Adaptation Strategy	PBC focuses on cost-benefit analysis of electrification, capacity, and journey time. Climate risk to coastal alignment (sea level rise, storm surge at Portmarnock, Rush, Skerries) not prominently assessed in publicly available PBC documentation.	Absent in PBC. No scenario-based assessment of coastal flooding risk along the line under different warming trajectories identified in published PBC documents.	No adaptation measures specified at PBC stage for the coastal sections of the alignment.	The coastal nature of significant sections of this route makes it one of the higher-risk rail corridors in Ireland from a sea level rise and storm surge perspective. This risk is not visible in the PBC. Needs to be addressed before Railway Order application is lodged.
Energy	Celtic Interconnector (EirGrid — Cork to France subsea cable)	Yes — EIAR includes climate chapter	Climate treated primarily as mitigation context (renewables integration, security of supply). Physical	No evidence of scenario-based metocean or storm climate projections applied to cable landfall design parameters.	Limited. No explicit adaptation measures beyond standard engineering for cable burial	Approved before Ireland's National Climate Change Risk Assessment (June 2025) was published. Decision

			risk to onshore cable route and Knockraha substation assessed qualitatively.	Application predates NCCRA (2025).	depth and substation flood defence. Long-term operational climate risk not addressed.	therefore made without access to the most current national climate hazard inventory. Systemic gap affecting all pre-2025 applications.
Energy	North-South 400kV Interconnector (EirGrid — overhead line, border region)	Yes — EIS includes climate section	EIS and planning process focused almost entirely on visual impact, landscape, and community concerns. Physical climate resilience of pylon/overhead line infrastructure not a prominent assessment topic.	Absent. No scenario-based assessment of changing wind loading, storm frequency or icing on pylons under different climate trajectories.	Absent. No adaptation measures for the overhead line infrastructure identified in the planning record.	Climate mitigation infrastructure (enabling renewable integration) was not itself assessed through a climate adaptation lens. Post-Éowyn, overhead line resilience is now a live policy issue — but this asset was designed and consented without that consideration.
Energy	ORESS 1 Offshore Wind Projects (multiple developers, Celtic Sea/Irish Sea)	Partial — climate referenced in policy context; metocean surveys underway	Full EIARs not yet submitted. EirGrid deploying MetOcean buoys to collect baseline data. Scale and depth of climate risk assessment in forthcoming SID applications not yet publicly visible.	Uncertain. 25–30 year operational life of turbines means climate projections for 2050s–2060s carry very wide confidence intervals. No public evidence that RCP/SSP scenario approaches are being applied to wave/wind	Not yet specified. Adaptation measures (e.g. design tolerances for future storm conditions, cable burial depths accounting for future seabed mobility) will need to be addressed in	Most technically challenging climate risk assessment challenge in the current pipeline. ACPI has issued extensive Further Information Requests to developers. The question of how to handle deep uncertainty in long-run

				modelling at current stage.	SID applications.	metocean projections for 25–30 year design life is unresolved methodologically in Ireland.
Water	Water Supply Project — Eastern & Midlands Region (Uisce Éireann — Shannon to Dublin pipeline)	Yes — climate risk is the primary driver of project need	Strong on demand-side climate risk (drought reducing Liffey yields; 34% supply deficit by 2044). Moderate on physical risk to the 170km+ pipeline route itself. EIAR chapter on climate included but depth of asset-level risk assessment to be confirmed from application documents.	Unclear. Earlier Uisce Éireann framework plans used outdated AR4 (IPCC 4th Assessment) projections. Whether this SID application has updated to AR6-based projections is a critical question for scrutiny. Long-run demand projections under different warming scenarios not publicly visible.	Strong on supply diversification as an adaptation measure (reducing dependence on single Liffey source). Limited public detail on physical adaptation measures for the pipeline route under future climate conditions.	Largest water infrastructure SID in State history. Climate risk is central to the need case — but methodological rigour of climate projections underlying demand forecasts, and physical risk along the pipeline route, must be scrutinised in the application. AR4 vs AR6 baseline is a key research question.
Water	Greater Dublin Area Water Supply Resilience (Uisce Éireann — interim measures)	Yes — climate risk acknowledged in National Water Resources Plan	NWRP identifies climate change (drought, reduced source yields) as key driver. Asset-level climate risk assessment for individual schemes less visible. Post-Éowyn revealed pumping stations lacked backup power — suggesting	National Water Resources Plan uses a 25-year horizon, which experts have identified as too short for large infrastructure. Climate projections underlying forecasts not clearly specified.	Post-Éowyn reactive investment (100 generators procured). Supply diversification through WSP Eastern & Midlands is the primary long-term adaptation. Demand management	The 25-year planning horizon has been criticised as too short for infrastructure that takes 10+ years to design, permit and build. The single-source dependency (85% of GDA supply from River Liffey) is a known climate

			physical resilience not systematically assessed.		and leakage reduction also contribute.	risk that the Water Supply Project addresses — but interim resilience is low.
Telecommunications	National Broadband Plan (NBI — fibre to rural Ireland)	Partial — climate referenced in policy context; resilience cited as benefit of fibre over copper	No publicly available climate risk assessment for the NBP infrastructure. The fibre transition is presented as incidentally more resilient than copper but no systematic assessment of exposure to flooding, wind damage or other climate hazards along the rural network route.	Absent. No evidence of climate scenario analysis applied to network design, route selection, or underground/overhead decisions.	Partial. Underground ducting (where used) provides some resilience vs overhead copper. Backup power for exchanges not systematically addressed in NBP design — exposed by Storm Éowyn.	NBP represents the largest telecoms infrastructure investment in the State's history but climate resilience was not a design criterion. Post-Éowyn, the new Telecoms Sectoral Adaptation Plan (Nov 2025) and T-RRG represent the first structured response — but are reactive rather than embedded in the NBP from inception.
Telecommunications	Telecoms Sectoral Adaptation Plan (Dept of Environment / ComReg — Nov 2025)	Yes — first dedicated telecoms climate adaptation plan	Moderate. SAP identifies climate hazards to communication networks. Builds on Storm Éowyn lessons. Does not constitute a project-level EIAR but sets framework for future	SAP does not specify which climate projections (RCP/SSP scenarios) operators must use for resilience planning. No quantitative climate risk thresholds specified. So	Moderate. Establishes Telecommunications Response and Resilience Group (T-RRG). Requires increased underground ducting, on-site backup power, and cross-sector	Important but reactive — published in response to Storm Éowyn rather than as a proactive measure. The SAP creates a policy framework but does not itself require project-level climate risk

			investment decisions.	weak on uncertainty.	coordination. Specific investment commitments not yet detailed.	assessment. Whether it will be embedded in future SID or planning applications remains to be tested.

Across the transport preliminary/final business cases reviewed, climate is typically framed first through policy alignment and emissions reduction, with quantified GHG impacts where tools/methods are available (e.g. appraisal tools used to estimate emissions impacts). For example, the BusConnects Cork PBC treats 'climate and environmental performance' as central, describing emissions reductions driven by modal shift and fleet transition, and noting the use of NTA environmental appraisal tooling to estimate GHG changes. Where climate resilience/adaptation appears, it is often (a) described at a high level in the business case (i.e. statements about designing to mitigate flooding and withstand climate impacts), and/or (b) handled through EIA/EIAR documentation and dedicated flood risk assessment reports. BusConnects Cork is a good example of the 'high-level in PBC, detail later' approach. It explicitly links infrastructure to resilience and mentions design responses to flooding and adverse weather, but frames detailed assessment as part of future EIAs for corridors rather than presenting a structured climate risk assessment in the PBC.

By contrast, where EIAR and specialist studies are provided, adaptation is treated much more methodically. The DART+ West EIAR Climate chapter is explicitly structured around assessing impacts on climate across construction and operation and includes a defined section on the vulnerability of the proposed development to climate change (alongside methodology, mitigation, monitoring, and residual effects). The accompanying site-specific flood risk assessment (SSFRA) then provides a clear statement of conclusions, including how flood risks are identified/managed and that the scheme satisfies the OPW justification test requirements.

Finally, some rail business case material shows adaptation being incorporated via risk screening/scoring within appraisal frameworks, particularly where flooding is a known constraint. For the Cork Area Commuter Rail project, flood extents and risks are described (including CFRAM mapping and overtopping risk), the rail line is treated as "essential transport infrastructure" with high sensitivity, and climate change adaptation is scored using TAF guidance (with a negative score recorded for options where the level of impact remains "limited impact"). A summary of how and where climate adaptation is considered in transport projects is provided in Table 5 below.

Across many of the water services projects, climate risk is assessed a using semi quantitative approach primarily within the standard EIAR chapters on climate, flood management, risk of disaster and cumulative effects while also being mentioned at a high level within the planning reports and strategic needs sections as a project driver. For example, climate change is recognised as a driver within large new infrastructure projects such as the Greater Dublin Drainage project and the Eastern and Midlands Water Supply Projects, but vulnerability assessment is high-level and strategic rather than technical. It is dealt with specifically as future risk, with iterative reviews of the available data sets to be reflected within the design stages of the project. The primary design focus is put on flood risk management.

Table 4 - Review of how transport projects are treating adaptation and climate risks in their project development

Transport Project	Doc type / stage	Adaptation / physical climate risk treatment	Where the "detail" sits (in practice)	Notes
BusConnects Cork – Preliminary Business Case (July 2025)	PBC	Resilience referenced, including flooding events; corridors expected to undergo EIAs to ensure they can withstand climate impacts.	PBC sets intent; corridor-level EIAs expected to carry adaptation detail.	Illustrates a common pattern: adaptation acknowledged but not "decision-grade" in the PBC.
Luas Finglas – Preliminary Business Case	PBC	No adaptation method visible in the extracted passages reviewed (from your sample snippets); climate framing is largely mitigation/policy led.	Likely to sit later in EIAR / design standards rather than early business case narrative (based on what's visible here).	Useful "counterpoint" example: climate risk may be absent/implicit at PBC level unless driven by known hazards or sector guidance.
DART+ West – EIAR Chapter 13 (Climate)	EIAR / consenting	Explicit structured treatment: methodology + "vulnerability to climate change" section + impacts/mitigation/monitoring.	EIAR chapter is where climate/adaptation structure is explicit.	Shows what "good practice" looks like when EIA requires a structured narrative and significance criteria.
DART+ West – Site-Specific Flood Risk Assessment	Specialist risk study	Clear flood-risk conclusions and planning compliance (incl. OPW justification test).	Standalone technical report used to evidence resilience and planning compliance.	Demonstrates that adaptation evidence often exists, but outside the business case (and may not translate into option ranking unless pulled through).
Cork Area Commuter Rail WP3	Business case	Flood risk described using CFRAM extents; identifies essential	Mix: business case contains a more explicit adaptation	Helpful example of adaptation being made legible in

(Glounthaune–Midleton Twin Tracking)	materi al (later-stage)	infrastructure sensitivity; applies TAF climate change adaptation scoring (negative scores recorded).	scoring element; detailed flood analysis still referenced through mapping/technical sources.	appraisal (even if via relatively coarse scoring).

4.2 Existing Critical Infrastructure

Ireland's critical infrastructure across water, transport, energy, and telecommunications sectors is characterised by significant age, with much of it originally designed and constructed in the mid-to-late twentieth century to standards that did not contemplate the climate conditions now projected for Ireland over the coming decades. The water network, large portions of which date to the Victorian era and earlier, continues to experience high levels of leakage. The road network, while subject to ongoing investment, includes substantial legacy infrastructure not designed to withstand the increased frequency and intensity of flooding, prolonged drought, or the accelerated pavement degradation associated with more extreme thermal cycling. The electricity distribution network, approximately 84% of which is overhead, was built to mid-century loading standards and, as Storm Éowyn demonstrated in January 2025, remains acutely vulnerable to extreme wind events. Recent IEA report on Powering Ireland’s Energy Future highlighted that transmission and distribution systems are already at risk with 57% of high-voltage stations exceeding 60 years old by 2040 (IEA, 2025).

The telecommunications network, heavily dependent on the electricity grid and on legacy copper infrastructure that is only gradually being replaced by fibre, shares many of these vulnerabilities. Critically, infrastructure designed with a service life of fifty to one hundred years is now being asked to perform reliably under climate conditions that were not part of its original design envelope. In many cases, the cost and complexity of retrofitting resilience measures into existing assets far exceeds what would have been required had climate risk been embedded at the design stage. This legacy infrastructure deficit therefore represents not merely a maintenance challenge, but a fundamental climate adaptation gap that must be addressed as part of any coherent long-term infrastructure strategy for Ireland.

For existing critical infrastructure, requirements to consider climate risk are most consistently articulated through Ireland’s sectoral adaptation planning framework under the National Adaptation Framework (NAF) (DECC, 2024), with sectoral plans setting expectations for risk identification, prioritisation, governance, monitoring and implementation over time. Much of Ireland’s existing critical infrastructure. The second-round sectoral adaptation plans published in late 2025 for transport, electricity & gas networks, water services/water quality, and communication networks provide the clearest signal of what good practice should look like at sector and subsector level, including action programmes and monitoring approaches. Table 6 provides a summary of how each sector deals with climate risk assessments and manages the required actions.

