

Who owns the risk?

Allocating responsibility for climate resilience of critical infrastructure in EU Member States

Adèle Tanguy, Julie Pouzol, Marta Torres Gunfaus (IDDRI)

Critical systems and their underlying infrastructure, essential for people, the economy and society, are affected by the increasing impacts of climate change. Adapting them raises several challenges that need to be anticipated and addressed, such as the risk of lock-in and stranded assets, the need for efficient collaboration between public authorities, operators and infrastructure managers, the need to manage transboundary and cascading risks, and to coordinate across levels of governance. The recently published European Commission's Integrated Framework on Climate Resilience (IFCR) is an opportunity to strengthen support to Member States (MS) and address the challenge of risk ownership across EU policies and MS and gaps that cannot be filled by national authorities alone.

This *Study* analyzes how choices over the climate resilience of critical infrastructure are made across countries, their coordination with operators' planning, and by showing the diversity of practices through sectoral examples anchored in different country contexts. As such, it provides a basis for sharing practices between MS, identifying common challenges related to interdependencies and informing necessary trade-offs. Ultimately, this *Study* aims at supporting decision-makers and operators in their effort to coordinate to adapt critical infrastructure to climate change and informing on how the IFCR can strengthen these efforts.

KEY MESSAGES

National experience shows that decision-making on climate resilience of critical infrastructure is fragmented across stakeholders and policy documents with different priorities and timeframes. Adaptation trade-offs and priority setting between public and private stakeholders can be based on various criteria, ranging from ensuring economic viability to societal value of critical infrastructure. In the absence of explicit public directives, operators are responsible for the strategic decisions to set the resilience levels to adapt infrastructure.

Setting and aligning responsibilities (for choosing the level of resilience, the type of adaptation and the level of investment) is a prerequisite to ensuring that adaptation decisions reflect societal priorities. This is determined by mandates, governance, financing models and capacity, which vary across countries and sectors. As national authorities are starting to clarify risk ownership, the IFCR can act as an enabler by clearly mandating national authorities to act and creating a space for structured exchange of practices.

Both public and private stakeholders are shifting their approach from protecting or strengthening specific assets to ensuring broader system resilience, integrating climate resilience in the operation of infrastructure systems and addressing interconnections across networks and territories. But gaps remain that cannot be solved by national authorities alone. The IFCR is an opportunity to provide the right coordination mechanism for addressing transboundary and cascading risks, and a common language and methods to integrate "resilience by design" within sectors.

There is still limited recognition that full resilience will not be possible in all situations due to time and financial constraints. The relocation of assets or anticipation of transformations are only marginally discussed as long-term options, and nature-based solutions are often undervalued due to co-benefits that are harder to monetize. With post-disaster costs generally backed by public authorities, insufficient anticipation is putting growing pressure on public budgets. Clearer directives are therefore needed on levels of ambition and priorities for resilience.

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EXECUTIVE SUMMARY

Introduction

Climate resilience is gaining momentum within the European Union (EU) and Member States' agendas, a trend that was further accelerated by the summer's record-breaking temperatures and their impacts on people and systems. In the short term, this political attention is culminating with the publication by the European Commission of the Integrated Framework on Climate Resilience (IFCR). This framework offers an opportunity to strengthen support for Member States and address the challenge of risk ownership and integration across EU policies. Risk ownership is still insufficiently defined, with different ways of approaching it, and responsibilities with regards to adaptation remain fragmented. At a time where the EU is trying to bring more coherence in the way risk ownership is approached across Member States and policy areas, this *Study* investigates how different countries and sectors already address the split of responsibilities for choosing the level of resilience and adaptation objective, and related coordination across stakeholders.

To address these questions, the *Study* focuses on the climate resilience of critical infrastructure, which provide essential services and constitute the backbone of our societies and are vital to the functioning of economies, public health, safety, and environmental protection. It proceeds in five steps. First, based on a literature review, it exposes the main climate risks and impacts to critical infrastructure across Europe, including consequences on the economy and society, current challenges for the resilience of critical infrastructure and how the EU framework currently responds through both adaptation specific and sectoral policies and frameworks. Then, it delves into five country cases to analyze existing policies, strategies and plans, namely, **Spain, France, Belgium, Germany and the Netherlands** through academic and grey literature complemented by interviews. These countries were selected for their common transboundary challenges and diverse climate impacts and risks

affecting critical infrastructure. The small number of countries explored is however a limitation, with Northern or Eastern European countries being left out. A third step is dedicated to the exploration of two sectoral case studies across the five selected countries, one on electricity and the other on railway transport. This was based on interviews with policymakers, asset managers and operators and a few complementary interviews with independent agencies, regulators as well as a review of public policy documents and strategies from operators and relevant contractual documents, decisions, regulations to identify roles and responsibilities on selected items that included setting resilience goals and targets, prioritizing measures and infrastructure, and financing adaptation as well as post-disaster reconstruction, and managing interdependencies. From this, we identify several cross-cutting learnings as well as the remaining gaps that the Integrated Framework on Climate Resilience can fill.

The imperative for clearly defined responsibilities

The European Critical Entities Resilience (CER) Directive defines critical entities as "necessary for the provision of an essential service" crucial for maintaining vital societal functions. Yet both extreme climate events and slow onset trends reinforced by climate change already reveal vulnerabilities of both infrastructure and services, and projections show that both impacts and economic damages will further increase, and even more without strong mitigation and adaptation action. Projections indicate economic damage to European infrastructure could reach €19.6 billion per year by the 2050s and €37 billion per year by the 2080s, with the strongest increases in energy and transport sectors (Forzieri *et al.* 2018). The current adaptation gap leaves societies increasingly exposed to cascading failures that threaten security of supply, public welfare, and economic stability.

The *Study* reveals that decision-making on climate resilience is fragmented across stakeholders, policy documents, priorities, and timeframes. Risk ownership remains unevenly defined across

countries. Most national adaptation plans acknowledge critical infrastructure but lack explicit residual risk thresholds (at what point does climate-induced disruption become unacceptable?), clear identification of risk owners responsible for defining and managing these thresholds and clear prioritization criteria for investment allocation between public and private stakeholders.

In the meantime, multiple stakeholders are involved in shaping the resilience of critical infrastructure and their systems, and benefit from (or are affected by the lack of) their resilience, which complicates the allocation of risk ownership. Well adapted critical infrastructure and essential services that they provide bring benefits not only to the ones who manage them and operate the service, but also to territories, communities and economic activities they serve. They are highly interlinked with these territories, and the collective benefits of resilience measures are therefore difficult to monetize and integrate in economic analysis and business cases.

Yet, as damages and disruption accumulate, the associated costs could become large enough to affect public finances, financial assets and economic stability over the medium term. In parallel, a significant gap remains between risk awareness and investment in resilience. Traditional business cases do not always capture the value of prevention, service continuity, nature or avoided systemic risks. Stronger incentives, risk-sharing mechanisms and public-private coordination are needed to translate risk assessments into investment.

The level of resilience of critical infrastructure reflects specific social pacts and governance models

In the absence of explicit public directives, operators make *de facto* strategic decisions about resilience levels, in line with the level of continuity and quality of infrastructure and/or service that is defined in relevant regulations and contractual arrangements. Setting and aligning responsibilities (for choosing the level of resilience, type of adaptation and level of investment) is a prerequisite to ensuring that adaptation decisions reflect societal priorities. This is in part determined by mandates, governance, financing models and capacity, which vary across countries and sectors. In parallel, defining the desired level of resilience is ultimately a political and social choice. It requires decisions about who adapts, who pays, what level of service society expects, and what level of disruption or residual risk is acceptable by citizens – which ultimately depend on social pacts that are different from one country to the other.

Interdependencies, transboundary and cascading risks require moving from asset to system resilience

Resilience needs to be approached at the level of interconnected systems and services, not only individual assets. Resilience is well mainstreamed in critical infrastructure technical rules and sectoral regulation. However, asset-level decisions do not necessarily deliver system resilience to climate change; planning

needs to account for interdependencies, cascading risks, redundancy and continuity of services. It also requires a better understanding and mapping of the drivers of vulnerabilities, beyond climate risks alone. Moving from an asset-centred vision of resilience to system resilience for critical infrastructure and services requires going beyond cooperation across the supply chain to find new ways of collaborating on climate risks and shared adaptation strategies across the ecosystem. This means, for operators, strengthening collaboration with counterparts despite competition and sensitivity of data and considering redundancy (e.g. having a second line for a critical network) as a factor of resilience (increasing reliability of the system in case one of its components fails). Moving from asset to system resilience and managing interdependencies across sectors and countries require a shift in governance and risk ownership, to clarify who owns risks, who is accountable and how risks are shared across the infrastructure ecosystem, value redundancy and put in place mechanisms for sharing information.

The role the EU Integrated Framework on Climate Resilience can play to support current practices and fill shared gaps across Member States

Released on 27 October 2026, the IFCR policy package contains three main elements: (1) a legislative proposal, (2) a communication, and (3) digital tools including a European Climate Viewer. Our analysis identifies two sets of functions this framework can fulfil:

1) National-level engagement and support functions: engaging MS in clarifying risk ownership and responsibilities by designating accountable entities for each major climate risk, setting operational risk thresholds and embedding them in sectoral and contractual arrangements, and structuring mechanisms for peer-learning and for exchanging practices, methodologies, and lessons learned across Member States and sectors.

2) EU-level enabling functions: first, establishing a mechanism for transboundary coordination, placing risk ownership at the centre of discussions. Second, the IFCR gives an opportunity to address adaptation funding gaps by reinforcing joint investment mechanisms (between the EU and MS, and with operators), defining common principles for climate resilience and guidance on valuing ecosystem-based measures in cost-benefit analysis. Third, it can support a better alignment of heterogeneous systems by facilitating common methods and terminology for risk assessment, vulnerability analysis, prioritization, and investment planning. This can partly be achieved by leveraging the European Climate Viewer and common reference scenarios to bring coherence across obligations under the CER Directive, Taxonomy, CSRD, and EIB climate proofing. Finally, policy coherence with other European frameworks will require engagement across key Commission services to integrate IFCR elements into relevant policy areas. To support that, the IFCR can be used as an opportunity to create coordination mechanisms across key Commission services.

1. THE CONTEXT OF ADAPTING CRITICAL INFRASTRUCTURE TO CLIMATE RISKS IN THE EU

1.1. Climate risks and impacts on critical infrastructures in the EU

The notion of critical infrastructure refers to assets that are vital to the functioning of society or the economy. According to European Critical Entities Resilience (CER) Directive, it is defined as "an asset, a facility, equipment, a network or a system, or a part of an asset, a facility, equipment, a network or a system, which is necessary for the provision of an essential service", i.e. a service "which is crucial for the maintenance of vital societal functions, economic activities, public health and safety, or the environment" (EU, 2022). In practice, different definitions apply from one EU member country to the other, as the sectors and categories of entities identified vary.

1.2. Consequences on the economy and society

Critical infrastructure is a key foundation of our economic and social systems. Therefore, disruptions result in direct costs for operators but, even more critically, in consequences for the economy and people. It concerns the private sector, from businesses and industrials depending on the critical services provided by these infrastructures (transporting goods, having access to energy, water) to operators, as well as workers in the sectors in charge of the infrastructure, maintenance and service, and above all, citizens who depend on and pay tariffs for these services. It affects public authorities from local to national and European scale. It also has implications on financial stakeholders, both because of the level of investments needed to adapt the infrastructure, as well as for covering the losses and rebuilding in the case of damage, which is partly covered by public or private insurance. According to the JRC, the annual cost of damage to critical infrastructure under business-as-usual scenarios could increase more than tenfold by the end of the century, and reach

TABLE 1. Recent examples of impacts of extreme events on critical infrastructure across Europe

DATE	EVENT	IMPACTS ON INFRASTRUCTURE AND SOCIETY
2021	Floods in Germany, Belgium and the Netherlands	In Germany, over 200,000 people were impacted by power outages (Koks <i>et al.</i> , 2022). Transport infrastructures (roads, bridges, motorway, railway) were severely damaged (ERA, 2026; Heeg, 2021; Hauser, 2021). Asset damages were estimated around €1,3 billion for the railway only (Koks <i>et al.</i> , 2022). In Belgium, over 41,500 people were impacted by power outages (<i>ibid</i>). Several towns experienced disruptions in water supply and it took over six months to repair the water supply infrastructures (Koks <i>et al.</i> , 2022; SWDE, 2022). Railway repair costs approximated €50 millions (Rozendaal, 2021). For the Netherlands, between 1,000 and 2,000 households were affected by power outages (Koks <i>et al.</i> , 2022). Approximately 7,000 households were affected by disrupted telecommunication services (Koks <i>et al.</i> , 2022). Overall, the damages caused by the flood across the three countries exceeded €38 billion (SWECO, 2023).
2022	Heatwave and droughts	The 2022 summer heatwave had severe impacts on transport, water and energy infrastructure. In France, Belgium, Spain, the Netherlands and the UK, rail traffic was disrupted by power outages, heat impacts and fires (Geerts, 2022; Slavicek, 2022). Several countries were forced to impose restrictions on households and the agriculture sector because of impacts on the water and energy sectors (Horowitz, 2022; Bhargava and Granados, 2022)
2023	Floods and storms in Northern (Norway) and Southern Europe	Major floods impacted railway lines in Italy in May 2023, interrupting traffic for up to over six months depending on the location. The repair costs reached over €150 million. In August 2023, major floods disrupted one of the busiest railway lines in Slovenia. The storm even reached Croatia destroying some lines and caused the closure of the traffic for almost 2 months resulting in economic losses (ERA, 2026). In Norway, storms caused a critical railway bridge to collapse. At first traffic (passenger and freight) were diverted to another line but shortly after, landslides caused by heavy rainfall shut down that line as well (Bryant, 2023; Geerts, 2023).
2021-2022-2023	Consecutive floods in Greece	During three consecutive years, Greece has been impacted by heavy flash floods, torrential rains and storms. They affected many roads railways, and bridges that collapsed, and led to deaths and numbers of evacuations in 2022 and 2023. This led to high damages to the economy and to an initial support from the EU of €2.25 billion to mitigate the impacts of the 2023 floods (Deidda <i>et al.</i> , 2026).
2024	Dana flood in Spain	The floods had a significant impact on the sanitation infrastructure, disrupting services affecting a population of 200,000 inhabitants (Martin-Moreno <i>et al.</i> , 2025). Roads and railway infrastructures were also severely damaged (at least 160 km of the state road network, over 274 km of commuter train lines and 149,1 km of high-speed rail lines (Boira, 2025). Emergency work alone cost over €212 million (ERA, 2026) and costs lives of 150+ citizens.
2025	High temperatures in France and Spain	Temperatures reached 45°C melting pavements and causing rail tracks to buckle. In consequence, operation on the TEN-T and regional networks were interrupted (Global Railway Review, 2026)
2026	Repeated heatwaves	In June 2026, several incidents affected the transmission and distribution network in France (Brachet, 2026). Over 68,000 houses were impacted by power outages (Meunier, 2026). EDF (French electricity producer) was forced to shut down a nuclear reactor and reduce output at two others because of environmental constraints (<i>ibid</i>).

around €38 billion by the 2080s, with the strongest increase expected in the energy and transport sectors (Forzieri *et al.*, 2016). The same study states that adaptation strategies can strongly increase the resilience of critical infrastructure with a total of estimated benefits and avoided damages amounting €100 billion euros by 2040. This would require significant means as the estimated cost of €39 billion, including investments and maintenance and operational costs (Forzieri *et al.*, 2016).

TABLE 2. Consequences per type of actor due to climate change related impacts on critical infrastructure

TYPE OF STAKEHOLDER	HOW THEY ARE AFFECTED
Asset managers	Damage to infrastructure leads to increased costs for maintenance and reparation, loss of revenue and reputational risk.
Operators of service	Disruption in operations (interruptions, delays, reduced quality) creates loss of revenue and reputational risk.
Citizens	Reduced service availability and/or quality, impacts access to critical functions such as transport, electricity, water, etc. It can affect access to healthcare, jobs, reduce safety, etc.
Infrastructure workers	Affects health and security.
Businesses	Impacts access to critical functions such as transport, electricity, water, loss of productivity.
Insurances	Increased damages increase insured losses and repairing costs.
Local authorities	Service in their territory affected, affecting core functions.
Sectoral ministries	Political risk when disruptions are too frequent. Planning and investment pressure.
Finance ministries	Possible budgetary and fiscal impacts to deal with post-disaster needs and reconstruction of infrastructure. Ultimately, effects on economic and financial stability.

1.3. Challenges for the resilience of critical infrastructure

The climate resilience of critical infrastructure faces several challenges, including:

- **Long timeframes.** Critical infrastructures operate for long timeframes. Therefore, investments made today need to account for the climate conditions over more or less distant time scales (up to 80 years for electricity infrastructure for instance). Otherwise, there is a risk that investments or decisions lock infrastructures in trajectories or technology choices that can be unsuitable to future climate conditions, or socioeconomic or demographic conditions that might evolve due to climate impacts and adaptation choices. For instance, the French Transmission System Operator (TSO) RTE published a study “Energy Futures 2050” that analyzes trends in electricity consumption and compares six scenarios that ensure security of supply. The 2026 update shows that investment decisions regarding electricity infrastructure need to account on one side for future impacts of climate change on electricity production, but also on demand which

could be affected by, for instance, higher demand for air conditioning (RTE, 2026). Population centers or types of economic activities could also change as a result of regional adaptation decisions and have an impact on the infrastructure serving them.

- **Mix of public and private interests.** Critical sectors are organized differently depending on countries, but they are mostly characterized by a mix of public and private interests, due to the societal function that these critical services ensure. This translates in the involvement of both public and private stakeholders, as well as a mix of public and private funding and investment, based on various types of arrangements. For instance, companies that operate critical services often have public capital, and are often regulated by public bodies and/or tied to contracts with public authorities. This also requires close cooperation between the public and private sectors and a clear share of roles and responsibilities, as well as efficient collaboration on setting resilience objectives and planning for climate adaptation to make sure that investments are made in the same direction and align with the objectives set.
- **Interdependencies, cascading and compounding risks.** Due to systems’ interdependencies, failures caused by climate impacts in one can cascade to others (EEA, 2024). For instance, climate impacts on energy infrastructure can cause disruptions affecting transport systems, water treatment and supply, etc, even crossing borders to impact all along the supply chain. All crisis response systems also rely on functional telecommunication services, and maintenance depends on the capacity to access damaged infrastructure, for instance through functional roads. These interdependencies require coordination among sectors to plan for their climate resilience, on sharing responsibility, risk management, financing (repairs and investments), and adaptation planning. Due to climate change, projections show that extreme events will also happen closer in time or simultaneously, affecting different countries and parts of the network at the same time and creating compounding risks, impeding the ability of systems to recover quickly.
- **Multiple levels of governance involved.** The European Climate Risk Assessment (EUCRA) (EEA, 2024) acknowledges that risk ownership for critical infrastructure is shared between EU and national levels and recognizes that moderate policy readiness already exists through multiple instruments. Local authorities also play a major role, as they are most often directly contracting with operators in practice and integrate infrastructure within local planning exercises. The climate resilience of this infrastructure and the priorities and decisions made around it directly relate to territorial stakes, such as, which parts of a region will have service restored first in the event of an extreme weather event—and why.
- **Co-benefits that are hard to value.** The resilience of critical infrastructure and the essential services they provide bring benefits not only to the ones who manage them and the ones who operate the service, but also to territories and commu-

nities they serve. They are highly interlinked with these territories, and the collective benefits of resilience measures are therefore difficult to monetize and integrate in economic analysis. This is especially the case in relation to ecosystem-based adaptation and nature-based solutions, which have the potential to support cost-effective and flexible solutions to the resilience of infrastructure services (OECD, 2024) while bringing social and environmental co-benefits.

Yet there are also opportunities. For instance, in parts of Europe, infrastructure networks built after the Second World War are now aging. Planned renewals represent an opportunity to integrate climate resilience by design. The energy transition the EU wants to achieve through electrification, which will require new network development, is a unique opportunity to integrate it in the investments that it will require.

1.4. The current EU frameworks for adaptation and climate resilience

The European Union already has a legislative and policy framework addressing climate adaptation for critical infrastructure composed of several pieces:

- **The 2021 Climate Law** makes adaptation a legal obligation for Member States but does not mention any specific topics or sectors.
- **The 2021 Adaptation strategy.** Infrastructure was mentioned in the 2021 EU Adaptation Strategy (EC, 2021)¹, which aims to promote investment in resilient and climate proof infrastructure, as well as the role of nature-based solutions in infrastructure planning. It also mentions climate proofing guidance for major infrastructure projects developed by the Commission and aims at extending it to other EU funds "with special attention to critical infrastructure", as well as to promote it beyond EU funding.
- **The Critical Entities Resilience (CER) Directive.** Climate risks are explicitly integrated into the CER Directive, which entered into force in 2023. It establishes an overarching framework for resilience against hazards, both natural and man-made. Its scope covers eleven sectors: energy, transportation, banking, financial market infrastructure, health-care, drinking water, wastewater, digital infrastructure, public administration, space, and food production-processing-distribution. As for climate-change related risks, Member States must ensure that critical entities conduct risk assessments, develop and implement resilience plans that include risk reduction and climate adaptation measures, ensure the physical protection of their critical assets or services, respond to incidents including through risk and crisis management, recovery, and business continuity measures, as well as ensure the security and awareness of their employees.

A particular status is designed for "critical entities of European significance", i.e. the critical entities operating in the sectors identified by the CER Directive and in at least six EU Member States. These are subject to additional oversight by the European Commission. The directive addresses diverging national requirements that create varying resilience levels and obstacles to the internal market's proper functioning. However, the directive does not mandate uniform fines or sanctions at EU level, leaving penalties for non-compliance to Member State discretion during national transposition. While most countries have already transposed it into national law, as of September 2026, 5 had published the proposal or are still in the consultation phase—and one had not started the transposition process yet.

- **Financial Sustainability and Reporting Requirements.** The **Taxonomy Regulation (EU 2020/852)** invites transport and energy operators to assess climate risks to be eligible for green investments. A Delegated Act lists the criteria under which an activity can be classified as contributing to adaptation, including the obligation to perform climate risk assessments and implement related adaptation measures. The **Corporate Sustainable Reporting Directive (CSRD)** from 2022 requests that listed companies perform regular assessments of the social and environmental risks they face, as well as the impacts of their activities. The related standards include requirements for climate scenarios analysis and the identification of climate impacts, risks and opportunities (CERAC, 2025).
- **Sector-specific initiatives.** Alongside the CER framework, certain sectors operate under sector-specific legislation that also progressively integrates climate resilience, including through a particular focus on cross-border infrastructure governance. For instance, energy sector regulations referring to climate resilience include the **Energy union strategy** (2015/080), **Regulation on risk preparedness in the electricity sector** (2019/941), the **Energy system integration strategy** (2020/299), and the **Trans-European networks for energy (TEN-E) regulation** (2022/869), which entered into force in June 2022. The latter governs development of new cross-border energy infrastructure in Europe through collaborations to identify and develop "projects of common and mutual interest". It outlines needs to increase EU energy infrastructure resilience, disaster prevention capacity, and preparedness. Transportation follows similar patterns. The **Trans-European Transports networks (TEN-T) regulation** (2024/1679) covers all transport modes subject to growing risks including heatwaves, river floods, wildfires, and coastal floods. A Transport Vulnerability Index reveals vulnerability and preparedness differences substantially between Member States.
- **Guidelines and Standards.** Progress is made toward harmonization across MS and promoted by guidelines. For instance, the **Technical Guidelines on Climate Change Resilience of Infrastructure for 2021–2027** (2021/C373/01) put forward common principles and practices for the identification, classification and management of phys-

¹ https://climate.ec.europa.eu/areas-action/adaptation-and-resilience-climate-change/eu-adaptation-strategy_en

ical climate risks when planning and developing infrastructure projects. This effort is also taking place within specific sectors: for instance, the European Network of Transmission System Operators for Electricity ENTSO-E and Renewable Grids Initiative co-developed a framework with quantitative indicators for climate adaptation and resilience to integrate in the cost-benefit analysis methodologies, integrated into the 2026 ENTSO-E's Ten-Year Network Development Plan (TYNDP) update.