Table 5 - Review of sectoral requirements for assessing and managing climate risks

Sector / subsector	Current requirement for climate risk	What this means in practice	Examples of actions / expectations (from SAPs)	Guidance / documentation
Transport – Roads	Statutory transport adaptation planning (T-SAP II) under national adaptation framework	Climate risks should be embedded into maintenance, renewal and upgrades (not just new builds), and tracked through sector monitoring	T-SAP II sets out actions (2025–2030), supported by climate resilience indicators, MREL, and adaptation champions across organisations; indicators include integration into design & maintenance, risk management/emergency planning, training, and long-term investment	Transport Sectoral Adaptation Plan (T-SAP II) (published 14 Nov 2025).
Transport – Rail	T-SAP II	As above, with a focus on continuity of service and asset vulnerability along corridors and nodes	Same T-SAP II implementation mechanisms apply across modes (actions, KPIs/indicators, MREL, adaptation champions).	T-SAP II.
Transport – Maritime (ports/coastal)	T-SAP II (covers ports)	Increased emphasis on coastal flooding/sea level rise and knock-on impacts to supply chains and access	T-SAP II explicitly covers ports and identifies priority risks and cross-cutting actions (capacity building, financing, nature-based solutions, "just resilience"), with governance and monitoring arrangements.	T-SAP II.
Energy – Electricity transmission & distribution	Electricity & Gas Networks SAP 2025 (EGN SAP 2025) under Climate Act / NAF	Network operators are expected to identify/prioritise climate risks and implement adaptation actions (2025–2030+) with governance and monitoring	EGN SAP 2025 includes an Action Plan (38 actions) designed for 2025–2030+, framed around strengthening structures, capacity and delivery. Regulation also shapes delivery through CRU's economic regulation and periodic price reviews/controls (business plans, spending review, incentives).	EGN SAP 2025 (published 18 Nov 2025).
Energy – Gas networks	EGN SAP 2025	Similar expectations as above, with network integrity, station/site vulnerability and restoration considerations	EGN SAP 2025 action programme and governance/monitoring apply across gas networks as part of the sector plan.	EGN SAP 2025.
Water – Water	Water Quality & Water	Climate risk is to be mainstreamed into	WQWSI SAP stresses alignment with Water Action	Water Quality & Water

services infrastructure & water quality	Services Infrastructure SAP 2025 (WQWSI SAP) (and alignment with Water Action Plan)	water policy and delivery, including ongoing investment in resilient infrastructure and annual tracking of actions	Plan 2024 and the need for a robust adaptation planning process. It sets out a vision underpinned by goals/objectives delivered through 59 actions, selected from the Water Action Plan action list. Governance includes a Programme Delivery Office established under the Water Action Plan to coordinate, track and report on actions, with annual tracking of SAP actions.	Services Infrastructure SAP (published 17 Nov 2025).
Communications – Fixed & mobile networks (incl. critical sites/cabinets)	Communications Networks SAP 2025 under Climate Act / NAF	Stronger expectations around risk identification, data gaps (climate + geospatial network data), and preparedness for outages	SAP sets four goals: improve understanding/cooperation (incl. cross-sector with electricity), strengthen risk identification & prioritisation (addressing data gaps), build adaptive capacity (e.g., R&D), and prepare for network damage/outages. The plan includes a goals-and-actions framework and monitoring indicators, including attention to NIS2/CER alignment as part of implementation tracking.	Communication Networks SAP (published 14 Nov 2025) + associated technical report/case study.

4.3 Role of the Regulators

The CRU vision over the Strategic Plan period 2025-2027 is for "Resilient, efficient, sustainable, and safe energy and water services for Ireland" (CRU, 2025). Revenue controls are the framework through which the CRU can approve essential investment to deliver critical infrastructure. As the economic regulator for water services, they have set out the proposed funding and performance expectations for Uisce Éireann in the draft Determination on Water Revenue Control 4 (RC4) and for energy under Price Review 6.

Climate risk and resilience related to water and energy services is embedded across most of the strategic plan 2025-2027 priorities specifically under priorities No. 1 and No. 2.

- No.1: We will facilitate infrastructure investment, enhance system flexibility, and implement controls and incentives to support the transition to net zero.
- No. 2: We will support competition, reward flexibility and deliver alignment with EU requirements.

4.3.1 Water

CRU releases annual Capital Investment Plan monitoring reports to update on the yearly progress of their key policy objectives and alignment with Major Projects under the National Development Plan. These are primarily delivery/oversight reports on the Capital Investment Plan's progress, spend and outputs/outcomes and are their main mechanism for monitoring the delivery of new critical infrastructure. They do not set out a dedicated list of climate adaptation / resilience recommendations (e.g., flood protection standards, drought planning triggers, climate scenario requirements). However, they do contain regulatory expectations and investment emphases that can be treated as "must-have enablers" for climate resilience planning in capital and operational plans. There are several key actions implied by the CRU Monitoring reports under the change control and stimulus funding sections which can be taken as direct climate adaptation and resilience measures, these include:

- Implementing a formal "change control" process to manage reprioritisation (key for climate-driven reprioritisation after extreme events)
- Document drivers for reprioritisation (e.g., climate risk, outages, flooding) and make them visible to regulators/stakeholders
- Treat leakage reduction as a resilience measure (drought/demand stress; reduced abstraction pressure).

Legislation plays an integral role in the CRU's RC4 proposals for enhanced monitoring and reporting such as, for example, ensuring Uisce Éireann's compliance with its obligations under the DWD (Drinking Water Directive, S.I. No. 99/2023) and UWWT (Urban Wastewater treatment directive). The RC4 retains all 6 Performance Assessment Framework (PAF) incentives in order to operate and maintain delivery standards in the event of a climate risk. These incentives include customer service, security of water supply, quality of water supply, sewer incidents, environmental performance, energy and emissions.

Climate change resilience is listed as 1 of the 39 RC4 Delivery Obligations under the asset category of Sustainability. Hence, resilience is to be incorporated into all new projects and successful delivery measured as a % of projects. It is the responsibility of Uisce Éireann to develop operating procedures such as risk preparedness plans to ensure delivery of service in the face of acute or chronic climate risks. The EIAR and project business need documents for each project address the implications and design considerations for climate change risk and resilience.

4.3.2 Energy

Price Review 6 (PR6) covers the allowed revenues for the TSO (EirGrid) and DSO (ESB). PR6 provides an initial baseline investment allowance of €13.8 billion across Ireland's electricity transmission, distribution and offshore networks, with a maximum of €18.9 billion available. It does not cover revenue but focuses largely on planned maintenance which has a direct link to building resilience into the network.

PR6 is heavily focused on uncertainty, the framework has been designed to account for uncertainty as the investment requirement is so large. The priority projects are focused on the grid infrastructure projects needed to increase the capacity of the grid to deliver increasing amounts of power from an increasing amount of renewable energy sources (80% by 2030) (Eirgird & SONI, 2023). This includes future proofing the grid against demand and weather challenges by adding various new power management technologies, new power plants, lines and cables in addition to new and upgraded substations.

PR6 addresses the need, deliverability, cost effectiveness of the electricity network but does not take increased cost due to climate change resilience explicitly into account. Measures are included within the performance metrics, such as the number of planned and unplanned outages but not as a separate climate resilience metrics. The utilities own performance manager treats outages as a sign of network resilience along with power delivery within the frequency range. Annual reporting of outages is to be changed to monthly intervals in order to monitor resilience due to the number of priority projects under development as part of the decade of change to the electricity system planned under the "Shaping Our Electricity Future Roadmap ".

Incentives exist to target the reconnecting of vulnerable customers. CRU has in the past applied penalties for outages up to €10mill. In the updated document, Approach to Setting Financial Penalties November 2025, CRU sets out the calculation of financial penalties under the CRU strategy 2025-2027 for energy and water. Environmental risk and climate impact are both included under the gravity level in the Gain Methodology and Relevant Fine Methodology used to calculate penalties. These methodologies do not however count the time taken post storm events to restore power. It is not specifically stated as a critical to infrastructure or has a specific penalty applied.

The DSO has programs in place to strengthen climate resilience in the system, specifically based on experience of historical Extreme Weather Events, with a risk-based asset maintenance and replacement program. This includes:

- Winter Grid Resilience Plan 2025 focused on vegetation management, mobile generation units and wooden pole replacement.
- Risk-based asset maintenance and replacement program using asset condition and climate data to undertake targeted asset replacement and maintenance and condition-based assessments to prioritise work needed.
- HV station upgrades, strengthening overhead lines and connectors, wood pole replacement strategy and OHL conductor replacement.
- Climate adaptability framework, align with EU and national policies to identify climate hazards, monitor trends, and put in place climate risk control measures to protect vulnerable assets across the asset life cycle.
- Innovation towards reliable and resilient electricity network, heavier insulated conductors for forestry corridors and enhanced use of digital, data and AI e.g. LIDAR for timber management of high-risk areas, and data regarding weather patterns, vegetation species, and customer interruptions to target and prioritise timber cutting.

Whilst there is also acceptance that the network can be hardened to a limit, emergency response capabilities are also required. Hence, the following are under development to enhance response capabilities.

- National Emergency Co-Ordination Group has launched a cross-government review of the Response to Storm Éowyn.
- The DCEE is currently updating the EGN SAP includes an assessment of current and future climate risks for electricity transmission, distribution and generation, and will set out key actions to make Ireland's energy networks more resilient.
- Legislative changes are being pursued to address the issue of trees in close proximity to power lines.

Part of the recommendations of the cross sectoral security strategy include critical steps to ensure enabling infrastructure is delivered, one of these is to upgrade the infrastructure for physical resilience and remove current vulnerabilities to climate impacts.

4.3.3 Communications

The commission for Communication Regulation (ComReg) has been selected as the National Competent Authority (NCA) for the digital infrastructure under the CER. Additional to the CER, the EU Networks and Information Systems Directive (NIS2) state minimum standards the sector must meet for resilience, risk and incident management, albeit not climate risk. ComReg published their own Climate Action Roadmap under the CAP25. This focuses on emission reduction and elements of adaptation planning within its internal operations.

ComReg have carried out their first study on the adaptation of communication networks in Ireland titled 'Climate Change and its Effect on Network Resilience – A report by Frontier Economics' (ComREG, 2025). In line with objectives set out in the SAP, it identifies vulnerabilities of the network to climate change and adaptation measures operators are taking to improve resilience. Currently, there is no regulatory requirement for operators to carry out CCRAs on their networks.

The communications sector includes a diverse range of infrastructure, including data centres, overhead, underground and submarine cables. Projects often have different planning processes and compliance requirements.

The Google data centre development requires an EIAR to be complete during planning. The 'climate' chapter of the EIAR focuses on emissions during the construction and operational phase. It follows the Environmental Impact Assessment (EIA) Directive 2014/52/EU and EPA Guidelines on the Information to be contained in Environmental Impact Assessment Reports (EPA, 2022). The vulnerability of the proposed development to climate change is mentioned using the TII standard for undertaking a risk assessment. A risk assessment using the Met Éireann TRANSLATE data is mentioned but the details of the risk assessment are not included in the EIAR. A Flood Risk Assessment (FRA) is conducted as a need of compliance with DHLGH (Department of Housing, Local Government and Heritage), OPW and the county councils planning guidance. Mitigation measures are included but there is no mention of adaptation measures to increase the resilience of the infrastructure to future flood impacts.

Other projects like the National Broadband Plan (NBP) delivering high speed fibre broadband nationally are managed through LAs and not the planning commission. The works of broadband deployment often fall under minor development which often do not require an EIAR. A Strategic Environmental Assessment (SEA) was completed in the planning phase but does not follow through to the delivery of the project. It does not require the assessment of climate risks to assets. Climate change impacts are highlighted in the SEA as a key interdependency for the intervention strategy yet there is no mention of potential adaptation measures or methods to increase resilience. A bigger emphasis is placed on reduction of emissions contributing to a low carbon economy. Flood risk is discussed in more detail, with the aim to ensure flood protection of assets and the knock-on effect of its construction on other developments within the catchment area. 'The Planning System and FRM Guidelines for Planning Authorities' has ensured that the risk is incorporated into the planning system. From what is publicly available, there is no climate risk assessment for the construction or operational phase of the project. Given the long lifespan of communications assets, their exposure to extreme weather events and the dependence the public have on these services it would be beneficial.

5 Climate Risk Assessment

5.1 Climate Risk Assessment Frameworks

A wide range of climate risk assessment (CRA) frameworks exist at international, European and national levels, spanning scientific, engineering, corporate disclosure and urban planning applications. These include the IPCC AR6 framework, ISO 14090/14091, PIEVC, GIRI, EUCRA, TCFD/ISSB, CSRD and several others, reflecting a proliferation of approaches that, while individually useful, creates inconsistency in how climate risk is assessed across sectors and scales. No single framework is universally applied to critical infrastructure in Ireland, and the lack of a common methodology undermines comparability and the efficient allocation of adaptation investment.

The ISO 14090/14091 standards stand out as offering the most promising pathway towards consistency and standardisation. Their structured, process-based approach, covering risk identification, vulnerability assessment, scenario analysis and monitoring, is directly applicable to critical infrastructure. Critically, ISO certification offers a mechanism for independent assurance and accountability that no other framework currently provides. Establishing ISO 14091 as the baseline method for all critical infrastructure climate risk assessments in Ireland, supported by a national template for outputs and minimum evidence requirements, would represent a significant step towards a coherent and comparable national approach. Full detail on the frameworks reviewed for Irish critical infrastructure is provided in Appendix 1A in Section 10.

For comparison, the NCCRA follows a similar risk assessment methodology to ISO 14091 at national level. The outputs of the NCCRA include risks that the CI owner could apply at both asset and organisation level assessment.

5.2 Hazard Datasets

A range of publicly accessible datasets in Ireland can support screening and assessment of climate hazards for infrastructure planning and climate risk assessment. For meteorological hazards and future climate change, Met Éireann's TRANSLATE initiative provides standardised national climate projections, intended to meet decision-maker needs for consistent scenario information. For flood hazards, the OPW's Floodinfo.ie mapping platform provides national flood mapping and associated flood risk management information, including past flood events and datasets developed through the CFRAM programme (with notes on coverage limitations outside mapped areas). For ground instability hazards, the Geological Survey Ireland (GSI) provides a national landslide susceptibility mapping product with an online viewer and downloadable GIS layers.