Taken together, these policies suggest that EU policy already provides a starting ground for integrating climate adaptation and resilience into critical infrastructure planning, through a combination of horizontal requirements, sector-specific rules, investment conditions and guidance. The CER Directive is the strongest regulatory pillar as it requires critical entities across eleven sectors to assess risks and implement resilience measures, including climate adaptation, while sectoral legislation adds more specific requirements for resilient infrastructure and cross-border systems. Overall, the EU framework also sets expectations towards Member States for planning for adaptation and resilience, and ensuring continuity of essential services, while leaving significant room for Member States and sectors to determine how these requirements are implemented in practice. However, it lacks an overarching framework to bring these pieces together. Reports from the European Environment Agency (EEA) state that while adaptation policies are making progress across the EU and Member States, implementation remains slow, including due to coordination challenges across governance levels and sectors, unclear risk ownership, and lack of sufficient dedicated resources (EEA).

1.5. The upcoming Integrated Framework on Climate Resilience

In 2024, the European Commission (EC) responded to the EUCRA with a communication on climate risk management that emphasizes the need for transformational change, the avoidance of maladaptation, and the need for systemic and cross-sectoral action. This was followed by the announcement of a European adaptation plan, later named the "Integrated Framework for Climate Resilience" (IFCR) in line with the Commission President's political guidelines published in July 2024. After the Summer of 2026 and temperature records affecting countries and sectors across Europe, this framework got more political attention and was mentioned in the President of the Commission's State of the Union speech in September 2026 to tackle long-term risks through preventive and systemic action. This IFCR was released by the EC on 27 October 2026 with the ambition to integrate the principle of resilience by design across all EU policies, sectors and investments. It includes both a legislative proposal and non-legislative elements (including, digital tools to visualize climate risks and adaptation options, financial and technical support, and measures to increase the mobilization of private finance and the development of innovations).

2. PLANNING FOR THE CLIMATE RESILIENCE OF CRITICAL INFRASTRUCTURE AT MEMBER STATES LEVEL: 5 COUNTRY CASES

The resilience of critical infrastructure is often addressed through national adaptation frameworks (composed of strategies and plans) that set objectives and plan for adaptation measures. In this *Study*, we delve into 5 country cases: Spain, France, Germany, Belgium and the Netherlands. Although all located in Western Europe, these countries were selected because they share common transboundary challenges and yet, are faced with diverse climate impacts and risks affecting critical infrastructure. Their national adaptation frameworks have different approaches and levels of advancement. They are enshrined in diverse governance structures (between centralized and federal States), highlighting a wide range of challenges for the climate resilience of critical infrastructure.

2.1. Critical infrastructure in national adaptation frameworks

National adaptation frameworks all recognize critical infrastructure as a crucial challenge, albeit being addressed differently across the five countries studied. Table 3 presents the general approach to climate adaptation in each of the national frameworks, and how they address critical infrastructure, including the sectors covered, the level of preciseness, and the clarity on the share of responsibilities, objectives and measures.

TABLE 3. Critical infrastructure in national adaptation frameworks across the 5 countries

- NATIONAL ADAPTATION FRAMEWORK
- HOW IT ADDRESSES CRITICAL INFRASTRUCTURE

BELGIUM

● The Belgian federal government published in 2023 the *Mesures fédérales d'adaptation 2023-2026*. It is based on the IPCC's SRES AIB scenarios, transposed at the Belgian territory scale. The federal government and its relevant ministries are in charge of coordinating the implementation of this plan.

The regional governments are also responsible in terms of climate governance and have the power to conduct climate adaptation measures, developed within their own adaptation strategies and plans, without hierarchy between the federal plan and the regional ones.

The Climate and Environmental Risk Assessment Centre (CERAC) published in 2025 Belgium's climate risk assessment, which identifies risks with need for urgent action through a sectoral approach, and assesses political readiness, also considering cascading risks.

● Critical infrastructure is addressed through two sectors: transport and energy. For each, a line of action is proposed, and a timeline of implementation is set. Most measures across sectors are still at an early stage and consist of analysing the sensitivity of the infrastructure and identifying their vulnerability as well as the vulnerability of the service, with the aim to then plan for specific actions and measures for adapting the infrastructure. Measures are spread across different levels of governance, including Federal sectoral ministries, regional, or local authorities, and a few relate to enhancing risk management from the part of service operators or infrastructure managers.

GERMANY

● The German Federal Government published their latest framework for climate adaptation in 2024, *German strategy for Adaptation to Climate Change*. The Strategy is coordinated by the Federal Government, however the states are responsible for many policy areas related to climate adaptation, and hence, for the implementation of specific measures in that regard. The Strategy does not define a climate scenario; however the 2021 German climate impact and risk assessment (KWRA, 2021) was based on RCP 8.5, using the 15th and 85th percentiles to represent weak and strong climate change. The Federal Climate Adaptation Act (KAnG), in force since July 2024, obliges the federal States to adopt adaptation strategies and provides for climate risk analyses and adaptation concepts at local levels, therefore directly allocating responsibilities across governance levels.

● The German strategy addresses the resilience of critical infrastructure mostly within the transport and water sector. The strategy is more advanced for the transport sector, where a few adaptation measures are already identified to ensure security of service and supply, but the focus is mainly on waterways. The water sector is still at an early stage with a focus on improving current knowledge and mapping hazards and risks. The energy sector is left out, as the KWRA 2021 Climate Impact and Risk Assessment for Germany (Kahlenborn *et al.*, 2021) analyzed a low propensity for risk in the medium term. The targets and measures all have a line of action, but no timeline of implementation. Therefore, many targets are addressed and covered by the states' own climate adaptation strategies, programmes of measures etc. In their strategy, the Federal government mentions only the ministries as pilots to the measures they are implementing.

FRANCE

● The French government published their third national adaptation plan in 2025. It is based on a +4°C warming trajectory by the end of the century, which is the reference scenario to be adopted by local authorities and other actors to assess risks and plan for their adaptation. The coordination between adaptation measures is assessed through the central government and coordinated by the relevant ministries within the government. The ministry of the environment, and specifically the DGEC overlooks the national adaptation plan. France uses the TRACC scenarios for adaptation planning.

● The French NAP addresses critical infrastructure through five sectors: water, health, transport, energy, telecommunications, with specific measures including line of action and timeline for implementation. The water and health sectors are still at an early stage, with measures consisting in analysing the impact of climate change on the infrastructure, in order to determine what needs to be prioritized (Water), and the financial needs (Health). Some other sectors are more advanced, with a focus on defining targets for continuity of service for telecommunication networks or ongoing vulnerability studies in the energy and transport sectors and actions already identified and adaptation plans to be established. Each measure designates one or several entities responsible for its implementation, involving sectoral ministries, regional authorities and operators of critical infrastructure.

NETHERLANDS

● The Netherlands published their latest framework, the *National Climate Adaptation Implementation Programme* in 2023. They published in June 2026 a *Draft National Climate Adaptation Strategy 2026*, which revised the one from 2016. The new strategy proposes adaptation pathway maps. The maps are structured trajectories of successive categories of adaptation measures to reduce climate risks (preparation time, sequence, effectiveness and feasibility at different rates of climate change). Each sector has adaptation pathways maps drafted with two categories of measures. Some are intensification measures, meaning measures aimed at continuing within the current scenarios and preserving the current functions and uses. Others are transformative measures which are measures that seek to adapt functions and uses. Adaptation planning is based on four KNMI²³ scenarios which are IPCC scenarios (SSP5-8.5 for the high emissions scenario and SSP1-2.6 for the low emissions scenario, both split under a dry and a wet scenario) translated to the situation in the Netherlands and the Caribbean Netherlands. The coordination of adaptation is done by the central government and specifically the ministry of Infrastructure and Water Management.

The Netherlands also adopts a spatial approach to adaptation planning through the Delta Programme for Spatial Adaptation (Kennispotaal Klimaatadaptatie, n.d.)^a, through which the provinces of the Netherlands oversee spatial planning and implementation of adaptation measures.

● The Netherlands addresses one sector for the resilience of critical infrastructure in its first NAP: transport. Each adaptation measure for the sectors has a defined line of action as well as a timeline for implementation. The measures are specific to waterways and still at the stage of assessing the vulnerabilities and conducting stress tests. In the 2026 Draft National Climate Adaptation Strategy, more sectors are included:

for transport, rail and road are added along waterways and the ICT/telecommunication, energy, and drinking water sectors are also detailed. Categories of measures or adaptation options are proposed for sectors to increase the resilience of their infrastructure. For the transport sector, most of the intensification measures have already been implemented, whereas the transformative policy options are in the deployment phase. For the energy, ICT Telecommunication and water sectors are less advanced and seek to get a better insight into the risks the infrastructure is facing. The draft also assesses the interconnectiveness of critical infrastructure. In the programme, measures are piloted by different levels of governance, some by sectoral ministries, others by provincial, or regional or local authorities. Some measures are also dealt with by operators themselves. Sometimes it is a combination of different levels for a single measure or action.

SPAIN

● The Spanish government published their climate adaptation plan in 2020. The NAP is coordinated by the Ministry of the Ecological Transition and the Demographic Challenge. The sectoral ministries are also in charge of the coordination of the measures in their own sectors. As for Autonomous communities, despite being involved in the plan, they also have, for most, adopted their own adaptation plans, measures and strategies and are in charge of coordinating them. Spain uses the IPCC's RCP4.5 and RCP8.5 climate scenarios for their adaptation planning. In 2025 Spain also published its Risk and Impacts Assessments (OECC, 2025), characterising climate related risks with a sectoral perspective, identifying interconnected risks as well as risk thresholds for key risks. Following the NAP, the Spanish government published two work programmes for the operational planning and programming of adaptation. The first work program is for the period 2021-2025, and the second one 2026-2030.

● The NAP addresses adaptation of critical infrastructures through three specific sectors: transport, energy and water. For each of them, measures are detailed with a specific line of action, but no timeline of implementation.

The three sectors are still at early stages with measures focusing on identifying the risks and vulnerability of the infrastructure. The energy sector already has some measures to increase resilience but not detailed into a line of action. The transport sector also mentions existing infrastructure that they are in the process of identifying the critical sections of the network while identifying the vulnerabilities.

The measures are spread across different levels of governance: national authorities including sectoral ministries, local authorities Autonomous Communities, with, for some measures, a combination of different levels of governance responsible.

a) See <https://klimaatadaptatienederland.nl/en/policy-programmes/national-strategy/delta-programme-spatial-adaptation-dpra/>

Identifying critical infrastructure to adapt, including risks and vulnerabilities

There is a notable adaptation gap between sectors identified as critical—as part of the CER directive and in national security planning—and sectors covered in National Adaptation Plans. NAPs focus almost exclusively on the energy, water (that can cover, depending on the country, water management, drinking water, and wastewater) and transport sectors (with, again, different levels of specificity on the various modes of transport covered). The health and telecommunications sectors are also mentioned but only marginally. Sectors like finance, defence, digital infrastructure, etc. which are assessed as critical infrastructure by most are absent from the measures and action from NAPs in terms of climate adaptation.

National frameworks also often contribute to the identification of vulnerable critical infrastructure by providing a framework, methodology and data to assess climate risks and vulnerabilities, or through national-level assessments. CERAC's Belgium Climate Risk Assessment (2025b) for example aims to evaluate the potential impact of climate risks in Belgium to critical systems and services—public health, food systems, energy and transport infrastructure, etc. Countries commonly establish them based on climate data derived from IPCC scenarios, like Germany, the Netherlands, Belgium or Spain (often including several scenarios, including medium and more adverse such as RCP8.5). The French +4°C warming trajectory (TRACC) reveals a wider approach, as it is not only considered as a tool for national level assessments of future climate hazards, but is also meant to become a common reference for all stakeholders, including infrastructure managers to plan for their adaptation. In this regard, the warming trajectory was incorporated into the Environmental Code in January 2026² to integrate it into all relevant public planning documents, but without making it legally binding. In most countries, actions and measures for the resilience of critical infrastructure are more precise for the energy and transport sector than for other critical sectors.

Setting resilience objectives for critical infrastructure

There are objectives of different nature across countries and sectors (see Table 4).

- **Process objectives**, such as identifying risks through vulnerability assessments and risk mapping, planning for adaptation measures and strategies for the infrastructure or the network (e.g. Spain for transport networks, Netherlands for waterways, France for the transport of infrastructure and services, etc.).
- **Results objectives**, which are often general, framed as “increasing resilience” or “reducing the vulnerability of the infrastructure”.

However, the interviews highlighted that these national frameworks are progressively moving toward more specific and measurable goals:

- Objectives of service continuity, aiming to maintain provision during extreme events and avoid the disruption of services (e.g. France and water supply, the Netherlands and the transport sector).
- Objectives of reducing disruption of services, acknowledging the situation where some disruptions will be unavoidable and the continuity of service would be impossible to maintain (e.g. Germany and the transport sector, the Netherlands and the transport sector, France and telecommunications, etc.). This acknowledgement is slowly coming to the agenda and has been assessed mainly by the transport and telecommunication sector, as these would be more prone to it. However, across countries, thresholds for the acceptable levels of disruptions are not yet clearly defined.

The latter leads to emerging reflections on accepting part of the risk and level of disruption, such as in the Draft National Adaptation Strategy 2026 of the Netherlands, which states that ‘*Climate-resilient does not, however, mean that all risks can be eliminated, but rather that, at any given time, there is a well-considered and optimal mix of: (1) prevention; (2) the ability to manage and accept residual risks, and (3) flexibility for the future*’ (Ministry of Infrastructure and Water Management, 2026). It therefore brings the question of prioritization of infrastructure and investment in terms of climate resilience. Identifying where climate risks are acceptable, e.g. if other networks can ensure the supply, if the disruption is manageable or low effect, or prioritizing depending on the amount of people that could be affected by the disruption. Yet most NAPs still show a lack of prioritization in terms of resilience of infrastructure or a lack of directive on how to prioritize. Objectives of prioritization are not set clearly leaving the decision to the operators themselves. Some countries have started working on those questions: the Netherlands, Spain, France, but they are in the process of identifying methodologies and criteria for this prioritization.

² <https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000053399130>

TABLE 4. Types of objectives set for critical infrastructure in national adaptation frameworks and examples

COUNTRY	SECTOR	OBJECTIVES				
		IDENTIFYING IMPACTS/ VULNERABILITIES	PLANNING FOR ADAPTATION	IMPROVING RESILIENCE	ENSURING CONTINUITY	REDUCING DISRUPTION/ IMPACT
BELGIUM	Transport		Adapt sufficiently to climate change.	Improve the resilience of existing and future infrastructure.		
	Energy			Ensure a robust infrastructure and a resilient system.		
GERMANY	Transport			Make transport systems more resilient to the impacts of climate change.		Reduce susceptibility to disruptions and increasing reliability.
	Water			Strengthen the resilience of the water infrastructure.		
FRANCE	Water				Ensure a sustainable water supply (in terms of quality and quantity).	
	Health		Propose solutions for adapting our healthcare system.			
	Transport	Assess the vulnerability of our transport infrastructure and services...	...in order to draw up adaptation plans.			
	Energy			Ensure the resilience of the energy system as a whole.		
	Telecommunications		Adapt electronic telecommunications networks to climate change...	...strengthen their resilience...		...to minimize the risk of disruption to communication services.
NETHERLANDS	Transport	Get a clear picture of potential scenarios and what this means for design specifications, risk management and maintenance of roads, railways, waterways, airports, seaports (current NAP)	Waterways that can adapt to heat and to high and low water levels (current NAP).	Creating infrastructure networks that are resilient to climate change by 2050 (Draft NAS 2026).	The current level of accessibility and security of supply is maintained in the face of climate change (Draft NAS 2026).	Minimize damage due to heat, flooding and drought (current NAP).
	Energy/ ICT/ Drinking water			Climate resilient and reliably designed critical infrastructure (Draft NAS 2026).	Critical infrastructure remains reliable. Guarantee security of supply (Draft NAS 2026).	Must be resilient to disruptions (Draft NAS 2026).
SPAIN	Transport		Adopt adaptation measures to ensure their availability and operability.	Integrate resilience to climate change into the life cycle of infrastructures.	Adopt adaptation measures to ensure their availability and operability.	
	Energy			Guarantee an energy system that is resilient to the effects of climate change.		

Associated targets and indicators

In most countries, despite the general use of indicators to measure progress towards adaptation and resilience objectives, not all measures related to the adaptation of critical infrastructure are provided with associated targets and indicators. These can be of different levels of preciseness and nature, using either quantitative and qualitative targets and indicators. Most plans use process-oriented targets and indicators, aiming for a completion of risk and vulnerability analysis and an identification of vulnerable critical infrastructure. For targets that relate to adaptation and resilience outcomes, thresholds are increasingly being used to make them more precise: for instance, the *Belgian Federal adaptation measures 2023-2026* sets the target

to "Plan for storms and other extreme weather events: limit train speeds to 80 km/h in areas where wind speeds exceed 100 km/h; and suspend train service where wind speeds exceed 120 km/h".

Means of implementation

The timeline of implementation (start date/end date) is not always mentioned with the line of action depending on the country (see Table 3). Information on funding for the adaptation measures is also lacking across sectors and countries. For many, budgets are still to be defined or rely on regular budgets of the responsible departments (e.g. in the Spanish plan, most lines of action relating to critical infrastructure rely on "Regular budget of the agencies involved"). When a specific

budget is mentioned, there is not always an associated number to support it. For instance, the *Belgian Federal adaptation measures 2023-2026* mentions a budget of €40,000 for the measure relating to the security of energy supply and infrastructure, but regarding transport, only states that “the budget for implementing and monitoring the plans [...] is included in the transportation plan”.

Planning for cross-sectoral and systemic resilience

Cross-sectoral, systemic resilience is an emerging concern, with some of the NAPs or NAS explicitly mentioning as an objective the management of interdependencies and cascading effects from one sector to another—for instance, the Netherlands' *Draft Adaptation Strategy 2026* contains a dedicated part on “The interconnectedness of critical infrastructure”. This is influenced by the CER Directive and its all-hazards approach. Some countries have set different programmes or strategies to take into consideration systemic aspects, often referred to in their NAPs or NAS, e.g. the “Policy Approach to Critical Infrastructure” in the Netherlands which aims to maintain continuous insight into potential threats and foster close cooperation among all relevant parties or the Belgium NCCN's CCIP Programme, with cascading effects taken into consideration, etc. Yet accounting for these dimensions is still at an early stage. Cascading risks and the interconnectedness of sectors are identified and analyzed mostly in national climate risk assessments like the CERAC's BCRA in Belgium (CERAC, 2025) and ERICC-2025 (Evaluación de Riesgos e Impactos derivados del Cambio Climático en España, OECC, 2025) in Spain. However, they are still in the process of being assessed and determined. Further work is still needed to build resilience and answer questions on responsibility, financing, etc. As of now, it rarely translates into precise measures within NAPs.

2.2. Mainstreaming of climate resilience in sectoral and security planning

Beyond national adaptation plans, climate adaptation of critical infrastructure is also mainstreamed in sectoral and security planning at national level. Regarding sectoral planning and strategies, some integrate adaptation measures for their infrastructures. For instance, in Germany, the National Water Strategy (Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, 2023) includes measures for the further development of climate adapted water infrastructure, protection against extreme events and ensuring supply. Similarly, Spain launched the SAFE, Sustainable and Connected *Mobility Strategy 2030* (MITMOS, 2021) with one objective being to ensure an efficient, sustainable and resilient transport logistics system as well as the *Strategic Energy and Climate Framework* (MITERD, 2019) with an axis focusing on adaptation. The German Federal Ministry of Defence also developed a Strategy on Defence and Climate Change which contains a specific field of action on “defence-relevant infrastructure”, including civilian infrastructure of military interest, such as critical infrastructure

for transport, energy grids or telecommunications infrastructure, which “must be available and ready-to-use at all times” (BMVg, 2024). Sectoral planning also integrates crisis management, preparation and prevention, including to climate extreme events. In line with this, climate change is mainstreamed in risk preparedness plans for critical infrastructure in the electricity sectors as required by the EU Regulation 2019/941. In the first version of these documents³, submitted between 2023 and 2022, all five countries integrate climate risks or hazards as part of the scenarios (such as heatwaves, flooding, etc), and have measures to prepare for and manage crises. Most RPPs integrate a dynamic approach to these risks: the German plan mentions ‘changing climatic requirements’ as a reason to adapt installations (Federal Ministry for Economic Affairs and Climate Action, 2022). The French plan defines crisis management thresholds for three climate hazards (heatwave, drought and fires) for crisis management measures, and prevention measures that include adaptation of the grid (Ministry of Ecological Transition, 2022). As the directive requires Member States to update these plans every three years, all five countries are expected to revise them this year.

The mainstreaming of climate risks and adaptation consideration also results in practical implications within sectors such as the inclusion of climate-proofing in environmental impact assessment, in line with EU requirements (EC, 2021b). For this, several Member States have developed tools, reporting mechanisms, methodologies and guidelines to support and/or harmonize this exercise (EEA, 2026). Although not mandatory, France, the Netherlands and Spain are even integrating it in strategic environmental assessments (*ibid*). These are serving as tools to evaluate the impacts of public plans and programmes including for critical sectors such as transport, energy or waste management—showing a more strategic approach to resilience planning at territorial level.

Overall, the sectoral mainstreaming of climate resilience is progressing, with a focus on identifying climate risks and planning for preparedness and crisis management, as well as identifying cascading effects—especially through the system-level approach to resilience introduced by the CER Directive and its transposition within Member States. However, sectoral planning is still underused as a lever for planning for ex-ante adaptation and resilience by design to long term climate risks.

Often in national legislation, the protection of critical infrastructure is coordinated and supervised by specific bodies within the Ministry of Interior. They work with critical operators on resilience planning but for long, have emphasized terrorist and cyber threats before climate risks. The CER Directive, with its all-hazards approach, strengthens the integration of climate change into resilience objectives. Risk assessments are becoming an emerging obligation under the frame of the CER directive and its transposition (Member States had to transpose it into

³ https://energy.ec.europa.eu/topics/energy-security/security-electricity-supply/risk-preparedness-plans-electricity-sector-national-competent-authorities-and-commissions-opinions_en

national law by October 2024). Under the CER Directive, risk assessment must be conducted every four years by all the critical entities identified and operators are charged with the elaboration of resilience plans for their infrastructures. As required by the directive, specific bodies are identified or created in countries to be in charge of the security of critical infrastructure and services. All five countries had pre-existing organizations within their Ministry of Interior: the Critical Infrastructure Protection National Centre (CNPIC) in Spain, the Secretariat-General for National Defence and Security (SGDSN) in France, National Coordinator for Security and Counterterrorism (NCTV) in the Netherlands, the Federal Ministry of Interior (BMI) in Germany and the National Crisis Center (NCCN) in Belgium, all acting in coordination with sectoral authorities.