5.3 Climate Modelling Tools

There are a growing number of global climate modelling tools for physical risk assessment commercially available targeting differing user groups primarily banks, investors and insurers but including public sector and infrastructure[1]. Some allow for multiple scenarios to be modelled across a time series typically to 2100. Some also include structural engineering archetypes across all types of infrastructure down to materials and construction standard. Some also allow for multiple adaptation pathways to be modelled, which can be applied to existing or new building types and infrastructure. These are widely used globally and allow for an accelerated view of climate risk and adaptation pathways to be gathered across multiple locations and archetypes. Output metrics are specific to target user but vary from Financial Metrics to Impacts Scoring including Climate Adjusted Value, Productivity Loss, Adaptation Cost benefit analysis to developing optimal adaptation pathways.

Datasets are typically updated every 6 months to 2 years, from a variety of public and private sources. They can include threshold analysis and deterministic scenarios and cover both acute and chronic physical risks over short, medium and long term.

A sample methodology from XDI (Cross Dependency Initiative) is included in Figure 1 and an output for an industrial archetype shown in Figure 2.

[1] Resources – United Nations Environment – Finance Initiative

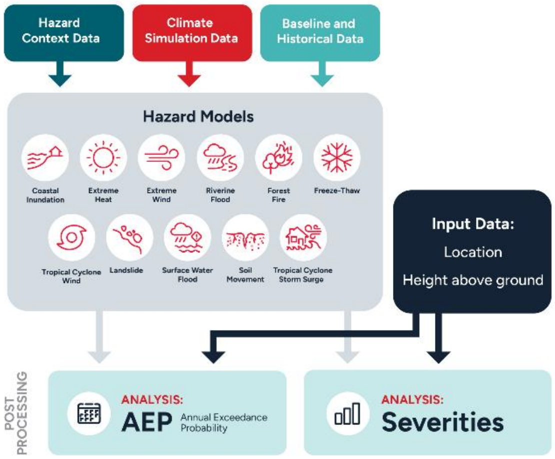

Figure 1 – XDI (Cross Dependency Initiative)

Figure 2 - Output for Industrial Archetype

5.4 Proposed Climate Risk Framework for Critical Infrastructure in Ireland

Through stakeholder engagement, Climate Matters' researchers were made aware that climate risk assessments were not widely carried out at organisation level but were more likely to occur at asset level for new assets. In addition, there were inconsistent methods applied to new assets. Hence, Climate Matters proposes a climate risk framework to support CI owners at both asset and organisation level as a stepping stone to ISO rather than a substitute for ISO suite. Initial supportive feedback from a limited number of CI owners and stakeholders has been received.

This section describes the proposed climate risk framework for critical infrastructure in Ireland. The key principles of the proposed framework are as follows:

- The framework should provide a consistent, staged approach to climate risk that is proportionate to the decision being taken. For example, early stages should enable rapid screening and prioritisation, while later stages should provide engineering-grade assurance for critical assets and major investments. The framework should align with the IPCC conceptualisation of risk as arising from the interaction of hazard, exposure and vulnerability, and use an ISO-style risk assessment process.
- The framework should also explicitly incorporate system interdependencies (cascading impacts across transport, energy, water and communications) and, where feasible, transboundary risks (e.g., cross-border services, supply chains, external dependencies). This can be operationalised through impact-chain logic that can include cross-sectoral interactions, supported by a standard requirement to map and test critical dependencies at each stage.
- The framework should consider cascading risk by design: treating infrastructure as a *system-of-systems* (e.g., power → water pumping → telecoms nodes) flagging interdependencies/cascading effects as a core design requirement.
- The Framework should consider multi-hazard and compound events: incorporating compound hazards (storm + surge + fluvial flooding) rather than single-hazard silos.

Appendix 1B in Section 11 contains a number of tools developed to support Critical Infrastructure in assessing climate risk including three complementary components:

Climate Risk Maturity Model

A simple framework to help organisations understand their current level of climate risk management capability and identify opportunities for improvement.

Climate Risk Assessment for Infrastructure Projects

Guidance aligned with the infrastructure project lifecycle describing how climate risks can be assessed during planning, appraisal, design and delivery of new infrastructure projects. Included are:

- CRA over Infrastructure Project Lifecycle
- Hazards for Critical Infrastructure
- Minimum CRA Framework for Infrastructure Projects

Climate Risk Assessment for Existing Infrastructure Portfolios

A portfolio-scale approach that enables infrastructure owners to assess climate risks across large asset networks and prioritise assets requiring more detailed analysis.

5.4.1 Potential for ISO Certification to Standardise CRA

Climate Matters carried out a review of the current climate risk assessments in Ireland against ISO 14090/91, through project review with publicly available documentation (Table 4) and through stakeholder discussion. Several gaps were highlighted as follows:

- the need for a common climate scenario basis,
- weak standardisation in appraisal practice,
- limited evidence of cross-sector coordination,
- unclear responsibility for existing assets,
- limited availability of damage functions and sector-specific variables.

Applying the ISO approach could offer the most value across the following areas:

1. Provide standard definitions and conceptual consistency.
   For example, ISO 14091 gives a clear structure for climate risk assessment. It distinguishes clearly between sensitivity and adaptive capacity.
2. Set minimum process requirements before analysis starts.
   This framework proposes stages whereas ISO 14091 is useful at defining specific details and structure.
3. Cross-sector dependencies are recognised, but not yet standardised.
   This framework highlights interdependencies and cascading failures. ISO 14091 supports exactly this by explicitly calling for analysis of cross-sectoral interdependencies and suggesting that impact chains be used to represent how

impacts in one area propagate into another.

4. Uncertainty and scenarios are acknowledged, but the decision rules are still too open. This paper identifies and discusses the policy gaps on selecting which scenarios to design to. It also recommends scenario sensitivity testing and DMDU-style thinking, but as yet there is no national minimum rule set. ISO 14091 helps by requiring explicit time horizons and by expecting uncertainty to be considered in interpreting results.
5. Reporting outputs are not yet standardised enough for comparison across sector. This paper's staged model identifies useful outputs but it has not yet specified a single required report structure for all sectors as it is highlighting the need for more cross sectoral agreement. ISO14090 also stresses that results should be tangible and usable by decision-makers who were not involved in producing them.
6. Monitoring, learning, and reassessment need firmer standardisation. This paper emphasises how risk should be updated over time and that monitoring and periodic reassessment are needed, particularly as data sources evolve. ISO 14090 and ISO/TS 14092 can give more structure here. ISO 14090 also states indicators should be quantitative where possible and linked to long-term outcomes.

If implemented, the ISO standards would call for more specification in the frameworks areas of independent review/assurance, roles and accountability, adaptive capacity and thresholds and tolerances.

The paper broadly aligns with ISO14090. Attaining collaboration and agreement on the requirements of the 6 areas mentioned above would take the recommended staged approach into a minimum required process specification for critical infrastructure which is required to fully implement the standard.

This could then allow the following next steps in a standardised approach:

- Make ISO 14091 the base method for all CI climate risk assessments in Ireland.
- Issue a national template for outputs, indicators, and minimum evidence requirements.
- Require explicit asset-life time horizons and common scenario/testing rules.
- Mandate impact-chain dependency mapping and residual-risk reporting.
- Add independent review for major projects and critical entities.
- Standardise monitoring, post-event review, and reassessment triggers.

6 Uncertainty Management

The IPCC defines uncertainty as "a state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable." The process of evaluating climate change risk or its components can be described in terms of multiple steps, with uncertainties at each step.

Uncertainty may be characterised across several levels. In terms of low uncertainty, probabilistic uncertainty can be quantified through probability density functions, typically used for well-understood hazards with good historical data. At the deeper end, deep uncertainty (sometimes termed "unknown unknowns") arises when uncertainties are so profound that multiple parties cannot agree on the appropriate probability distributions, system models, or even the range of possible outcomes. For long-lived infrastructure, assets are often designed for 50–100 year lifespans, deep uncertainty is the norm rather than the exception.

6.1 Scenario-Based Approaches

The dominant tool for representing climate uncertainty is emission pathway scenario analysis. Under the CMIP5 generation of climate modelling, these pathways are expressed as Representative Concentration Pathways (RCPs), which describe trajectories of greenhouse gas concentrations and the resulting radiative forcing by 2100 (e.g. RCP2.6, RCP4.5, RCP8.5). In CMIP6 (IPCC AR6), scenarios are expressed as Shared Socioeconomic Pathways (SSPs), which combine socioeconomic storylines with emissions outcomes and are commonly referred to using paired labels such as SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5.

A key critique, however, is that scenarios are not probabilities. The guiding principle of the RCP/SSP scenarios is that there is no associated likelihood and all should be treated equally. The reality however, is that some are more equal than others. Increasingly, scenario information is also communicated using Global Warming Levels / Thresholds (GWLs) (e.g. 1.5°C, 2°C), which “time-slice” model output around the period when the driving global models reach a specified level of global mean warming. This can be helpful for infrastructure planning because it aligns impacts with temperature thresholds rather than a fixed calendar period.

For Ireland, Met Éireann’s TRANSLATE datasets currently provide CMIP5-based projections with both (a) RCP scenarios and (b) Global Warming Levels. The interactive portal available on www.climateireland.ie shows scenario selections for RCP2.6, RCP4.5 and RCP8.5, alongside a baseline period (1976–2005) and multiple future time slices (e.g. 2021–2050, 2041–2070, 2071–2100 depending on variable), and it also offers warming levels of 1.5°C, 2.0°C, 2.5°C, 3.0°C and 4.0°C. This reflects the first TRANSLATE dataset, which was developed from dynamically downscaled CMIP5 projections and supplemented with warming-level products. Met Éireann note that TRANSLATE 2 (Aug 2023–Aug 2025) expands the original CMIP5-based dataset (including additional variables) and is moving from CMIP5 to CMIP6, with an initial set of downscaled CMIP6 models available and a larger CMIP6 ensemble planned for subsequent iterations. Met Éireann have indicated that TRANSLATE 3 will incorporate CMIP6 data and SSPs as these become available.

For flood mapping Ireland, the OPW provides future flood extents using two indicative climate change futures: the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS). These scenarios are implemented as allowances applied to key flood drivers rather than being defined directly as IPCC emissions pathways: for example, MRFS applies +20% to extreme rainfall depths and peak flood flows and +0.5 m mean sea-level rise, while HEFS applies +30% to rainfall/flows and +1.0 m mean sea-level rise (with additional parameter adjustments such as land movement and forestry allowances). For reporting and risk-assessment purposes, these OPW scenarios are commonly interpreted as representing a “mid-range” and “high-end” climate future broadly comparable to the range spanned by RCP4.5 and RCP8.5. Notably, Ireland’s National Climate Change Risk Assessment (NCCRA) methodology explicitly states that, because MRFS/HEFS are not assigned a specific future timeframe, they have been aligned to RCP4.5 and RCP8.5 (and associated time horizons) to support consistent national risk assessment.

Across Ireland’s transport, energy, water and communications sectors there is a growing, very practical request for a shared public planning basis for climate scenarios. In other words, so that asset owners are stress-testing like-for-like futures, results are comparable across projects and portfolios, and adaptation funding can be prioritised transparently against a consistent risk envelope. In the absence of an explicit whole-of-government consensus, organisations often default to “mid-range” and “high-end” futures (or to whatever a regulator/funder expects), but this can yield inconsistent assumptions across sectors (e.g. different emissions pathways, time horizons, percentile choices, or sea-level allowances). Other jurisdictions have moved toward more standardised approaches. For example, in England, the Environment Agency’s planning guidance requires the use of nationally defined climate change allowances for flood risk assessments (including “central/higher” bands and credible maximums for nationally significant/essential infrastructure), with allowances derived from UKCP18 and explicitly tied to scenario assumptions (notably RCP8.5 in the underlying methodology). Scotland similarly provides required national allowances for planning and flood assessment through SEPA guidance. In the Netherlands, long-term water and spatial decisions are stress-tested using agreed national Delta Scenarios alongside national climate scenarios produced by KNMI (recently updated as KNMI’23), giving a common scenario backbone for adaptation planning. Beyond Europe, New Zealand provides national projections and guidance that standardise the scenario set used for assessments, and Australia has recently progressed a national scenario guidance process aimed at improving consistency for disclosure, risk assessment, and long-lived infrastructure decisions (with related national advice often recommending at least two scenarios beyond 2030).

France has adopted a single, nationally agreed reference warming trajectory for adaptation: the TRACC (*Trajectoire de réchauffement de référence pour l’adaptation au changement climatique*). Rather than asking each infrastructure owner to choose among multiple RCP/SSP pathways, TRACC uses a Global Warming Level / warming-trajectory approach as a common planning basis for all adaptation actions by public and private actors. The French government position is that this shared reference reduces inconsistency across sectors and territories, and TRACC has been formalised through national regulation (decree/arrêté published 26 January 2026) as the reference trajectory for adaptation in France. In practical terms, TRACC is designed to align with a "trend" IPCC-consistent pathway and is used in France's national adaptation planning (e.g., PNACC3) to frame the climate conditions that organisations should prepare for over time. Public summaries describe TRACC as providing a single point of reference, and international/technical descriptions emphasise its time-horizon framing using warming levels (e.g. indicative milestones such as around +2°C by ~2030, ~+2.7°C by ~2050, and +4°C by 2100 in national adaptation-plan reporting), enabling consistent translation into sectoral hazards and design/stress-test assumptions.