Yet, as of June 2026, the CER Directive is not yet fully transposed across EU countries covered in this *Study* (see Table 5). The approaches adopted by countries show a common trend toward strengthening enforcement mechanisms (inspections, reporting, mandatory corrective measures, and in Belgium's case, criminal sanctions). With the transposition of the directive, most countries are moving from an approach centered on "asset resilience" toward service continuity and system resilience. For climate resilience, this opens the door to a better consideration of cascading risks, where the protection of individual assets is insufficient without ensuring the broader service remains operational.

TABLE 5. Status of the transposition of the CER directive (adapted from Cyber Risk GmbH⁴).

COUNTRY	STATUS	APPROACH
FRANCE	Implemented <i>via</i> amendments to the <i>Code de la sécurité intérieure</i> . Extends the existing system for "operators of vital importance."	Shifts towards a resilience-oriented model while preserving institutional structures. Focuses on ensuring service availability under significant disruption rather than just asset protection.
GERMANY	Umbrella Act for Critical Infrastructure Protection (KRITIS) passed in 2026. Includes an evaluation cycle every two years.	Broadening from specific asset protection to a comprehensive service continuity regime. Includes specific transparency obligations within the KRITIS Resilience Strategy.
SPAIN	Draft Law approved March 2026, currently negotiating in the Congress of Deputies. Not yet fully transposed.	Major transition from an asset-centered regime (<i>Ley 8/2011</i>) to an entity-resilience and service continuity regime. Applies to both public and private entities.
BELGIUM	Act published in <i>Belgisch Staatsblad</i> (Jan 2026), based on the law of Dec 2025.	Significant restructuring shifting focus from protecting specific physical assets to systemic resilience and managing cross-sector dependencies.
NETHERLANDS	The <i>Wet weerbaarheid kritieke entiteiten</i> (Critical Entities Resilience Act) has completed the full legislative cycle and entered into force in August 2026.	Approach was to create a new horizontal legal framework for the transposition. It imposes a direct obligation on entities to adopt proportionate technical and organizational security measures, and obligation to report on disruptions.

⁴ <https://www.critical-entities-resilience-directive.com/Transposition/>

3. DISTRIBUTION OF ROLES AND RESPONSIBILITIES AROUND CLIMATE RESILIENCE IN PRACTICE: FOCUS ON 2 SECTORS

3.1. Case study 1: Electricity infrastructure

Electricity infrastructure and services are the backbone of many systems. They are also central to Europe's electrification—an essential pillar to meet strategic autonomy and climate mitigation goals—which entails a major expansion and transformation of energy infrastructure, as for security and autonomy. Given the long lifetimes of these investments, infrastructure developed today will need to be resilient to future climate conditions and able to support the energy transition over the coming decades. This makes their resilience central to support economic, social and critical services.

Climate change has several impacts on electricity infrastructure. Regarding electricity networks, it can affect both the transmission and distribution (IEA, 2021). For transmission, the vulnerability of the high and medium voltage transmission network to heatwaves is mainly linked to overhead lines, which expand under the effect of heat and may come closer to the ground. Overhead lines and pylones are also at risk of storms and strong winds. Flooding is also a major risk for substations.

Beyond the network, climate change also has broader impacts, including on production infrastructure as well as generation, as rising temperature and heat stress can decrease the electricity generation capacity of power plants (e.g. thermal and nuclear power plants), droughts and water stress can affect hydropower production and rising sea levels as well as flooding put at risks power plants located along coasts or riverbeds (Carlin & Arshad, 2024). It also impacts demand and consumption with higher need for cooling during heatwaves for instance. These effects also need to be considered when designing resilient infrastructure.

How operators account for climate resilience

Responsibilities around the climate resilience of electricity infrastructure are spread across different stakeholders. The CER Directive enforces on Member States to take specific measures and elaborate a national strategy to ensure the resilience of essential services to the functioning of society and hence supervise the resilience planning of entities in the sector.

In most of the countries explored, a single TSO is responsible for managing the majority of the national electricity transmission network, and hence, for ensuring its climate resilience (except in the case of Germany where the transmission network is organized at regional level)—while the distribution system is the responsibility of a larger number of Distribution System Operators (DSOs). Operators are in charge of analysing the risks and vulnerabilities of their infrastructure and network and subsequently planning for the climate resilience of their infrastructure,

existing and new. This is set in the CER Directive and can also be a requirement in the form of a national mandate—either as a legal obligation or requested by governments in national adaptation plans (e.g. France). The need for a climate risk and vulnerability analysis of the network can also be mandated by investors or insurers in the requirement for financing new projects for infrastructure. Across the countries studied, few operators have completed assessments of all risks and vulnerabilities with associated costs for adaptation. Operators tend to start their risk analysis on the weather events they are most likely to experience (flood-focused in Belgium and the Netherlands or Germany, wind-focused for Spain, etc.). Some operators build their risk analysis based on different scenarios for different time horizons (short term, medium term, long term). Overall, operators are considering several scenarios including the most adverse ones such as the RCP8.5, at least for stress-testing. For most operators, climate resilience is integrated in business continuity and contingency planning, risk management procedures and plans—for instance, the Belgian TSO Elia, also active in Northern Germany, integrates extreme weather events as part of regional crisis scenarios tested for both assets and business continuity (Elia Group, 2025). Less frequently, it also starts to be integrated in network development and investment planning, as in the French TSO RTE's 2025 network development plan. Regardless of that, all operators already implement climate adaptation measures, for instance through reviewing standards for new infrastructure projects or renewal (for instance, so that overhead cables can withstand stronger winds), maintenance and repair work, in reaction to current or future anticipated climate impacts.

The role of public authorities

Public authorities possess a strong lever to act on the electricity sector, as regulators, and can therefore act on the integration of climate resilience in energy planning—beyond solely estimating impacts of climate change on the sector and identifying potential solutions to promote. Operators act under the supervision of regulatory bodies (which are mainly national or federal for TSOs and can be national or regional for DSOs). They commonly set targets and performance indicators relating to the quality and continuity of supply, such as frequency or average interruption time, defined thresholds for restoration time, etc. Indicators are often tracked under normal conditions (excluding extreme climate events), however while their frequency increases, this raises questions about the relevance of these exemptions if this becomes the norm—especially for DSOs. Regulators also validate investment strategies, with a core mission to arbitrate between different objectives, including affordability, development and modernization of the network. Climate resilience is starting to gain importance among these objectives, although the level of awareness is heterogeneous from one country to another, with few incentives coming from the European scale to consider climate protection as a major objective of network regulation (EESC, 2022). Yet there are some signs of progress in the integration of climate resilience in regulators' missions: the Royal Decree of 22 April 2019 and the Ministerial decrees

on load-shedding in Belgium further strengthened operational resilience by codifying procedures for managing stress in the grids (CERAC, 2025).

Financing climate resilience

The responsibility to invest in and finance adaptation measures mostly comes back to the operators through their regular budget, mostly based on revenue from consumer tariffs, set by the national regulators. Most electricity operators are either fully (e.g. the TSO Tennet in the Netherlands, or the DSO Enedis in France) or partly state-owned (e.g. Redeia in Spain), hence depending on government budgets. Across the countries studied, there is often no dedicated budget line allocated to climate adaptation and it is usually integrated into other project funding. In the case of repairing assets degraded by climate events, the costs are often covered by the maintenance and repair funding in the operators' budget, not a specific adaptation fund. Rebuilding and reparation of assets are often mentioned by operators as an opportunity to 'build back better' and integrate climate-proofing, even though this is tied to available budgets. Although this concept is more anchored in discussions related to housing insurance as a way to incentivize or constrain insurance players to finance resilient rebuilding after damages, it is a growing concern for critical infrastructure as well (Der Sarkissian *et al.*, 2023).

In case of major destruction, regulations can include mechanisms to adjust the difference between projected expenses and revenues and those actually recorded, thereby covering losses for distribution operators above a certain amount (e.g. the CRCP mechanism in France).

Other operators integrate adaptation costs in broader management, improvement, and renewing plans without allocating funds specifically for adaptation. Some regulators also have a role and a say in the financing of adaptation measures as they are setting the tariffs. However, infrastructure planning and climate adaptation are often spread across different ministries, which can create difficulties for the operator to integrate the costs of climate resilience into infrastructure planning.

Prioritizing infrastructure for climate resilience

One of the main challenges is to arbitrate between the level of investments needed versus prioritization to renew and make the network resilient. When climate resilience is not part of an explicit mandate, operators highlight the need for greater public support in order to integrate these reflexions—in the form of retributions to support investment, but also legitimization of decisions and priorities.

In order to prioritize infrastructure resilience and adaptation investments, some TSOs are beginning to integrate into their various investment scenarios, adaptation options. These are based on vulnerability analyses to maintain their level of performance while taking into account financial constraints, for example through proposals for prioritizing resilience measures. Common criteria are emerging among TSOs for this prioritization: for instance, RTE's 2025 ten-year network development plan aligns investments with the planned renewal cycles of aging

infrastructure, and is therefore adopting a phase approach, aiming to make 80% of its infrastructure resilient by 2040 (RTE, 2025a). This represents €94 billion, funded by the Public Electricity Network Usage Charge (consumers' bills) and phased over several years (Brachet, 2026). RTE prioritizes its most critical assets in terms of age, capacity to resist and recover from the changing climate, prone to multiple climate risks. For other operators, it is difficult to have an actual view on which assets to prioritize as most of them are still in the process of identifying the risks and the vulnerabilities of their networks. The responsibility of prioritizing is not yet completely defined either, despite coming back to the operators as they handle the network and the risk analysis. The governments through their national strategies have a role in guiding the prioritization according to the CER Directive.

3.2. Case study 2: Railway transport infrastructure

Transport infrastructure, including rail, are also part of national services that are highly interconnected with other systems (electricity, telecommunications), productive sectors (through freight) and households (mobility and accessibility services). Its vulnerability to climate impacts is widely recognized across national climate risks assessments and plans, with several impacts on:

- rail infrastructure networks, affected by high temperatures, floods, landslides, trees falling on railways;
- the rolling material, e.g. through increasing temperatures;
- sites and buildings, which can be affected by heatwaves (with impacts on comfort and health), flooding, etc.

Climate impacts affect the infrastructures themselves, but also have repercussions on the service they deliver, with consequences on the level and quality of service: increasing delays because of extreme events like wildfires or storms or cancellations, passengers' comfort during heatwaves, as well as on working conditions and security for workers.

How infrastructure managers and operators account for climate resilience

These various elements are integrated in infrastructure managers' and service operators' planning. Indeed, the CER Directive also applies to the sector, giving a framework for Member States to set the responsibility to entities managing and operating railway transport systems to assess climate risks and plan for their climate resilience. Although not all have a dedicated adaptation strategy or plan, they all tackle climate resilience under different forms:

- All undergo climate risk and vulnerability assessment, either on all or on the most critical parts of their infrastructure and operations.
- Some have pre-existing plans in the form of heatwave plans, winter plans, plans for exceptional circumstances that integrate climate adaptation.
- Some have specific adaptation strategies and plans, which can be at infrastructure/network level, and/or at system

level when the infrastructure manager and service operator are integrated in the same group (e.g. SNCF Group in France plans for its adaptation at group level covering the seven branches, including SNCF Réseau, the infrastructure manager, and SNCF Voyageurs and SNCF Gares & Connexions, the service operators). In all cases, infrastructure managers and service operators closely cooperate to harmonize data, share risk analysis and response measures.

- Even in the absence of a dedicated adaptation plan made by the operator (at the level of the organization or for the network), all the operators and infrastructure managers take adaptation measures that can include:
 - Integrating climate resilience in contingency planning and crisis management, with thresholds based on weather warnings for instance;
 - Operations and maintenance, such as temporary speed limitations, suspension of services in the event of a storm, or managing vegetation around tracks, increasing surveillance, etc.;
 - Integrating new standards (e.g. temperature standards for tracks) in the renewal of assets.

Overall, the level of advancement varies across infrastructure operators. Some are still assessing their overall vulnerabilities and others have already started adaptation planning and elaborating the related costs. Some are starting to figure out how to prioritize their infrastructure and define the level of acceptance.

Most operators consider a combination of different scenarios for different time horizons, often including RPC8.5 scenarios to assess their risks or to stress-test their infrastructures. This is often based on IPCC or national models and/or the operators' own downscaled data and hence, with diverging downscaling methods and type of information used from one operator to the other. This results in adaptation measures that are not always labelled as such, but most often consisting in a mix of maintenance strategies and measures, operational measures, system level measures and strategies.

The role of public authorities

Public authorities and ministries are working in close relation with operators. In most of the countries, transport operators have management and performance contracts as well as business plans with the States laying down the basis for the level of service expected of them as well as the budget. Some of these contracts can explicitly integrate obligations on climate resilience, such as integrating it in business plans. Public authorities are usually in charge of supervising adaptation progress monitoring from operators, although the frequency of this reporting varies (every year in Belgium, four times a year in the Netherlands). Ensuring that climate resilience is in progression can be done through its inscription in business plans. Often, ministries can sanction operators if they lack adaptation strategies.

In some countries, regional bodies or governments can share part of the responsibility as some part of the networks or services fall under their jurisdiction. In the case of Belgium, the difficulty

of adaptation can increase because of the different level of governance in the country. The federal government is considered as equal to regional governments. Operators are subject to regional regulations, and adaptation strategies can differ across regions therefore one operator, operating across the different regions, needs to adapt its own plans to the regional regulations. In the Netherlands, some local governments have their own contracts with operators. In terms of financing, the local government also has a say on the prioritization and the adaptation measures undertaken as a paying entity. Sometimes multi-level coordination is needed as the train stations are owned between different levels of governance (operator, regional and national, e.g. platforms owned by states and managed by operators, station building owned by operators and surrounding area owned by local government). Therefore, the responsibility of climate resilience is shared by those different levels, and they must coordinate on the planning and prioritization.

Accepting part of the risk is an emerging discussion as operators come to accept the impossibility of adapting the whole network, whether in terms of timing or financing. However, in many countries the level of acceptance is not clearly defined. That responsibility comes back to governments as they define the level of service expected in performance contracts. However, for now those do not include a climate variable. Some governments are in the process of defining them, e.g. the Netherlands' Ministry of Infrastructure and Water Management works in close relation with ProRail in defining the level of acceptance of the risks. Other operators chose to set the level of acceptance at the same level as the level of service instructed by the governments (SNCF, SNCB) at least for now. However, there are growing discussions in re-evaluating them to include the climate risk variable. Not achieving the level of service required is a risk for operators, both regarding financial compensation, sales and reputational. This provides a further incentive to adapt to be able to maintain that level in the case where it won't be re-evaluated with the evolving climate conditions. The acceptability of a risk is also determined in relation to the criticality of the infrastructure or of the section therefore it is closely linked to prioritization.

Prioritizing resilient infrastructure

Railway infrastructure managers, operators and governments share responsibility for prioritizing climate resilience measures. They usually collaborate on this, infrastructure managers often providing the information about the vulnerable sections, the risks, the possibility of occurrence etc. and the government in the role of the decision maker in terms of what is to prioritize. Despite not being clearly defined and set out in regulations or in the contracts, it is often expected for the government to have the final decision in that regard. Operators differ in their process to prioritize. In Belgium, priority is given to what cannot be backed up in case of failure. For France, prioritization has not been decided because of a need for a global vision on all networks and the places at highest risk. In the Netherlands, prioritization is in discussion between the States and operators. In Spain, Adif and Adif Alta Velocidad assess climate risks across

the railway network that they manage and identify those that require action. Based on these assessments, they define structural, non-structural and risk management measures aimed at reducing climate-related risks. They are working on prioritizing these measures considering not only severity and short-term risks, but also different time horizons, adaptation needs and resilience objectives across the lifecycle of infrastructure assets.

Financing climate resilience

In terms of funding and financing adaptation, the responsibility across the countries is often of the State as it is the main provider regarding the financing of the operators and their network or services. For the majority, the money allocated for adaptation is integrated in investment plans or usual budgets for operation and maintenance and does not constitute a dedicated budget line. However, it is beginning to be explicitly mentioned in new investments plans: the performance agreement between SNCF Réseau and the French government, currently under discussion, calls for a 50% increase in annual investments dedicated to the renewal and modernization of the national rail network, with adaptation to climate change as one of its objectives. The additional funding would come from a fund financed by SNCF's profits, financial aid intended to encourage energy savings from European funds, and private investors.

The capacity to invest in adaptation generally relies on usual budgets which depend on specific national arrangements, relying either on managers' budgets including usage fees to service and infrastructure operators or, in some cases, supported by government budget when infrastructure maintenance and renewal is covered by public funds (e.g. in the Netherlands). Mostly, private actors have not yet calculated adaptation costs, made a budget demand or have a detailed investment plan for adaptation. Across countries, investment schemes differ. While some infrastructure managers invest with core funding, in other countries, investments are made with the general budget or with public support programs. This is the case in the Netherlands, or in Germany where investment in modernization and renewal of the network is partially supported by the government through regular funding, but can also be covered by specific funds, such as the €500 billion infrastructure fund announced in 2025—which, however, does not explicitly mention climate resilience among the objectives (Amelang, 2025). In some cases, the state also works as the insurer and covers the fees to repair the damage caused by climate events.

Railway network infrastructure resilience is also largely financed through European funding. Funding mechanisms for infrastructure projects such as JASPERS, funded by the European Commission and the European Investment Bank, integrate climate resilience in their requirements (EIB, 2024). Hence, providing an incentive to analyse vulnerabilities and plan for the resilience of the network as well as figuring a methodology that can then be replicated to other parts of the network or infrastructure.

4. CROSS-CUTTING LEARNINGS

4.1. Learning 1. Managing interdependencies: how operators cooperate across sectors

Addressing complex interdependencies between critical infrastructure systems ranges from top-down regulatory coordination to map systemic risks, to bottom-up operational collaboration. Across the EU member states studied, governments are increasingly structuring the participation of private operators in adaptation planning, moving beyond isolated asset protection toward a holistic view of service continuity.

System-level analysis. Some governments are testing new approaches to assess system-level risks and map interdependencies. A notable example is ERICC-2025 (OECC, 2025), a national level report to assess climate risks across the country which provides executive frameworks for analyzing complex risks that span multiple subsystems.

Government-led dialogues. National authorities are progressively institutionalizing cross-sectoral dialogues, either in general on resilience by leveraging the transposition of the CER Directive to understand how disruptions cascade across sectors, or on climate adaptation in particular.

- In Germany, KRITIS serves as an example of government-organized transversal coordination. Under the act, the State fosters structured working groups where operators exchange practices on managing cross-sector dependencies bringing together entities from energy, transport, finance, and IT.
- France is adopting an approach that focuses more specifically on climate adaptation. Under its third national adaptation plan released in 2025, it has initiated specific sectoral dialogues. For instance, the Directorate General for Infrastructure, Transportation, and Mobility (DGITM) recently launched a dedicated working group comprising infrastructure network operators to exchange on methodologies and approaches to assess climate risks and implement adaptation within the sector while identifying interdependencies and cascading risks.

Operators-led initiatives. In addition to these, operators are often developing practical mechanisms and collaborations to exchange on and manage interdependencies, frequently going beyond these frameworks:

- **Evolving collaboration through existing channels to include climate change.** Interviews showed that across countries, collaboration across operators within existing formal channels is evolving to include cooperation on climate risk analyses and adaptation strategies. For instance, in the electricity sector, the traditional cooperation between TSOs and DSOs is expanding on this topic (DSO Entity, 2026).
- **Collaboration through informal transversal groups.** In France, beyond official working groups, informal collaborations between critical network and service operators (spanning transport, energy, and communications) have emerged to facilitate the rapid exchange of intelligence and joint simulation exercises. This allows operators to exchange on methodologies and think jointly about adaptation measures beyond national requirements.

Therefore, the question of interdependencies towards climate risks and cascading climate effects across critical infrastructure is still quite recent, but progressively gaining importance. While governments often provide a generic structure for dialogue and risk identification, operators also collaborate in practice on more technical aspects through both established channels and the creation of specific informal networks.

4.2. Learning 2. Managing cross-border risks: how operators cooperate across countries

While the EU has established mechanisms to coordinate efforts across Member States around cross-border risks, the practical implementation reveals a gap in national-level operational realities, particularly when it comes to assigning responsibility for transboundary effects.

The EU legislation increasingly tackles cross-border risks, particularly focusing on interconnections to enable flows across borders—it can therefore create vulnerability and cascading failures. TEN-E, TEN-T, are critical entities of European importance in the CER directive. This leads to the progressive institutionalization of coordination efforts at EU level, for instance through the European Network of Transmission System Operators for Electricity's (ENTSO-E) work on climate resilience. Similarly, following a request from the European Commission, the European Union Agency for Railways published a report in 2026 on Rail Resilience to Climate Change which addresses, among other topics, interoperability coordination for crisis management against extreme events and cross border mechanisms (ERA, 2026). Emergency response services from Member States are also communicating and coordinating across borders when events occur *via* networks like the EU Civil Protection Mechanism.

EU-funding mechanisms further reinforce this coordination, providing financial incentives for resilience planning when funding cross-border projects. However, these initiatives tend to concentrate on interdependencies and forms of vulnerability that are quantifiable and focus less on other factors of vulnerability such as inadequate governance or lack of emergency response coordination.

Operators' awareness yet remains insufficient and heterogeneous. Despite the availability of EU-level frameworks, interviews conducted as part of the study suggested that infrastructure operators still marginally integrate cross-border risks and their potential consequences. This is confirmed by a limited emphasis on the external dimension of climate risks in operators' climate resilience plans and strategies. Many private operators still frame their risk assessments primarily within national boundaries, as a first essential step before enlarging the scope. This creates blind spots as they may not adequately account for vulnerabilities coming from neighboring systems upon which they depend.

National framework limitations: Most national frameworks lack to integrate cross-border risks in their resilience planning. Hence, the EUCRA highlights that operational

responsibility for managing transboundary risks still remains fragmented (EEA, 2024a). Countries such as the Netherlands and Belgium are starting to explicitly identify cross-border risks and interdependencies between neighboring states as a challenge in their strategic documents. However, neither of them has established concrete responsibility mechanisms to address these risks. Others such as France and Germany lack dedicated transboundary responsibility mechanisms. Their structured partnerships between the State and operators focus primarily on national continuity. Overall, frameworks do not clarify accountability when climate impacts generate cross-border failures.

Further research into operator-level practices and bilateral agreements between Member States would help assess the extent of informal or local level coordination. For instance, following severe climate events, the idea of establishing cost-sharing arrangements for cross-border resilience seems to emerge among operators and policy makers, especially through decentralized cooperations. This is the case for three neighboring provinces in the Netherlands, Belgium and Germany following the 2021 floods in the region (provinces Of Limburg, Brabant and Gueldre) (Province of Limburg, 2021).