6.2 Decision Making under Deep Uncertainty

There is a growing number of approaches for navigating deep uncertainty in infrastructure planning, as outlined in Table 7.

Table 6 - Methodologies for Decision Making Under Deep Uncertainty

Type	Explanation	Example Applications for CI
Robust Decision Making (RDM)	• Developed specifically for decisions with long-term consequences and deep uncertainty. • Runs a model many times to stress test proposed decisions against a wide range of potential future scenarios.	(Hallegatte, S., Anjum, R., Avner, P., Shariq, A., Winglee, M., Knudsen, C., 2021) (Lawrence, J., Allison, A., 2024)
Dynamic Adaptive Policy Pathways (DAPP)	• Focuses on pre-determined adaptation thresholds, actions/options, lead times, indicators and triggers not timeframes. • Implementation of new adaptive actions as triggers are reached ahead of infrastructure performance loss and before damaging thresholds are reached. • Regular monitoring is a necessity.	(Hallegatte, S., Anjum, R., Avner, P., Shariq, A., Winglee, M., Knudsen, C., 2021) (Lawrence, J., Allison, A., 2024)
Climate Informed Decision Analysis (CIDA)	• Method of incorporating CC information into DM process by identifying which sets of CC would affect the project and the likelihood of those sets • Does not attempt to reduce uncertainties but attempts to	(Hallegatte, S., Shah, A., Lempert, R., Brown, C., Gill, S., 2012)

	determine which decision options are robust to a variety of plausible futures. • Good for long terms investments with climate uncertainties.	
"No Climate Risk" baseline analysis	• based on standard assessment of projects costs and CBA assuming no consideration of natural hazards or CC. • then uses empirical equations to introduce natural hazard & CC costs	(Hallegatte, S., Anjum, R., Avner, P., Shariq, A., Winglee, M., Knudsen, C., 2021)
Multi Criteria Analysis (MCA)	• used in complex decision-making scenarios where conflicting objectives arise • allows the comparison of qualitative and quantitative variables.	(Clarke, J., Acosta, E., Brede, H., 2021)
Economic Analysis: CBA & CEA	• Cost Benefit Analysis (CBA) • Cost Effectiveness Analysis (CEA) - identify the least-cost option for achieving a specific objective.	(Clarke, J., Acosta, E., Brede, H., 2021; Ryan, P. C., Hawchar, L., Naughton, O., Stewart, M. S., 2021)

6.3 Infrastructure Vulnerability Uncertainty

Damage functions are helpful to assess the relationship between hazard characteristics e.g. flood depth (Figure 3), gust speed, temperature to quantify an impact metric, often damage percentage. Internationally, most current damage functions are derived through stakeholder engagement rather than empirical data. While the application of global damage functions can provide an initial indication of potential damage associated with specific hazards, significant variability across published curves reflects their strong dependence on local or regional datasets and asset characteristics. The damage functions typically account for direct physical losses and do not take into consideration indirect losses such as service disruption or delays.

The development of damage functions for CI globally is limited compared to those available for residential and commercial buildings. This likely reflects the bespoke nature of CI assets. Williams et al. 2025 developed flood damage functions for CI network components in New Zealand. In the absence of empirical data, these functions were derived through structured stakeholder engagement conducted across multiple workshops. The comparison of these damage functions shows notable variability to others in literature, stressing the value of developing damage functions using local or regional empirical data where available.

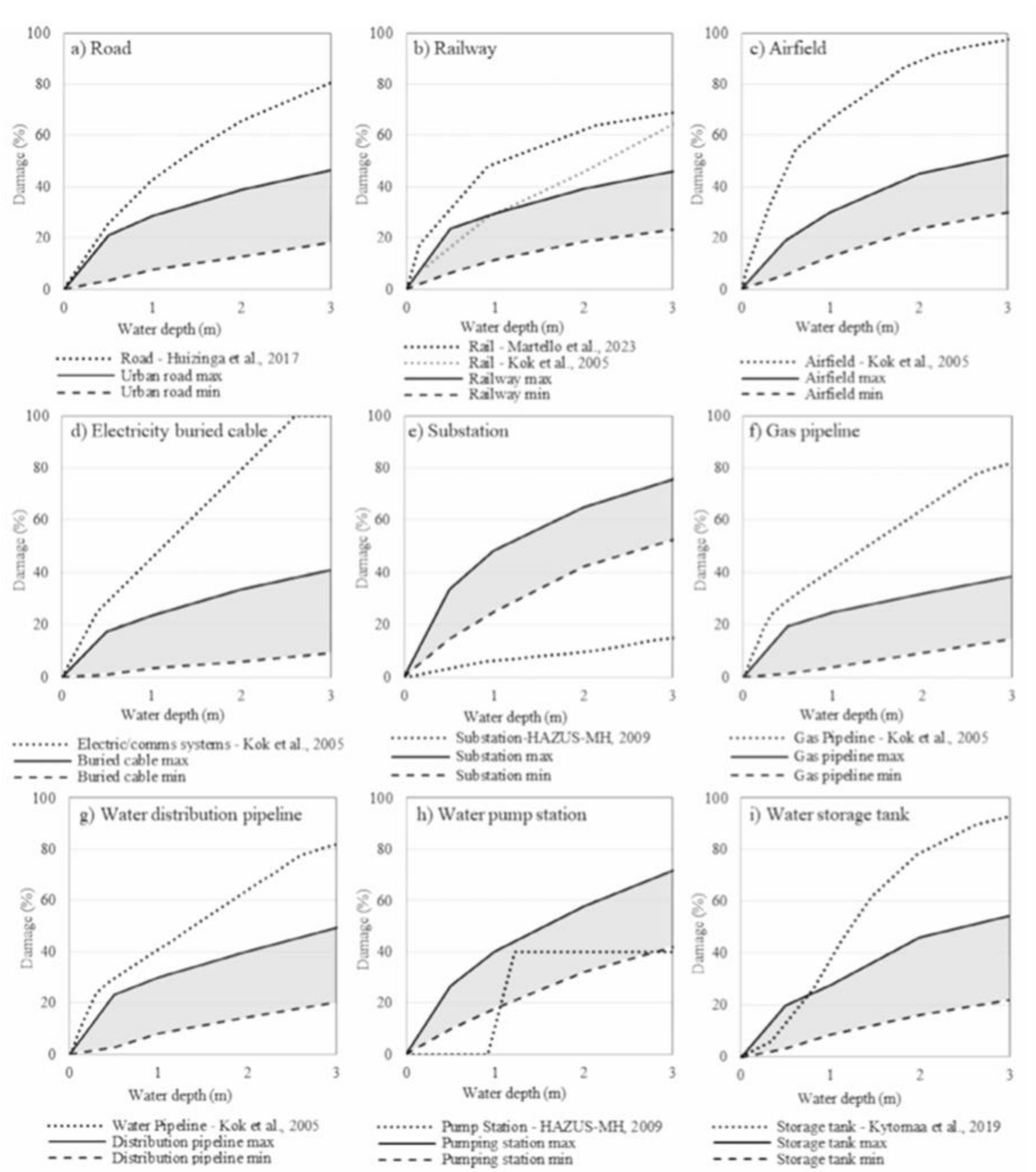

FIGURE 11 | Benchmarking of selected flood damage curves (shaded min to max damage percentage from this study) with comparable flood damage curves from literature (Data S1).

Figure 3 - Flood damage curves

CI vulnerability in Ireland varies by sector, requiring bespoke damage functions in line with the relevant primary hazard identified. Transport infrastructure is primarily exposed to flooding, while electricity networks are more vulnerable to extreme winds. (Ryan, P. C., Hawchar, L., Naughton, O., Stewart, M. S., 2021)assessed the current and future vulnerability of Irish timber power poles in Dublin and Cork using a probabilistic Monte Carlo simulation framework. Climate inputs were derived from Regional Climate Models (RCMs), under three emission scenarios; a no climate change baseline, RCP4.5 and RCP8.5.

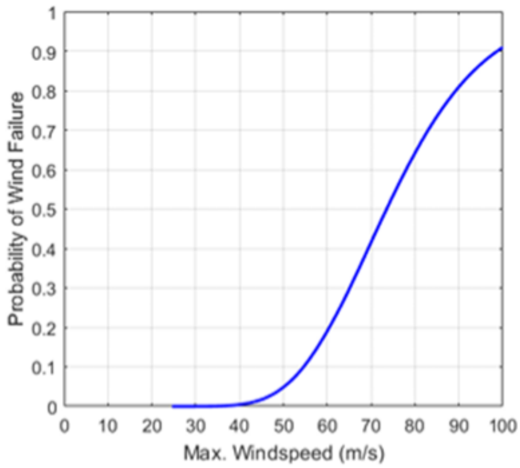

Figure 4 - Vulnerability curves

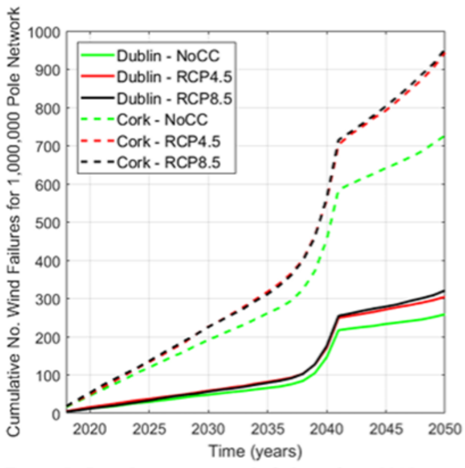

Figure 5 - Cumulative power pole failures

At present, limited damage functions have been developed for the Irish context, particularly for flood hazards, highlighting a significant research gap. Developing context specific damage functions would enable accurate risk assessments and better inform actions to enhance the resilience of CI.

7 Climate Risk Management: Illustrative Examples

Earlier sections of this report have highlighted the range of climate uncertainties relevant to Ireland's critical infrastructure, from changing precipitation patterns and sea level rise to increased frequency of extreme weather events. However, the approaches currently applied across much of Ireland's infrastructure sector have yet to fully account for this uncertainty or to adopt decision frameworks that respond to defined risk thresholds. This section examines a selection of international examples where more structured and proactive approaches to climate risk management have been developed and applied, with a view to identifying lessons that could inform better practice across Ireland's critical infrastructure sectors. Further examples of practical guidance for enhancing resilience are included in Appendix 3.

7.1 Example 1 – Adaptation Pathways Approach

One of the most significant methodological advances in climate adaptation planning for long-lived infrastructure in recent decades has been the development and formalisation of the adaptation pathways approach. Originally conceived in the context of coastal flood risk management — most notably through the Thames Estuary 2100 project — the approach has since been adopted as an international standard through BS 8631:2021 *Adaptation to Climate Change: Using Adaptation Pathways for Decision Making*. It is increasingly recognised internationally as best practice for infrastructure assets whose operational lifetimes extend well into a period of significant and uncertain climate change, precisely because it replaces the conventional single design standard with a flexible, sequenced decision framework that can accommodate a wide range of possible climate futures.

The most comprehensively documented application of the adaptation pathways approach to a national rail network is that developed by Network Rail in Great Britain. Network Rail's *Climate Change Adaptation Pathways Methodology* (NR/GN/ESD41, Issue 2, August 2024) represents the first large-scale application of BS 8631:2021 in a railway context and provides a detailed, replicable framework that offers valuable lessons for any national rail operator seeking to embed structured climate adaptation into its asset management and long-term investment planning processes.

Phase 1 determines the strategic value of different parts of the rail network and identifies and prioritises locations facing the highest climate change risk. For each location identified in Phase 1, a Rapid Adaptation Pathways Assessment (Rapid APA) is conducted. Phase 2 reviews asset, weather and climate impact data to assess risk and identify potential adaptation interventions at different severity and time thresholds for each shortlisted location. Locations identified by the Rapid APA as requiring detailed analysis proceed to a Full Adaptation Pathways Assessment. Phase 3 fully develops the adaptation pathway for each selected location, setting out the timing and triggers for decisions, when investment is needed, and the stepping stones and building blocks between now and when major interventions are required. Phase 4 produces a regional adaptation pathway strategy and investment plan, summarising key findings and setting out the long-term strategy for the region, integrating adaptation pathways decisions into control period planning and providing the basis for government liaison on funding and policy requirements.

7.1.1 Application to Ireland’s Critical Infrastructure

Ireland's critical infrastructure, including transport networks, energy systems, water services, flood defences and communications, faces a range of physical climate hazards that make the structured, long-term approach embodied by the adaptation pathways methodology directly relevant. Coastal erosion and sea level rise threaten exposed assets across multiple sectors; fluvial and surface water flooding affects low-lying infrastructure and ageing river crossing structures throughout the country; and the increasing frequency and intensity of extreme wind and rainfall events poses risks to operational continuity and asset integrity across the board. These are not projected future threats, they are already manifesting, and their frequency and severity are projected to increase materially over the operational lifetimes of infrastructure assets currently in service or in planning.

There are already examples of more rigorous climate risk integration emerging within individual sectors and programmes. These demonstrate that it is technically feasible to embed structured, forward-looking climate risk assessment into Irish infrastructure planning. The adaptation pathways methodology offers a framework through which this capacity could be extended, standardised and applied systematically across critical infrastructure sectors. The key conceptual shift is from reactive responses to already-visible threats at known locations, to proactive, asset-portfolio-wide strategies that identify, sequence and govern responses to all significant climate vulnerabilities, including those that are not yet acute but will become so within the operational lifetimes of current assets.