4.3. Learning 3. A mix of responses: from adapting the asset or the system to transforming it

National and operators' plans and interviews revealed many ways in which critical infrastructures, and the services they support, can become more adapted to climate change, which reflect diverse political and economic choices and can be explained by different governance structures across countries. However, clarity on the interaction between these approaches is needed to develop coherent adaptation trajectories. They include:

- **Maintenance and repair** after climate-related damage.
- **Protection measures** around infrastructure, such as building dikes to protect infrastructure, or maintenance of embankments along the tracks, vegetation management along infrastructure routes and, to a lesser extent, more territorial/collective ecosystem-based protection measures such as floodplain restoration, for which co-benefits are harder to monetize (EEA, 2021).
- **Rebuilding and reconstruction**, including seizing planned intervention opportunities to incorporate adaptive measures or resize infrastructure (for instance, with more resilient material or higher standards, such as temperature standards for rail infrastructure).
- **Planning for redundancy**. Anticipating temporary infrastructure failure while ensuring service delivery through backup routes or systems.
- **Operational adaptation and management**. Optimizing how existing capacity is deployed, adjusting operations (e.g., modify schedules, routes, or reduce speed for transport, use other transmission routes for electricity).
- **Relocation of infrastructure**. Selecting less vulnerable sites for new infrastructure or relocating existing assets (as in Dutch water management strategy).

- **Intermodality and cross-system planning**. Coordinating across infrastructure types to identify alternatives when one system fails.

Organized together, they show various approaches that can be categorized along a spectrum from asset-centered hardening to system-level resilience planning (and are often combined in practice):

- **Asset-centered resilience**: Most current adaptation strategies focus primarily on the hardening and resilience of physical assets themselves. It requires more upstream investments, including for upfront rebuilding and reconstruction to prevent damages.
- **System-level resilience** is emerging following the CER Directive, shifting focus from the resilience of infrastructure to the resilience of the service it delivers. Under this paradigm, infrastructure may be temporarily unusable while sustaining minimal damage, but service continuity is maintained through alternative means.
- **Transformative approaches** can be complementary to the two above as they rely on anticipating and accompanying shifts, for instance in uses, locations, etc. This can include accepting to abandon some infrastructure or accepting a part of malfunctioning (and hence, service discontinuity) under specifically pre-determined conditions. For instance, the 2024 Adaptation strategy of the French SNCF Réseau recognizes that "looking ahead, achieving absolute resilience—aimed at maintaining 100% of current functionality—seems difficult to achieve, both technically and financially". These transformative approaches are still marginal and, when mentioned in plans, are only considered for long term horizons like the Netherlands' adaptation pathway strategy for the transport sector (Ministry of Infrastructure and Water Management, 2026)—while also representing a reputational risk for operators. They also involve carrying out parallel work on the conditions for social acceptance and changes in behaviour.

4.4. Learning 4. Trade-offs in decision-making

Different adaptation measures intervene at different points in the causal chain from climate hazard to service disruption. Therefore, choosing between them is not merely a technical question of how to protect an asset; it reflects different assumptions about what needs to be made resilient—an asset, a system, or the service—and about what levels of disruption and transformation are acceptable. Hence, this reveals several trade-offs:

- **Costs and investment levels**. Adaptation choices reflect financial calculations between increasing maintenance/repair costs versus high upfront costs for renewal, and between capital expenditure and operational expenditure. These choices are influenced by financial capacity and financing models, from privately financed adaptation by operators' budgets, which ultimately raises affordability questions when investment costs are passed, to customers

through higher service rates, to public support through national funds (financed through taxes for instance).

- **Thresholds for acceptable risks and level of accepted discontinuity.** This tension raises fundamental questions about acceptable thresholds for risks and service interruption that are often implicitly resolved in security and contingency planning, but that national regulators have yet to define clearly under a changing climate. For instance, discontinuity of service is rarely mentioned in strategic documents—or treated as a last resort option and primarily for the transport sector. It seems less conceivable for the energy sector, despite growing evidence of service interruptions due to climate impacts (see Table 1).
- **Priority-setting criteria.** Under constrained financial capacity, determining priorities to increase resilience within the infrastructure network is necessary. Criteria can include: economic viability (e.g. number of users served, economic activity supported); geopolitical/commercial importance (e.g. criticality for transboundary networks as part of CER requirements, level of importance for security concerns and military corridors); or maintaining public good function and considering social vulnerability (e.g. ensuring service delivery to remote areas with few alternatives even when economic rationale is weak). As of today, most countries studied do not yet have a comprehensive vision of priority networks for climate resilience at national/government level within a specific national inventory and mostly rely on operators to prioritize infrastructure in the face of climate change. However, this is beginning to emerge as a future avenue for further work between the state and operators, and national-level climate risk assessments for critical infrastructure start to be undertaken as a first step. For instance, in the Netherlands as part of the upcoming National Adaptation Strategy a prioritization exercise has been launched by the Ministry in collaboration with operators, reflecting greater public oversight of these strategic decisions (develop). In Belgium, the Belgian National Risk Assessment (BNRA) led every three years by the National Crisis Center is assessing various scenarios of different kinds and their possible consequences and impacts (economic, social, casualties, etc.), including those relating to climate risks, on the basis of the data and analyses provided by CERAC. This serves as a basis for informing sectoral and sub-sectoral analysis within the framework of the CER, in collaboration with sectoral authorities.

These trade-offs are often rendered invisible by the decision-making structure: rather than being explicitly deliberated, they are implicitly resolved according to the mandate, responsibilities, priorities and time horizons of the decision-making stakeholders. This can lead to potentially overlooking implications that would become visible from a broader system or societal perspective.

4.5. Learning 5: The emerging issue of residual risks: cost-sharing mechanisms and accountability

Who pays for residual risks and recovery?

Beyond hardening, protecting infrastructure and ensuring continuity of service, a remaining challenge is about how to pay for reparations. This is essential to think of cost sharing mechanisms for increasing resilience: as climate risks increase due to a changing climate, risks and costs-bearers are increasingly finding themselves in a position where they want to limit these costs by planning ahead for resilience. Several types of actors can usually be involved:

- **Insurance companies.** Insurance policies include the coverage of physical assets (like substations and transmission lines) against natural disasters, but often private insurers are unwilling to insure large infrastructure because of the high costs (Lonergan *et al.*, 2023).
- **Infrastructure asset managers** through day-to-day maintenance and reparations. Moreover, asset owners are most of the time self-insured in the case of large assets. As of today, according to operators, the capacity to cover repair and maintenance costs to critical infrastructure against climate impacts does not seem to be a challenge for them—however, this also relies on the capacity of public budgets to absorb part of the costs due to extreme events.
- **Public stakeholders.** Countries also have public mechanisms in place in the case of extreme events, especially for publicly-owned companies and infrastructure, and when costs exceed the financial capacity of asset managers. This adds up to EU mechanisms such as the EU Solidarity Fund (EUSF), established after the 2002 floods in central Europe, to provide support for emergency action and reconstruction to affected Member States in the face of major natural disasters when damages are over 0.6% of GNI or 1.5% of the GDP of the affected region, including for critical infrastructure (Radu, 2021).

Responsibility and accountability mechanisms

Accountability frameworks for climate impacts affecting the continuity of critical infrastructure and services are still unclear. Across the EU, the CER Directive does not provide for uniform fines or sanctions at the EU level, therefore it is up to Member States to determine sanctions for non-compliance when they transpose the directive into their national law. However, interviews showed that across countries, there is no clear legal responsibility if the “resilience” is not met because of climate impacts. Yet, through performance contracts, financial payments or public contributions, operators are bound by annual targets and performance indicators which they are compelled to account for. For instance, the German LuFV with the Deutsche Bahn states that “if the contractually agreed targets in the LuFV are missed, the federal government can reclaim its infrastructure contribution in whole or in part” (EBA, 2026).

As a result, through the interviews, some operators were starting to question the implications of climate impacts and their

potential accountability and liability, either as a legal obligation or moral commitment to compensate. It specifically applied in the case of a discontinuity of service, hence questioning to what extent this also reshapes the objectives that they must achieve as part of their agreements with public authorities. Some countries already have mechanisms that explicitly mention this scenario. In France for instance, since 2021, in the event of a natural disaster (recognized by public authorities), unplanned electricity disruption lasting more than 5 consecutive hours open the right to compensation, paid by the electricity operator (DSO) via the energy supplier, through consumers' bills (CRE, 2021).⁵ In many other countries, extreme weather events and natural disasters are typically part of what is considered as 'force majeure' events, i.e. beyond the control of the utility, and therefore excluded from compensations for disruptions. In the Netherlands, a public mechanism, Disaster Damage Compensation Act (*Wet tegemoetkoming schade bij rampen*, WTS),⁶ is in place to compensate individuals for physical damage from uninsurable and unavoidable risks (e.g. against floods from the sea, rivers, large lakes; including damage to public infrastructure). It is funded by public resources.

5. CONCLUSIONS AND RECOMMENDATIONS

The case studies explored in the previous sections show a variety of practices to set and implement adaptation objectives and integrate them in planning across public authorities and operators, that are enshrined in national contexts and governance structures. They provide a good basis for exchange across countries.

Despite differences, the electricity and railway case studies reveal common drivers across the five countries under study for operators faced with similar gaps to integrate climate adaptation and resilience in their practices. Hence, a possible twofold role for the upcoming EU framework on climate resilience: 1) to support the exchange of practices across countries, and 2) to help address these gaps, both by supporting MS planning efforts and by ensuring the right enabling functions at the EU scale.

5.1. Drivers to integrate climate adaptation and resilience

The sectoral case studies and the interviews underpinning this work show that there are several drivers for operators to account for the climate resilience of critical infrastructure. These drivers

can relate to public policies, precede them or lead operators to go beyond requirements. They include:

1. **Perception of climate risks and willingness to act** owing to:

- **Past extreme climate events**, acting as triggers to put climate risks on the agenda (e.g. the 1999 windstorm in France, the 2021 floods in Belgium, Germany and the Netherlands, or the 2022 heatwave).
- **Reputational risk**, a growing concern among operators, who see their key performance indicators affected by climate impacts and fear that this will affect the way they are perceived by the general public.

2. **Public policies and plans**, which may include:

- **National plans/strategies**, spanning from generic approaches (a general intention to enhance resilience) to more specific approaches (with, for instance, detailed milestones and targets per sector, such as in Germany) to structured resilience programmes with lines of action, or regulatory approaches—such as mandate to consider adaptation—and common methodologies (e.g. recommended climate scenarios, provision of climate data).
- **Financial programming**, with associated funding and budgets, beyond project-based funding.
- **Adaptation objectives** and targets with associated monitoring, indicators and implementation strategy.
- **Explicit sharing of responsibilities between policy-makers and operators and collaboration** on the adaptation strategy/action plan.
- **Explicit sharing of roles** and responsibilities across levels of government.
- **Prioritization guidelines** for operators.

3. **Integration of climate resilience in implementation tools, such as in public schemes and public contracts** is also essential as these tools define and organize the conception, maintenance, operation and dismantling of public infrastructure. For instance, performance contracts are where performance targets for infrastructure managers are defined and reviewed, guiding the strategic decisions along their lifetime. They also organize the remuneration through operating revenue (Le Club des Juristes, 2026).

4. **Resources: capacity to invest** depends on how it is funded, sector and organization, often constrained to the level of awareness/willingness of government/regulator to integrate it in investment plans.

5. **National-level requirements or EU funding requirements** for new infrastructure projects to have a risk assessment and adaptation plans, as climate-proofing is often required to access EU co-funding for infrastructure projects.

⁵ Délibération de la Commission de régulation de l'énergie (CRE) du 21 janvier 2021 (annexe 7—Régulation incitative de la qualité d'alimentation)

⁶ <https://www.inview.nl/openCitation/id6eee2034579d6605610a3979e92a8c79/wet-tegemoetkoming-schade-bij-rampen-artikel-4?ctx=b34fa2e3289155736538c16868e8fb07&undefined>

5.2. Current gaps in national and EU frameworks

Despite the enabling environment, there are gaps in the national and EU frameworks, that can be classified along three main dimensions:

Governance gaps

Risk ownership is unevenly defined across countries. Most national adaptation plans acknowledge critical infrastructure but lack explicit residual risk thresholds (e.g. at what point does climate-induced disruption become unacceptable?), or explicit identification of risk owners, in charge of defining them. Without such nationally-defined tolerance levels, operators make *de facto* prioritization decisions without democratic legitimacy or coherence across assets.