In practical terms, applying an adaptation pathways approach across Ireland's critical infrastructure would involve four broadly equivalent phases to those described above. A portfolio-wide screening exercise, drawing on Met Éireann's TRANSLATE climate projections and OPW flood mapping data, would identify and prioritise the most vulnerable assets and locations across each sector. Rapid assessments at each priority location would characterise risk trajectories under multiple climate scenarios and generate structured lists of potential interventions. Full assessments at the highest-risk locations would produce sequenced, costed decision trees with defined trigger thresholds. A National Critical Infrastructure Climate Resilience Strategy, integrated with the National Development Plan cycle and Sectoral Adaptation Plans, would then translate asset-level findings into coherent, long-term investment programmes, ones that give government and funders transparent visibility of what adaptation will cost, when it will be needed, and what the consequences of deferral are.

Such an approach would also create the conditions for more effective cross-sectoral coordination, which is essential given that climate risks frequently cut across sectoral boundaries and that the adaptive capacity of one sector often depends on the actions of another. The structured, location-by-location format of the adaptation pathways approach, with its explicit identification of interdependencies and partnership opportunities at each stage, provides a natural mechanism for bringing infrastructure owners, OPW, Local Authorities and other relevant bodies together around shared vulnerabilities and shared investment decisions, rather than each optimising independently within its own sectoral boundary.

7.2 Example 2 – Electricity Networks Climate Resilience Actions

7.2.1 Climate Risk Assessment approach across Networks

Scottish and Southern Electricity Networks (SSEN) developed a proactive, risk-based climate resilience strategy to ensure the long-term reliability of its electricity distribution network under increasing climate pressures. The strategy aligns with Ofgem regulatory expectations (RIIO-ED2) and broader UK resilience frameworks, embedding climate adaptation into core business planning and asset management. Their climate resilience strategy is characterised by:

- Integration of climate risk into core planning and operations.
- Movement toward predictive, risk-based adaptation.
- Alignment with regulatory, TCFD, and infrastructure resilience best practice.

Table 8 provides a direct, structured comparison of SSEN vs ESB (PR6) vs Northern Powergrid (NPg) focused specifically on climate resilience and adaptation based on a review undertaken as part of this case study.

Table 7 - Comparison of three electricity network operators in relation to climate resilience and adaptation approaches

	SSEN	NPg	ESB (PR6)
Approach	Proactive and risk based	Structured, compliance driven	Strategic, less operationalised
Maturity	Structured Risk Assessment, quantified and aligned with best practice	Structured Risk assessment, mostly qualitative	Partially structured, limited quantification of risks,
Focus	Operational, investment focused	Planning, regulatory alignment	Strategic, policy level

In summary, SSEN appears to be comparatively most advanced in their planning for climate resilience, NPg shows good compliance and structure but has less advanced data modelling and investment linkage whilst ESB is strategic with strong ambition on system transformation but their direct approach to quantitative risk assessment, scenario modelling and investment linkage to adaptation actions isn't as strong as the others as they are focusing on overall system strengthening.

Figure 6 - Interdependency Mapping from SSEN Climate Resilience Strategy

SSEN is highlighted for showing a mature and structured approach relative to the other networks as they use scenario analysis (UKCP18), asset level risk mapping (geospatial), identification of direct and indirect impacts, hazard specific adaptation, integrating resilience standards following defined events, and demonstrating highly structured regulatory integration.

7.2.2 UK Governance of Climate Resilience Strategies

SSEN Distribution recently published their Climate Resilience Strategy1 under direction from Ofgem. It includes a detailed Annex2 which outlines how the strategy aligns with Ofgem's requirements, it is also aligned with the UK climate adaptation reporting (ARP) and TCFD. Under the UK's Climate Change Act 2008 organisations are asked to report on current and future predicted climate risks annually. This is undertaken through an annual report that states what each authority is doing to adapt to climate change submitted to the UK Adaptation Reporting Power (UK ARP). The UK ARP is the primary legislative lever available to the UK government to ensure that climate change impacts are being considered by key sectors (including those identified as critical infrastructure).

Ofgem is the independent regulator for GB energy networks, responsible for price controls through RIIO (Revenue, Incentives, innovation and outputs) framework, performance targets, reporting and compliance requirement. The RIIO framework sets a 5 year regulatory framework, RIIO-ED2 period 2023-2028 similar to ESB and EirGrids' PR6, which approves investment plans and resilience funding whilst DNO's such as SSEN are responsible for managing climate risk and resilience and must justify its investments, deliver agreed outputs and demonstrate value for money and what outcome the action improves, which forces SSEN to link climate actions to measurable benefits.

As part of the RIIO-ED2 price review Ofgem requested that network companies establish a group to look at climate resilience, so in 2021 the Climate Change Resilience Working Group (CCRWG) was formed. The group covers all aspects of climate resilience with a primary focus of addressing Ofgem's requirements for a Climate Resilience Metric that will measure how resilient networks are to the impacts of climate, both now and in the future. RIIO objective is to transform climate resilience from a voluntary activity into a regulated, incentivised, and performance-driven requirement. The ED3 period (expected ~2028 onward) is planning to increase climate governance and embed stronger resilience metrics like climate specific KPI's and extreme weather performance standards. The recently published ED3 Framework Decision introduces the new requirement of climate stress testing. Resilience planning remains in a transition phase as capabilities are built to shift climate adaptation from being a justified investment to a more regulated, standardised and testable system requirement as quantitative targets and metrics begin to get implemented to trial their effectiveness.

RIIO includes financial incentives for performance and penalties for underperformance which drives proactive resilience planning and focus on extreme weather performance. SSEN have developed a highly structured climate risk assessment and have developed fault forecasting models through RIIO funding for innovation and climate resilience solutions to quantify climate risks. The Weather-driven Fault Volume Forecasting model aims to understand and improve response times to faults that may occur due to changes in the short-term weather forecasts. Understanding fault predictions allows for improved resource planning and deployment, with the ultimate benefit of reducing Customer Minutes Lost (the average number of minutes that a customer has their supply interrupted) and Customer Interruptions (the number of supply interruptions recorded as a percentage of customers connected in a year).

7.2.3 Comparison of CRU and Ofgem approaches

The SSEN and NPg strategies demonstrate how their governance ensures climate risk is embedded in internal decision-making structures as climate adaptation is regulated and linked to the UK Adaptation Reporting Power (ARP) and their National Adaptation Programme.

Whereas the CRU employs a more principles-based, strategic approach. They handle climate risk via investment planning, network design and system resilience objectives which is a key contrast with Ofgem's approach. Climate resilience is encouraged and guided by the CRU, but with less explicit regulatory enforcement or incentives. CRU is also enabling adaptation through policy guidance and sectoral adaptation plans on which there is currently less regulatory pressure on demonstrating detailed implementation pathways than in the UK.

Neither framework mandates formal independent third-party verification of climate resilience strategies, climate risk assessments or adaptation plans, nor do they require third-party validation of scenario assumptions or asset-level resilience decisions in the way you might see in financial auditing or some EU climate-proofing guidance. However, there are elements of external scrutiny.

Ofgem uses independent challenge, industry standards, and post-event reviews which is closest to a "quasi-verification" system. They use ENA Engineering Technical reports and participation in ENA climate change resilience working group standards and industry validation and also make contributions to TCFD and resilience reporting.

CRU relies mainly on regulatory approval and performance monitoring and has less external technical scrutiny. PR6 business plan is subject to a regulatory approval process to assess investment justification as an external validation mechanism. This includes customer engagement, public consultation, willingness to pay studies, which is more social validation. They have no equivalent to the ENA CCRWG as a formal resilience validation mechanism, the ESB and EirGrid investment planning and deliver report is the closest equivalent annual report that covers climate change adaptation activities.

8 Conclusions

Ireland is at a critical juncture in its infrastructure investment programme. The National Development Plan commits unprecedented levels of public capital to assets whose operational lifetimes will extend well into the second half of this century, a period during which Ireland's physical climate will differ materially from the conditions under which the majority of its existing infrastructure was designed and built. The extent to which this investment delivers long-term value will depend significantly on whether climate risk is systematically addressed at the point of appraisal, design and consenting, rather than deferred to a point at which the costs of inadequate provision become unavoidable.

This research has found that while climate risk consideration across Ireland's critical infrastructure is improving, it remains fragmented and insufficiently embedded in the governance, regulatory and technical processes that govern infrastructure development and management. Across the transport, energy, water and communications sectors, the treatment of climate projection uncertainty is weak and inconsistent, structured multi-scenario stress testing is the exception rather than the norm, and risk assessments frequently draw on outdated climate data. Critical infrastructure sectors continue to be evaluated largely in isolation, despite their systemic interdependencies, a vulnerability illustrated with considerable clarity by the cascading service failures experienced during Storm Éowyn in January 2025. A substantial proportion of Ireland's operational asset base carries unquantified climate risk, having been designed to standards that did not account for projected changes in climate. Meanwhile, the planning, consenting and economic regulatory frameworks that govern infrastructure development have yet to function as effective and consistent drivers of climate resilience investment.

The consequences of continued inaction are not speculative. The cost of retrofitting climate resilience into assets already in service substantially exceeds the cost of embedding it at original design stage, and the current NDP investment cycle represents a narrowing window within which the next generation of infrastructure can be future-proofed at reasonable cost.

International experience provides a clear evidence-base for more effective approaches. Structured adaptation pathways methodologies, nationally agreed climate scenario baselines, and regulatory frameworks that explicitly incentivise resilience investment have each demonstrated their value in comparable jurisdictions. The climate data, technical tools and institutional capacity required to apply such approaches in an Irish context are, to a significant degree, already available. The principal gap is not technical but structural - the absence of a coherent policy and regulatory architecture that makes systematic climate risk integration a standard requirement across all critical infrastructure sectors, asset lifecycle stages, and both public and private ownership.

Addressing this gap requires coordinated action across a number of fronts. A nationally agreed climate scenario baseline is needed to ensure that stress-testing across sectors is conducted against consistent and credible futures. Economic regulation must be reformed to explicitly require and reward climate resilience investment as a distinct category. The planning and consenting system must be better equipped, through practitioner guidance, updated policy requirements and earlier intervention in the project lifecycle, to scrutinise climate risk with the rigour the subject demands. And a cross-sectoral approach to climate vulnerability assessment must be established that reflects the interdependent nature of the systems on which public services, economic activity and societal wellbeing depend.

The investment decisions being made under the current NDP will determine the climate resilience of Ireland's critical infrastructure for decades to come. There is a compelling public interest case, grounded in fiscal prudence, service continuity and long-term national resilience, for ensuring that those decisions are informed by the best available evidence on climate risk and made within a governance framework that treats resilience not as an optional consideration, but as a core requirement of responsible infrastructure stewardship.

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9 Appendix 1A: Climate Risk Assessment Frameworks Review

9.1 Existing Climate Risk Assessment Frameworks

A review of available climate risk frameworks and their applicability to Ireland's critical infrastructure (CI) networks have been assessed, as described in this section.

9.1.1 IPCC AR6 Scientific Framework

The **IPCC AR6 Risk Framework** is a scientific conceptual climate risk framework that is applicable to all sectors and all scales of assessment. It is mainly employed by scientists, national and regional developers, as well as developers of standards. The IPCC AR6 Risk Framework defines climate risk as a function of hazard, exposure and vulnerability, and it underpins many of the applied climate risk frameworks, as explored in later sections.

Definitions of key terms relating to climate risk are provided, including:

Risk - *The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species.*

Hazard - *The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.*

Exposure - *The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.*

Vulnerability - *The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.*

The IPCC AR6 Risk Framework is not an operational tool but rather a conceptual backbone employed by other climate risk frameworks.

9.1.2 Risk Assessment and Adaptation Standards

ISO 14090 Adaptation to Climate Change is a management system standard for climate adaptation that can be used by a range of organisation types. It sets out the principles, requirements and guidelines for integrating adaptation into organisational processes, e.g.

context analysis, risk assessment, option appraisal, implementation and monitoring.

ISO 14091 Adaptation to Climate Change – Vulnerability, Impacts and Risk Assessment provide a technical guidance standard for conducting a climate risk or vulnerability assessment. It sets out the principles, requirements and guidelines for conducting a climate risk assessment and it is aimed towards analysts and risk practitioners. ISO 14091 provides a step-by-step process for vulnerability and risk assessment: screening, detailed analysis, evaluation and communication, with explicit guidance on understanding vulnerability and assessing current and future risks.

The required inputs of the ISO 14091 methodology are as follows:

- Selected system or asset, e.g. transport corridor, power network, regional water system.
- Climate hazard information, e.g. regional climate projection for a future scenario.
- Exposure and vulnerability data, e.g. asset location, criticality, sensitivity, adaptive capacity.
- Risk criteria, e.g. tolerability thresholds, performance requirements.

The outputs of the climate risk or vulnerability assessment are as follows:

- Vulnerability and risk profile.
- Risk prioritisation, e.g. low–medium–high, or numerical scores.

Overall, ISO 14091 and ISO 14090 are very useful technical guidance standards for assessing the climate risk for CI networks. However, although the structure is clearly outlined, the user is required to have substantial knowledge in relation to the implementation of the methodology. There is no standardised climate scenario or minimum data quality specified. It does specify that, the details of the selected scenario and dataset and the criteria for their selection must be documented.

9.1.3 EU and National-Level Climate Risk Frameworks

The **European Climate Risk Assessment (EUCRA)** also considers climate risk as the interaction between hazard, exposure and vulnerability but additionally considers non-climatic risk drivers, such as social inequalities, ecosystem degradation, etc. The methodology also encompasses complex risk types, including cascading risks, compound risks and cross-border risks. The assessment is based on a systematic risk assessment process whereby major climate risks across Europe were initially identified. For these major risks, the risk severity over time was subsequently identified, alongside a policy analysis that considers urgency, magnitude and the potential policy relevance. The EUCRA provides a comprehensive view of which risks are most urgent and where adaptation should target vulnerability, exposure and resilience.

The first **National Climate Change Risk Assessment (NCCRA)** in Ireland adopted a systems-based approach to risk assessment, whereby Ireland's society and economy was classified into nine systems, and the climate risks were assessed across all nine systems. The process followed a multi-stage approach: 1. scope. 2. risk identification, 3. detailed assessment, 4. prioritisation / adaptation. This involved significant stakeholder engagement, and this information was considered as part of the semi-quantitative and iterative risk assessment methodology that blended scientific and technical evidence with qualitative expert judgement.

9.1.4 Engineering / System-Level Frameworks

The **PIEVC Protocol** (Public Infrastructure Engineering Vulnerability Committee) is an engineering-based climate risk assessment protocol for infrastructure. It provides a structured process for assessing the vulnerability and risk of individual infrastructure systems to current and future climate hazards that uses a hazard-component interaction matrix and semi-quantitative scoring. The PIEVC Protocol was developed in Canada but it is used internationally and there are over 100 examples of its application available. It covers all types and scales of civil infrastructures, including buildings.

The required inputs of the PIEVC Protocol are as follows:

- Asset definition, e.g. road segment, bridge, treatment plant, transmission line.
- Detailed characteristics of the assets, e.g. materials, age, design thresholds, to determine asset vulnerability, which is based on a combination of qualitative and quantitative data. As such, it requires input from infrastructure owners and operators who have intimate knowledge of the infrastructure.
- Climate hazard information, e.g. regional climate projections for a future scenario.
- Performance and service-level requirements and expert judgement on sensitivity.

The outputs of the PIEVC Protocol are as follows:

- A risk matrix showing *probability x consequence* for each component-hazard pair.
- A ranked list of high-risk assets / components and associated failure modes.
- Identification of adaptation options.

The PIEVC methodology is conducted at the infrastructure asset / component level (e.g. foundation, building envelope, roof, electrical and mechanical systems), rather than network level, although it can consider network effects but requires bespoke modelling by the user. It uses the best information available for project assessments, including design parameters, operational and maintenance data (including performance records from past severe climate events). It specified the level of data required to carry out a climate risk assessment at various stages of a project, as shown in Figure 7.

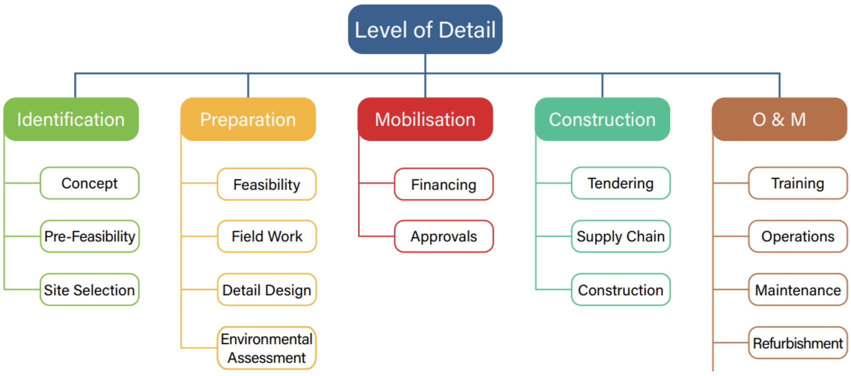

Figure 7 - Level of Detail for Climate Risk Assessments

Overall, the PIEVC methodology provides a high-level understanding of climate risks that is often sufficient to support adaptation and resilience decision-making. Use of the PIEVC Protocol is free for public infrastructure vulnerability assessments but users are required to sign a Non-Disclosure and Release Agreement (NDRA) to access the full documentation.

The Coalition for Disaster Resilient Infrastructure's **(CDRI) Global Infrastructure Risk Model and Resilience Index (GIRI)** is a global probabilistic risk model and resilience index for infrastructure across multiple sectors (e.g. power, telecommunications, transport, water, health, education). The CDRI define resilience as the capacity to 1) resist and absorb the shocks caused by disaster impacts, 2) response to the damages caused by those damages and maintain basic levels of service continuity during crises, 3) restore services as quickly as possible, as highlighted in Figure 8. The GIRI is designed to capture direct risks, cascading risks and systemic risks.

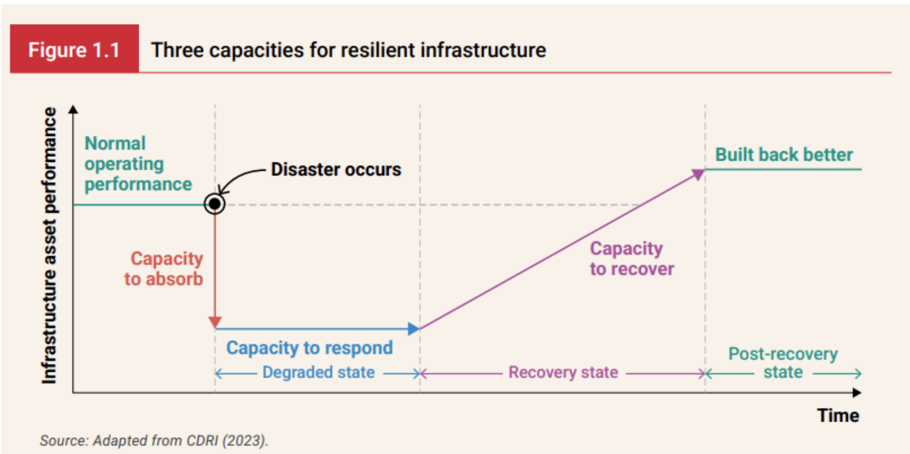

Figure 8 - Capacity for resilient infrastructure

The inputs required for the GIRI are as follows:

- Geospatial datasets of infrastructure assets, e.g. location, type.
- Climate hazard information, e.g. regional climate projections for a future scenario.
- Asset vulnerability functions (or damage curves) and exposure values.
- Socio-economic indicators for resilience and recovery capacity.

The outputs of the GIRI are as follows:

- Financial risk metrics, including Average Annual Loss (AAL) and Probably Maximum Loss (PML) by sector and geographical region.
- A resilience index, which summarises risk and resilience performance across countries / regions.
- Scenario-based risk estimates under various climate and development assumptions.

The CDRI have highlighted that while national-level risk assessments can assist governments in providing an overview of risks across different sectors to better shape national policies, more granular analysis, as provided by GIRI, is required to translate policies into action. The GIRI appears to be most suited for capturing system-level loss estimates at sector level.

9.1.5 Urban / Regional Climate Risk & Adaptation Frameworks

The **C40 / Global Covenant of Mayors Climate Risk & Vulnerability Assessment Framework** is a city-level climate risk and vulnerability assessment framework that is targeted towards cities and metropolitan regions. It employs a Climate Risk and Adaptation Framework and Taxonomy (CRAFT) that provides guidance and a standardised reporting framework covering hazards and impacts, risk and vulnerability assessment, and adaptation planning.

The required inputs are as follows:

- Regional boundary.
- Details of relevant climate hazards, including probability, intensity and time period of concern.
- Data on exposed people, assets and services.
- Qualitative and quantitative information on vulnerability and adaptive capacity.

The outputs of the C40 are as follows:

- Hazard-impact-risk matrices across different sectors, including infrastructure networks.
- Categorisation of risk levels (e.g. low – extreme) by hazard and sector.
- A semi-quantitative scoring and a narrative for informing an adaptation plan.

Overall, the C40 provides a suitable methodology for qualitatively / semi-quantitatively assessing the climate risks across multiple sectors and including sectoral interdependencies at city level.

The Europe Environment Agency has developed a **Regional Adaptation Support Tool (RAST)** that can be employed by local and regional authorities in Europe to inform regional and local climate adaptation strategies. It guides authorities through six steps as follows: 1. Preparation, 2. Assessing vulnerabilities, 3. Assessing risks, 4. Identifying adaptation options, 5. Adaptation implementation, 6. Adaptation monitoring. It requires substantial stakeholder input to define regional priorities, etc.

They also produced the first European Climate Risk Assessment (EUCRA), following the risk concept of the IPCC AR6, as announced in the 2021 EU strategy on adaptation to climate change. The report aim was to identify policy priorities related to climate change adaptation and policy development for the climate sensitive sectors and systems. The report identified 26 sectoral risks, 19 with increased risk, 7 with no trend and none have a decreasing risk. The report made the following key summary points:

- EU and its Member States have made considerable progress in understanding the climate risks they are facing and preparing for them. National climate risk assessments are increasingly used to inform adaptation policy development. However, societal preparedness is still low, as policy implementation is lagging substantially behind quickly increasing risk levels.
- Adaptation policies can both support and conflict with other environmental, social and economic policy objectives. Thus, an integrated policy approach considering multiple policy objectives is essential for ensuring efficient adaptation

An EU project has developed a Climate Risk Assessment Framework and Toolbox, **CLIMAXX**, for conducting a multi-hazard climate risk assessment, which targeted towards regions and communities in Europe. The CLIMAXX framework emphasises five operational steps: 1. scoping, 2. risk exploration, 3. risk analysis, 4. key risk assessment, 5. monitoring and evaluation.

The required inputs for the CLIMAXX framework are as follows:

- Hazard data from EU datasets, e.g. flooding, heat, drought, etc.
- Exposure and vulnerability data for people, assets and infrastructure.

The outputs of the CLIMAXX framework are as follows:

- Harmonised risk indicators for different hazards and sectors.
- Methodological guidance for integrating results into adaptation planning.

9.1.6 Corporate / Financial Risk & Disclosure Frameworks

The recommendation from the **Task Force on Climate-related Financial Disclosures (TCFD)** included a voluntary disclosure framework for climate-related financial risk. It is targeted at corporates, financial institutions and investors, and covers physical and transition climate risks. The framework offers a risk assessment structure but not a methodology. Furthermore, TCFD doesn't define specific risk metrics but allows organisations to choose their own metrics, e.g. expected loss.

TCFD has been absorbed into the **ISSB** while **SASB** has also consolidated under ISSB. The TCFD, ISSB and SASB play complementary roles in climate risk assessment, primarily from a financial materiality perspective. TCFD established the foundational framework for identifying, assessing and disclosing climate-related risks and opportunities, structured around governance, strategy, risk management, and metrics and targets, and introduced the expectation of scenario analysis to test business resilience. ISSB has now embedded and formalised this approach through **IFRS S1** and **IFRS S2**, consolidating TCFD's architecture into a global baseline standard for sustainability and climate-related financial disclosures, while requiring transparent explanation of risk assessment processes and assumptions. SASB, now maintained by the ISSB, provides industry-specific metrics that help organisations identify which climate risks are most likely to be financially material within their sector.

The **UNEP FI Physical Climate Risk Assessment Framework** is aimed at banks, investors and insurers. It provides sector-specific methodologies that inform the users about integration of physical climate risk into decision-making and TCFD-aligned disclosure. The inputs are asset-level and portfolio-level data on location, sector and financial exposure, and climate hazard and impact data. The outputs are financial risk metrics, e.g. credit risk parameters, expected loss.

Within Europe, the Corporate Sustainability Report Directive (**CSRD**) is the EU's mandatory sustainability reporting regime requiring large EU companies, listed SMEs (except micro-entities), and certain non-EU companies with significant EU activity to disclose detailed ESG information in line with the European Sustainability Reporting Standards (ESRS). Under **ESRS E1** (Climate Change), companies must conduct and disclose a double materiality assessment, including how climate-related physical and transition risks and opportunities affect the business (financial materiality) and how the business impacts climate (impact materiality), supported by scenario analysis where relevant.

The Voluntary Sustainability Reporting Standard for SMEs (**VSME**) is a simplified, voluntary ESRS-based framework for non-listed SMEs that are not in scope of CSRD but may face supply-chain or lender information requests.

There are many other voluntary disclosure platforms which require growing levels of information on climate risks, such as **CDP**, **GRESB** and **Ecovadis**.

10 Appendix 1B: Practical Climate Risk Assessment Guidance

How to Use This Guidance

This appendix is not intended to replace ISO 14091 or other standards but to provide practical guidance on integrating climate risk assessment into infrastructure planning, development and asset management. The guidance is intended to support infrastructure owners, project developers and public authorities in conducting proportionate climate risk assessments across different stages of the infrastructure lifecycle. The framework presented in this appendix outlines the minimum information that is recommended to be included in a Climate Risk Assessment. More complex infrastructure projects may require more detailed or quantitative assessments depending on project scale, complexity and climate risk exposure.

Appendix 1B contains three complementary components:

A1.1 Climate Risk Maturity Model

A simple framework to help organisations understand their current level of climate risk management capability and identify opportunities for improvement.

A1.2 Climate Risk Assessment for Infrastructure Projects

Guidance aligned with the infrastructure project lifecycle describing how climate risks can be assessed during planning, appraisal, design and delivery of new infrastructure projects. Included are:

A1.2.1 CRA over Infrastructure Project Lifecycle

A1.2.2 Hazards for Critical Infrastructure

A1.2.3 Minimum CRA Framework for Infrastructure Projects

A1.3 Climate Risk Assessment for Existing Infrastructure Portfolios

A portfolio-scale approach that enables infrastructure owners to assess climate risks across large asset networks and prioritise assets requiring more detailed analysis.

10.1 Climate Risk Maturity Model

Firstly, consider the **maturity of the organisation's climate risk and adaptation** status. Table 10 presents one example of how an organisation's climate risk maturity could be viewed. However, organisations will not progress linearly and may occupy different positions across climate risk assessment and management dimensions. Effective climate resilience requires both robust risk assessment and the implementation of appropriate adaptation measures. Overemphasis on either dimension can result in suboptimal outcomes—either unmanaged risks or inefficient allocation of resources. Hence Figure 9 aims to represent visually the level of risk assessment versus risk management.

Table 8 - Climate Risk Maturity Levels and Organisational Characteristics

Maturity Level	Description	Typical Characteristics	Typical Indicators / Evidence	Example Outputs
Level 1 – Awareness	Climate change is recognised as a potential risk but is not systematically assessed.	Climate risks referenced in policies or sustainability strategies. Limited use of climate data. Risks mainly considered through compliance processes (e.g. EIAR, SEA).	Climate change mentioned in corporate strategy or sustainability reporting. No structured climate risk assessments carried out.	High-level statements on climate risks.
Level 2 – Qualitative Risk Identification	Organisations begin identifying climate risks using structured qualitative approaches.	Climate hazards identified for key assets. Use of hazard–exposure–vulnerability concepts. Climate risks included in organisational risk registers.	Climate risks appear in enterprise risk registers. Initial screening of hazards affecting assets.	Qualitative climate risk register.
Level 3 – Structured Risk Assessment	Climate risks are assessed using structured methodologies and datasets.	Use of climate projections and hazard datasets. Multi-hazard risk assessment. Risk scoring using likelihood–consequence matrices. Identification of adaptation options.	Climate risk assessments conducted for infrastructure projects or asset portfolios. Use of climate datasets and scenario assumptions documented.	Climate risk assessments supporting planning and investment decisions.
Level 4 – Quantitative Climate Risk Assessment	Climate risks are analysed using quantitative or	Use of geospatial hazard modelling. Asset-level vulnerability analysis.	Use of geospatial hazard analysis tools or quantitative risk	Quantified climate risk metrics and prioritised

	model-based approaches.	Estimation of potential damages or service disruptions. Integration into asset management planning.	models. Climate risk metrics used in infrastructure planning or investment decisions.	adaptation investments.
Level 5 – Adaptive Climate Risk Management	Climate risk management is fully embedded within infrastructure planning, operations and governance.	Continuous monitoring of climate risks. Integration of climate resilience into asset management systems. Adaptive planning and periodic reassessment of risks. Coordination across infrastructure sectors.	Climate risk integrated into asset management plans and capital investment programmes. Regular updates to risk assessments based on new climate information.	Dynamic climate risk management and resilience planning.

Risk Management & Implementation				
	High	Analysis Paralysis	Technically Strong, Operational Gap	Advanced Resilience
	Medium	Assessment Heavy Action Light	Developing Capability	Risk-informed Management
	Low	Potential Blind Spot	Reactive Operator	Operationally Resilient
		Low	*Medium*	*High*
	Risk Identification & Assessment			

Figure 9 - Risk Assessment versus Risk Management

10.2 Climate Risk Assessment for Infrastructure Projects

10.2.1 Climate Risk Assessment (CRA) During Project Lifecycle

The guidance outlines climate risk assessment activities by Infrastructure Project Lifecycle Stage. For those infrastructure owners, where the Infrastructure Guidelines project lifecycle stages apply, these stages have also been identified *(IG Stages).*

Table 9 - Climate Risk Assessment Activities Across the Infrastructure Project Lifecycle

Infrastructure Project Lifecycle Stage *(IG Stages)*	Purpose of Climate Risk Assessment	Minimum Climate Risk Assessment Activities	Key Outputs
Strategic Planning *(Strategic Assessment)*	Identify whether climate risks could materially affect the proposed infrastructure investment and determine whether further assessment is required.	• Identify project location and expected asset lifetime and service criticality • Screen for relevant climate hazards (flooding, storms, heat, drought, sea level rise) • At a minimum, use national hazard datasets (e.g. TRANSLATE projections, OPW flood maps) • Identify potential dependencies with other infrastructure systems	• Climate Risk Screening Summary • Identification of key climate hazards • Decision on whether detailed climate risk assessment is required
Project Preparation *(Preliminary Business Case)*	Assess climate risks associated with different project options and ensure climate resilience is considered in option appraisal.	• Define relevant climate scenarios and time horizons • Conduct hazard analysis under future climate scenarios • Assess exposure of infrastructure assets to climate hazards • Identify potential vulnerabilities in project options • Conduct qualitative or semi-quantitative risk assessment	• Climate Risk Register • Identification of high-priority risks • Climate resilience considerations incorporated into option appraisal

		• Identify initial adaptation or resilience measures	
Project Appraisal and Design *(Final Business Case)*	Ensure that the preferred project option is designed to remain resilient under future climate conditions.	• Detailed engineering vulnerability assessment • Stress-testing infrastructure design under future climate scenarios • Identification and evaluation of adaptation measures • Assessment of residual climate risks • Consideration of cascading risks across infrastructure systems	• Detailed Climate Risk Assessment • Adaptation and resilience measures incorporated into project design • Residual risk assessment
Implementation	Ensure climate resilience measures identified during appraisal are incorporated into project delivery.	• Integrate climate adaptation measures into detailed design • Confirm climate assumptions used in engineering design • Ensure contractors and delivery teams are aware of climate resilience requirements • Document climate risk management measures	• Climate-resilient infrastructure design • Implementation of adaptation measures • Documentation of climate risk management actions
Operations and Asset Management *(Review and Asset Management)*	Manage climate risks throughout the operational life of the infrastructure asset.	• Monitor climate hazards and infrastructure performance • Maintain climate risk register for the asset • Review infrastructure performance following extreme events • Update climate risk assessments periodically • Adjust operational procedures and maintenance where necessary	• Updated climate risk register • Monitoring and resilience indicators • Periodic review of climate risks and adaptation measures

10.2.2 Hazards For Critical Infrastructure

Climate change may affect infrastructure systems through a range of hazards, including flooding, storms, extreme temperatures and changes in water availability. The relevance of these hazards varies across infrastructure sectors depending on asset characteristics and operating conditions. Table 12 below summarises key climate hazards relevant to major infrastructure sectors in Ireland. Note that climate hazards do not occur singularly and multiple hazards can occur at the same time so consideration to events with multiple hazards should occur e.g. storms and flooding. Also, hazards outside of Ireland influence material and resource sourcing during construction as well as operations.

Table 10 - Key Climate Hazards Affecting Critical Infrastructure Sectors

Climate Hazard	Transport Infrastructure	Electricity Infrastructure	Water Infrastructure	Telecommunications Infrastructure
Flooding (fluvial and pluvial)	Flooding of roads, rail lines and tunnels; disruption to transport corridors; damage to drainage and signalling systems	Flooding of substations; damage to underground cables; restricted access for maintenance crews	Flooding of treatment plants and pumping stations; sewer overflows; disruption to water supply operations	Flooding of telecom exchanges and network nodes; disruption to underground fibre networks
Coastal flooding and sea level rise	Damage to coastal roads, rail infrastructure and port facilities; erosion affecting transport corridors	Flooding risks to coastal substations and grid infrastructure; exposure of coastal cables	Flooding of coastal wastewater treatment plants and pumping infrastructure	Flood risk to coastal telecom infrastructure and subsea cable landing stations
Extreme precipitation	Surface water flooding on roads and rail networks; slope instability affecting infrastructure	Flooding of substations and network assets; erosion affecting tower foundations	Increased inflows to wastewater systems; capacity challenges for drainage and	Water ingress affecting underground telecom infrastructure and roadside equipment

	corridors; drainage failures		treatment systems	
Severe convective storms (wind, lightning and intense rainfall)	Debris on roads and rail networks; damage to signalling systems; disruption to ports and ferry operations	Damage to overhead transmission and distribution lines; lightning strikes causing line faults and equipment damage; vegetation impacts leading to outages	Power outages affecting water treatment plants and pumping systems; storm-related damage to infrastructure	Damage to telecom masts and aerial cables; outages caused by lightning strikes or wind damage
Extreme heat	Rail track expansion or deformation; road surface degradation; impacts on transport operations	Reduced efficiency of transformers and cables; overheating of electrical equipment	Increased water demand; impacts on treatment processes and reservoir management	Increased cooling requirements for telecom equipment and data centres
Drought and water scarcity	Reduced water availability for construction and maintenance activities	Reduced availability of cooling water for generation infrastructure (where relevant)	Reduced reservoir levels; water supply stress; impacts on river abstraction	Potential impacts on cooling systems for telecom facilities and data centres
Landslides and slope instability	Damage to road and rail infrastructure in steep terrain; disruption to transport corridors	Access issues for transmission infrastructure in upland areas; instability affecting tower foundations	Damage to water pipelines and associated infrastructure	Damage to telecom cables and infrastructure located along transport corridors

10.2.3 Minimum CRA Framework for Infrastructure Projects

This framework outlines the minimum information that should be included in a climate risk assessment for infrastructure projects in Ireland across the project lifecycle and supporting a multi-hazard approach to climate risk assessment. The framework is intended to provide a proportionate and practical structure that can be applied across infrastructure sectors, including transport, electricity, water and communications infrastructure.

A minimum climate risk assessment should:

- Consider multiple climate hazards
- Document datasets, assumptions and scenarios used
- Assess exposure and vulnerability of infrastructure assets
- Identify adaptation measures integrated into project design
- Include a risk register and monitoring plan.

1. Project Overview

Table 11 - Project Overview Information Requirements for Climate Risk Assessment

Item	Description
Project name	
Infrastructure sector	Transport / Electricity / Water / Telecommunications / Other
Infrastructure type	e.g. road corridor, substation, water treatment plant
Project location	
Expected asset lifetime	
Infrastructure Guidelines stage	Strategic Assessment / Preliminary Business Case / Final Business Case

2. Climate Hazard Screening

Table 12 - Climate Hazard Screening for Infrastructure Projects

Climate Hazard	Relevant to Project? (Yes/No)	Notes
Flooding (fluvial / pluvial)		
Coastal flooding / sea level rise		
Extreme precipitation		
Severe storms (wind / lightning)		
Extreme heat		
Drought / water scarcity		
Landslides / slope instability		

3. Climate and Hazard Datasets

Table 13 - Climate and Hazard Datasets Used in Risk Assessment

Dataset	Source	Spatial Resolution	Dataset version / year	Data confidence (High / Medium / Low)	Notes
Climate projection dataset					
Flood hazard dataset					
Coastal hazard dataset					
Other hazard datasets					

Where possible, datasets used in climate risk assessments should be appropriate to the spatial scale of the infrastructure asset or network being assessed.

4. Considering Uncertainty

How uncertainty is dealt with in its many forms should be recorded. Some examples are included below:

Table 14 - Approaches to Managing Uncertainty in Climate Risk Assessment

Uncertainty Type	Description	Approach Used	Confidence Level	Implication for Decision
Climate model uncertainty	Variation across projections	Multi-scenario analysis	Medium	Design for upper-bound where critical
Data uncertainty	Resolution / quality limitations	Use of proxy datasets	Low	Apply safety margins
Asset vulnerability uncertainty	Limited failure data	Expert judgement	Medium	Conservative assumptions applied
Future pathway uncertainty	Policy / emissions uncertainty	Scenario range (e.g. RCP/SSP)	High	Flexible/adaptive design

5. Climate Scenarios and Time Horizons

Table 15 - Climate Scenarios and Time Horizons Considered in Assessment

Parameter	Description
Climate scenarios considered	e.g. mid-range and high-end climate futures
Time horizons considered	e.g. 2030 / 2050 / 2080
Asset lifetime considered	

Key assumptions	

6. Exposure and Vulnerability Assessment

Table 16 - Exposure and Vulnerability Assessment of Climate Hazards

Hazard	Exposure (Low/Medium/High)	Vulnerability (Low/Medium/High)	Notes
Flooding			
Severe storms / lightning			
Extreme precipitation			
Extreme heat			
Drought / water scarcity			
Coastal flooding (where relevant)			
Other hazard			

7. Climate Risk Register

Table 17 - Climate Risk Register for Infrastructure Projects

Hazard	Existing Controls	Likelihood	Consequence	Risk Rating	Potential Impact
Flooding					• Infrastructure damage • Service disruption • Safety risks • Cascading impacts on other infrastructure systems.
Storm damage					

Heat impacts					

8. Adaptation and Resilience Measures

Adaptation measures should be proportionate to the level of risk identified and integrated into project design, operational procedures or asset management plans.

Table 18 - Adaptation and Resilience Measures by Climate Risk

Climate Risk	Adaptation Measure	Project Stage Implemented
Flood risk	e.g. improved drainage / raised infrastructure	Design stage
Storm damage	e.g. vegetation management / structural reinforcement	Design stage
Heat impacts	e.g. temperature-resilient materials	Design stage

9. Residual Risk and Monitoring

Table 19 - Residual Climate Risks and Monitoring Measures

Residual Risk	Monitoring Measure	Responsible Organisation	Trigger Thresholds
Flood risk	e.g. Monitoring of flood levels	Asset operator	X mm in y hours
Storm damage	e.g. Vegetation inspection programme	Asset operator	X gust speed over y timeframe

10.3 Climate Risk Assessment for Existing Infrastructure Portfolios

Many infrastructure organisations operate large networks of assets that vary in age, design and location. Conducting detailed engineering climate risk assessments for each individual asset may not be feasible. Portfolio-scale climate risk assessments can provide a practical approach for identifying climate risk hotspots across infrastructure systems and prioritising assets for more detailed analysis. Portfolio-scale assessments are increasingly supported by geospatial climate risk analytics platforms that combine climate hazard datasets with infrastructure asset information to rapidly identify potential climate risk hotspots. Portfolio-scale assessments allow infrastructure organisations to rapidly identify climate risk hotspots across large infrastructure networks and prioritise assets for more detailed engineering analysis.

Stress testing scenarios, which impact operations of the system tend be bespoke per sector and even sub-sector or organisation level. For example, a renewable energy company may need to assess the impact of a period of very low wind yield (for example 14 days) to its operations and profitability including where it may need to purchase back the loss of power from the market to meet Power Purchase Agreements.

Table 20 - Portfolio-Scale Climate Risk Assessment Process for Infrastructure Assets

Step	Purpose	Key Activities	Typical Outputs
1. Asset inventory and classification	Identify infrastructure assets and group them into relevant archetypes	• Compile asset database (location, asset type, age) • Group assets into archetypes (e.g. substations, rail corridors, pumping stations)	Asset inventory and archetype classification
2.Hazard exposure analysis	Identify climate hazards affecting asset locations	• Overlay asset locations with climate hazard datasets • Assess exposure to flooding, storms, heat, drought and other hazards	Hazard exposure maps and asset exposure indicators
3. Vulnerability screening	Assess sensitivity of asset types to hazards	• Define vulnerability characteristics for asset archetypes • Identify critical thresholds (e.g. flood depth, temperature limits)	Vulnerability profiles for asset archetypes
4. Portfolio risk assessment	Identify assets with highest climate risk	• Combine hazard, exposure and vulnerability data • Develop risk indicators or scores for assets	Portfolio climate risk map and prioritised asset list
5. Prioritisation of detailed assessment	Identify assets requiring further engineering analysis	• Identify high-risk assets • Prioritise sites for detailed climate risk assessment	List of priority assets for detailed assessment
6. Adaptation planning	Identify resilience measures for vulnerable assets	• Identify adaptation measures (e.g. flood	Infrastructure resilience strategy

		protection, relocation, operational changes) • Integrate adaptation into asset management plans	

11 Appendix 2: Stakeholder Engagement (Referenced in Section2)

Table 21 - Details of Stakeholder Engagement

Sector	Type	Importance of Stakeholder
Cross-cutting (policy / resilience)	Policy / national resilience lead	Critical entities resilience oversight and cross-sector preparedness/coordination.
Energy	Owner/operator (TSO)	Electricity transmission system operation, planning, and system resilience.
Energy	Owner/operator	Generation assets and operational resilience planning.
Energy	Owner/operator (DSO)	Distribution network operations; frontline exposure to storms/flooding and restoration.
Water	Owner/operator	Water and wastewater services; dependent on power/telecoms and exposed to flooding/drought.
Transport	Owner/operator / delivery body	National roads and light rail delivery; climate risk in project appraisal and asset management.
Transport	Owner/operator	Rail operations and infrastructure resilience, including service continuity under extreme events.
Transport	Policy / planning / funding	Public transport planning, investment decisions, and network performance requirements.
Transport (maritime)	Owner/operator	Port infrastructure and continuity; coastal flooding/storm surge exposure and supply-chain criticality.
Transport (maritime)	Owner/operator	Regional port operations; climate exposure and interdependencies with energy/transport links.
Finance / investment	Investor / finance	Financing perspective on risk, resilience and investment decision-making.
Regulation	Regulator (energy & water)	Regulatory requirements and incentives shaping resilience, reliability and investment.
Telecommunications	Owner/operator	National telecoms infrastructure and service continuity; interdependency with electricity supply.
Climate / hazard data	Data / national service	Climate and weather data/scenarios used to inform hazard assessment and stress testing.
Flood Risk Managers	Flood Risk and Adaptation National Level	Provision of data, scenarios and maps in relation to SLR and Flood

Climate Risk Tool Providers	Commercial tools for assessing climate risks	Infrastructure stress tests, adaptation design, quantitative risk assessment
Technical Expert	Global perspective	Expert across multi-jurisdictions on comms continuity
Insurer	Industry Body	Approach to climate risk, adaptation measures, insurance for assets
Asset Developer	Asset Development	Approach to short- and long-term asset risk from climate change
Engineering Company	Engineering	Requested by asset owners or developers to carry out CRA
Asset Owner	Asset owner/manager	Comparable investment within private sector
OECD	Global perspective	International experience on climate risk/ adaptation for infrastructure
ISIF, NTMA, New Era	Investor / Oversight	Multiple roles including oversight of semi-states, investors in infrastructure and companies.

12 Appendix 3: Practical Guidance for Enhancing Resilience

This appendix puts forward a compilation of case studies of varying scales across various critical infrastructure sectors to highlight different international experiences, methods of adaptation suited to each location and examples of co-operation towards enhancing critical infrastructure resilience to extreme weather events. Whilst table 9 sets out a more generic list of adaptation examples across all sectors.

Energy examples include:

- Sweden's response to Storm Gudrun in 2005 included amending its Electricity Act to require power generators to restore service within 24 hours or face substantial financial penalties, creating a strong economic incentive for distribution system operators to invest in resilience.
- The United Kingdom maintains dedicated submarine cable repair capabilities through contracted access to specialised vessels, enabling rapid responses to undersea infrastructure damage. This contrasts with other regions where restricted commercial vessel availability can cause repair mobilisation times to exceed four months. Ireland's increasing reliance on submarine interconnectors means that it will need similar rapid repair capabilities.
- In Belgium and France the LIFE Elia-RTE project[2] combines electrical safety of grid lines with biodiversity-friendly vegetation management by creating green corridors under high-voltage overhead lines, thus reducing the risk of trees falling on the lines and creating condition under which tree growth will be much slower in order to avoid recurrent tree cutting. This project relies on a multi-partner approach. It was run between 2011-2017, together between the Belgian TSO, Elia, French TSO, RTE, and ecological consultancy, Ecofirst.

12.1 Climate-Adapt Case Studies

More detailed case studies taken from the Climate-Adapt program include energy and water adaptation examples from Finland and the UK.

- Case Study 1. Finland Replacing Overhead Lines with Underground Cables.

The second largest DSO in Finland, Elania, is substantially investing in replacing most of its overhead power lines with underground cables, which are protected against storms, snow and ice accumulation. The substantial costs of doing so are reduced by partnering with telecommunication companies, which can use the same excavations for their own communication cables.

In order to adapt to increasingly frequent and extreme weather events and to adhere to the outage requirements of Finland's Electricity Market Act, Elenia, the second largest electricity

[2] https://renewables-grid.eu/database/green-corridors/

distribution system operator behind Caruna, plans to increase the share of underground cables in its network from 41 % currently to 75 % by 2028. These measures were adopted in response to a recently introduced legal requirement to limit electricity outages related to extreme weather, in particular storms and heavy snow.

- Case Study 2. Flood Defence Framework for National Grid Substations in United Kingdom.

The United Kingdom has historically experienced severe flood events, including that of the summer 2007, which resulted in the loss of essential services including water and energy supply, as well as the destruction of infrastructures, with estimated costs exceeding £3.2 billion.

Following the outcome of the Pitt Review: Lessons learned from the 2007 floods, the Energy Networks Association (ENA) Substation Resilience to Flooding Task Group was established as part of an assessment of the resilience to flooding of HV substations to identify the steps required to mitigate current and future risks. The assessment led to the publication of the ENA Engineering Technical Report, with input from the National Grid Electricity Transmission and other energy transmission and distribution companies.

The first step focused on the assessment of vulnerability and flooding risk, the second step dealt with identification, design and implementation of flood defence solutions for critical substations. The substations which could be impacted under the high UKCP09 emission scenario were identified. In stage one of the project 11 high risk substations were protected, in stage 2 a further 38 medium risk substations were to be protected by 2021 followed by a further 100 surface water risk sites to be protected during the period 2021-2026.[3]

Table 22 - Examples of Adaptation Measures

Sector	Subsector	Management & Planning	Physical measure	Co-Benefits of Measures	Links to case studies
Energy	Electricity Generation	Climate proofed standards for design Climate risk modelling built into location decision making process Predictive maintenance using sensor	Hydropower: • Spillways as flood adaptation measure. Power plants: • Dry cooling as an alternative to water.	Hydropower - Spillways: • help to maintain natural river dynamics, preventing sediment accumulation on downstream ecosystems. Powerplants – dry cooling: • Reduces water consumption.	

[3] https://climate-adapt.eea.europa.eu/en/metadata/case-studies/flood-defence-framework-for-national-grid-substations-in-united-kingdom

		technology/ data analytics			
	Electricity Distribution	Determine areas of high exposure & ensure critical equipment is not located in these areas Identify routes least exposed for overhead cables	Tree management (TM) – need to consider environmental impacts. Underground cabling – more secure energy chain Installing conductors with higher operating limits	Effective TM can lead to: • Reduction of impact of storm events on electricity outages. • enhanced carbon sequestration. • improved ecosystem services e.g. water regulation & habitat provision.	202409_RGI_IVM_Guide.pdf Selecting and Managing Trees to Avoid Conflicts With Overhead Utility Lines Construction sites on the map - Elenia
	Electricity Transmission	Determine areas of higher exposure and ensure critical equipment is not located in these areas.	Underground cabling – more secure energy chain Flood defences for substations e.g. drainage diversions, embankments.	Underground Cabling: • Reduces exposure to storms, high winds, lightning. • Reduces the need for TM - potential disruption to habitats /ecosystems.	National_Grid_Flood_Resilience_2016.indd
Transport	Road	Climate proofed standards for design, construction, maintenance. Identify CI routes	Permeable pavements/porous top layer. Culverts designed to accommodate higher water flow in shorter periods	Permeable Pavements: • Reduction of stormwater runoff • Filter pollutants improving quality of water. • Reduction of UHI as allows water to evaporate from surface. Culverts: • Channel surface water away from roads preventing flooding/erosion. • Help reduce amount of sediment and pollutant entering waterways	LIFE UrbanStorm shows nature-based solutions are key to managing urban floods - European Climate, Infrastructure and Environment

				• enhancing water quality. • Help preserve natural watercourse, supporting biodiversity.	Executive Agency
	Rail	Incorporate cc projections into design and drainage systems Develop strategies e.g. rerouting models, replacement of services etc.	Nb measures to protect from direct sunlight e.g. tree canopy cover. Dikes/embankments Painting of rails white.	Tree Canopy cover: • Increases evaporative cooling, reducing exposure to heat waves & reducing UHI effect. • Supports biodiversity – providing habitats & food for species. • Improves air quality. • Carbon sequestration. Dikes/embankments: • Improve slope stability. • Help to control water flow – flood management. Painting of rails white: • Reduces solar gain, therefore buckling. • Minimises the need for other cooling measures which may require energy consumption.	Implications of climate change for railway infrastructure Why does Network Rail paint rails white for the summer? - Network Rail
	Maritime	Establishment of emergency procedures. Evaluation/ monitoring of return periods for coastal/ flood events. Monitoring to identify potential modification of dredging Contingency plan for back up	Infrastructure/electrical equipment elevation to account for SLR. Inland location of processing sites. Storm defences – breakwaters, seawalls.	Breakwaters/Seawalls: • Dissipates wave energy, preventing coastal erosion/flooding. • Creates habitats promoting the establishment of native marine species.	Building-Coastal Resilience through Nature-Based and Integrated Solutions: Nature-Based Seawall Concept

		critical equipment e.g. RORO ramp.			ual Design Review Living Breakwaters - SCAPE Projects – Reefy
	Air Travel	Collaboration with interconnected sectors/stakeholders to discuss operational resilience. Improved winter maintenance capacity e.g. de-icing, clearing of runway.	Improved drainage systems including backflow valves. Waterproofing of underground electrical cables.	Backflow valves: • Help to maintain a high standard of water quality. • Help to reduce water pollution.	Adaptation measures to increase climate resilience of airports | Adaptation options | Discover the key services, thematic features and tools of Climate-ADAPT Climate-ADAPT
	Active Travel		Sustainable Urban Drainage systems (SUDs) Tree canopy cover	SuDs: • Manage stormwater – reducing surface water runoff. • Filters out pollutants, improving water quality. • Enables infiltration of rainwater into the ground, leading to sustainable water management.	Developing a river park to boost urban resilience | Resilient Watersheds Toolbox

				• Designs often include ponds/swales creating habitats for species. Tree Canopy cover: • Increases evaporative cooling, reducing exposure to heat waves & reducing UHI effect. • Supports biodiversity – providing habitats & food for species. • Improves air quality. • Carbon sequestration.	
Water	Water Quality	Development of drought management plans	NbS – integrated catchment management, rainwater gardens, permeable pavements, constructed wetlands	NbS: • Reduces surface water runoff • Improves biodiversity by restoring habitats/ ecosystems. • Improves air quality. • Contributes to ecosystem services e.g. carbon sequestration, water regulation, soil stabilisation.	Green rainwater solution creates a new beautiful urban space in Copenhagen - Climate Change Adaptation
	Water Services	Backup generators/spare parts for critical WW treatment plants – ensure these are situated at low exposure areas.	Flood barriers for infrastructure assets. Increase water storage capacity	Flood Barriers: Increased water stored capacity: • Ensures safe and sustainable water supply.	Water Treatment Works | Flood Control International | Case Study
Communications	Electronic Communications Network (ECN)	Provision of backup power i.e. batteries or mobile/permanent generators at key locations.	Transition from copper to fibre networks Elevation of ground-based cabinets above flood level/ movement of	Transition from copper to fibre networks: • Reduces CO_2 emissions, therefore GHG emissions. • Reduces energy consumption.	Microsoft Word - Määräys_viestintäverkkojen_var

		Coordination with ESB networks for priority restoration agreements. Integration of renewable energy sources	cabinets from areas of high flood risk. Install backflow valves in underground chambers. Tree management – need to consider environmental factors.		mistamisesta_perustelumuistio_EN_09122021_viimeistelty_ja_stilisoitu.docx
	Electronic Communications Services (ECS)	Dual link contingencies to remove single points of failure/diversification of power supply lines. Coordination with ESB networks for priority restoration agreements.			