There are also **transboundary climate risks and disruptions, and adaptation challenges** for which risk ownership is insufficiently defined. While the CER Directive identifies "critical entities of European significance," operational accountability for transboundary climate impacts and related failures is often lacking. For instance, there is often no formal cost-sharing or liability mechanisms when one Member State's infrastructure failure triggers disruptions in another.

Multilevel coordination challenges or lack of alignment between frameworks and policies across levels of government is also an issue that mostly depends on specific governance frameworks between national and regional authorities. In some cases, stakeholders that operate infrastructure across multiple jurisdictions are faced with different norms, baselines and targets.

Interdependencies between sectors and systems are still only marginally analyzed both in national risk assessments and from the part of operators, and often lack translation into concrete measures, partly due to barriers to collaboration across systems, organizations and countries for multiple reasons that can range from transparency challenges to methodological issues.

Policy and implementation gaps

A major policy gap is the lack of properly defined climate resilience objectives for the resilience of critical infrastructure associated with clear means of implementations. Resilience objectives often lack specific timelines and lines of action for implementation, associated and allocated budget, precise targets and indicators to monitor progress. They also mostly lack explicit translation into sectoral public/private contracts, which rarely account for climate risks in service targets or objectives set to operators. Moreover, often, monitoring indicators for service targets are often measured under normal conditions and exclude climate events.

The *Study* reflects imbalance across sectors, which relates to the level of progress and level of awareness among sector stakeholders within each sector. This is also very dependent on the climate impacts already experienced by these stakeholders and the effect it already proved on the infrastructure, service and economic activities and model.

The focus for resilience is progressively shifting from asset-centered to system-level resilience. Transformative options (such as, substantial changes in locations, uses, functions) remain marginal and politically unaddressed.

Finance gaps

There is overall a lack of dedicated budget lines for adaptation. For instance, in national public budgets, budget allocations for adaptation measures are often undefined. Public support mechanisms to infrastructure often lack explicit climate resilience allocation. On operators' side, this also reflects in a lack of dedicated adaptation funds separate from usual or maintenance budgets

Lastly, most stakeholders highlight the challenge that they face in reflecting societal benefits in cost benefit analysis and economic criteria. This is especially the case for ecosystem-based measures, whose co-benefits are rarely monetized and hence, harder to integrate in resilience business cases. This also raises the challenge of linking tariff setting and regulations to resilience efforts, with underlying questions on whether tariffs could and should be adjusted value the resilience premium or if other mechanisms could be envisaged to support the additional investment.

Responsibilities for post-disaster *versus* ex-ante adaptation are still largely unclear. When disruptions occur, extreme weather events are often treated as exceptions under mechanisms that fail to account for climate change and the fact that they are slowly becoming the new norm, raising questions of accountability and responsibility over ex-ante adaptation.

Still insufficient exchanges across sectors and countries

The interviews conducted for this *Study* revealed a strong interest—and yet, lack of knowledge—from all types of stakeholders for the mechanisms, modes of collaboration and ways of working on climate risks and adaptation in other countries and sectors. Even though these practices are anchored in specific national contexts, and inherently dependent on pre-existing modes of governance and institutional relations between stakeholders, there would be a great value in strengthening peer-learning on these issues that are increasingly treated as important concerns, both between governments and operators.

5.3. What role for the European integrated framework on climate resilience?

This section presents the main elements of the IFCR policy package and identifies several functions through which the EU Integrated framework on climate resilience can support current practices and fill identified gaps: (1) engaging and supporting states in raising their level of ambition and advancing implementation and (2) putting in place the right enabling conditions at the EU scale to fill gaps that cannot be answered solely by the national level, following a principle of complementary responsibilities. This section is based on the learnings of the

Study and interviews as well as a dialogue organized at the European Economic and Social Committee entitled 'Climate Resilience across EU Member States: Identifying Challenges and Exchanging Practices on Critical Infrastructures in the context of the EU Integrated Framework on Climate Resilience' on 2 October 2026, that brought together 71 participants from different horizons: private sector, service operators, asset managers, public sector, researchers, public institutions, financial actors, insurers, decision-makers, representatives of national governments and representatives of EU institutions to discuss the climate resilience of critical infrastructures across EU Member States, showing strong interest in the topic of climate resilience and adaptation and a clear engagement to exchange across sectors and across Europe.⁷

Main elements of the IFCR policy package

The IFCR policy package was presented by the European Commission on 27 October 2026. It contains three main elements: 1) a legislative proposal 2) a communication and 3) digital tools, including a European Climate Viewer to be further developed.

The legislative proposal contains a common reference scenario based on a 3°C global warming by 2100 and a duty to consider it in national and EU climate-risk assessments; a duty to adopt strategic plans and set objectives and measurable targets for most relevant policy areas, identify risk owners for most important climate risks, and clarify responsibilities for protecting assets and policies, both at EU and national levels and an obligation for Member States to plan for climate resilience covering the most vulnerable policy sectors, as a condition for accessing EU funding. It is accompanied by "resilience by design" as a guiding principle for all levels of governance, and applicable across all sectoral policies, promoting anticipatory and proactive approaches.

One of the objectives of the IFCR is also to reduce fragmentation and create more coherence in the way resilience is addressed. For this, it is explicitly linked to several EU sectoral policies and initiatives, including, most relevant to this *Study*, the Directive on requirements for budgetary frameworks, the Taxonomy Regulation, the CER Directive and Risk-Preparedness Regulation, the Nature Restoration Regulation, environmental assessments guidelines and instruments.

In terms of reporting, the IFCR attempts to avoid duplication and new reporting requirements by building on existing obligations under Article 19 of the Governance Regulation. For this, it seeks to amend the Governance Regulation to ensure alignment with the IFCR proposal and the deletion of overlapping requirements through its planned revision.

National-level engagement and support functions

Based on this analysis and stakeholders engagement, key functions to provide in support to national action are:

- Facilitating exchanges across countries on planning approaches to topics such as prioritization of priority networks and methodologies, funding allocation, facilitation of cross-sector collaboration;
- Engaging national governments in:
 - **Clarifying mandates.** The obligation for Member States to define risk owners is crucial especially at the interface between different responsibilities, for instance where infrastructure crosses land managed by other stakeholders (e.g., private land, or space owned by local authorities).
 - **Setting nationally-binding operational targets and residual risk thresholds by sector** (e.g., maximum acceptable power outage duration during 1-in-50-year heat-wave) and linking these to risk ownership and emergency management (to make clear who is responsible to act when the threshold is exceeded, and link these to CER resilience plans and crisis planning);
 - **Embedding climate change** in public-private contractual arrangements in order to support clarity around risk ownership and operationally translate objectives, targets and thresholds. Enough flexibility should be left for revision according to the materialization of climate risks and evolving knowledge on the subject.
 - Addressing participation and transparency in the way resilience is prioritized, acceptable levels of disruption and restoration priorities defined, and according to what criteria (including economic viability, social vulnerability, importance for security, priority territories or economic activities, etc.) to ensure legitimacy of adaptation and resilience choices. Prioritizing nature-based solutions to climate wherever possible, including in spending programmes, in order to address the issue of the lack of private return on investment in nature and ecosystem-based adaptation. Such prioritization should also be reflected in monitoring frameworks and for climate resilience, including in sectoral policies.

EU-level enabling functions

Based on this analysis and stakeholders engagement, key functions to provide in support to national action are:

- **Putting in place a mechanism for transboundary coordination** to place risk ownership at the center of transboundary discussions. Without coordinated anticipation, response is slower, frictions across actors rise as they try and shift responsibility to others. Current evidence suggests that while the EU has laid the groundwork for transboundary resilience planning (e.g. TEN-E, TEN-T, CER), operationalizing shared responsibility, particularly regarding financing, liability, and emergency response, requires more explicit mandates and enforcement mechanisms at both the EU and national levels. For this, a governance mechanism to manage systemic climate risk could be set up under the IFCR, for instance based on the proposition made by Cox *et al.* (2026) of a four-layer-approach including a systemic climate risk assessment process at EU and MS scales; a risk ownership and obligations framework for systemic climate

⁷ <https://www.crosscascade.eu/news/brussels-climate-resilience-dialogue>

risks; a graduated compliance and escalation mechanism; and financial incentives.

- **Addressing the adaptation funding gap through the financial architecture:** Even if the share of costs for the resilience of critical infrastructure is inherently tied to national governance frameworks and collective choices, the EU can support the financial effort needed for climate resilience by reinforcing joint investment mechanisms and ensuring co-responsibility and coordination, especially by addressing and defining common principles and criteria for climate resilience within the upcoming Multiyear Financial Framework. It is also an opportunity to provide guidance on how to integrate and value ecosystem-based and hybrid measures providing collective resilience in adaptation and resilience planning, through common guidance on how to account for multiple benefits in cost-benefit analysis.
- **Facilitating common methods and terminology** to support sectors in their effort to address climate resilience through methods for risk and vulnerability assessment, prioritization, integration in operational management, investment planning, crisis management etc, and integrating them in regulatory frameworks at EU level, and co-funding mechanisms. Especially, a common methodology based on the European Climate Viewer developed by the European Commission under the IFCR and the common reference scenario could serve multiple EU obligations and bring coherence across them, including the CER Directive, the European Taxonomy/ CSRD and EIB climate proofing, hence lowering costs for both operators and public authorities. Developing integrated, multi-hazard and multi-modal approaches for risk assessment, policy design, and investment planning would also support a greater capacity to respond to compounding and cascading risks due to multiple or consecutive extremes happening at the same time that can strain infrastructure systems' recovery capacity.

- **Ensuring policy coherence consistency with other European policies** and frameworks. This includes as sectoral policies and regulations like the European Grids Package and TEN-E regulation, the TEN-T regulation and their implementation, as well as investment needs to support it (Schade *et al.*, 2024, Már Baldursson, 2023). This also requires the engagement and uptake across key services of the European Commission to take ownership of the IFCR's main elements and integrate them in the various relevant policy areas and frameworks.

These functions are essential for the IFCR and its implementation to respond to the needs and gaps identified on the basis of current practices within MS and sectors. Following the recent publication of the proposal by the European Commission, a discussion on those priorities in the light of the legislative process and the implementation of the framework is expected in the coming months, which will require focusing on the concrete elements that can ensure effective achievement of these functions.

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ANNEX

Table of interviewees

NAME	INSTITUTION	TYPE	COUNTRY	DATE
Diego Jimenez Gonzalez	Adif	Infrastructure manager	Spain	11 June 2026
Pieter Wynant	CERAC	Public Institution	Belgium	28 May 2026
Laurie Senaux	CRE	Regulator	France	10 June 2026
Maxime Saliez	CREG	Regulator	Belgium	11 June 2026
Stefan Jordan	Deutsche Bahn	Infrastructure manager	Germany	10 August 2026
Baptiste Eisele	DGITM	Government	France	20 May 2026
Marielle Wilgenkamp	DGMo–Ministerie van Infrastructuur en Waterstaat	Government	Netherlands	17 May 2026
Sjoerd Brouns	DGWB–Ministerie van Infrastructuur en Waterstaat	Government	Netherlands	27 May 2026
Marianne Houman	Elia Group	Transmission system operator	Belgium	19 May 2026
Vincent Dufour	Elia Group	Transmission system operator	Belgium	19 May 2026
Thomas Abeling, Frederic Schaffer	Ministry of the Environment–German Federal Ministry	Government	Germany	22 April 2026
Miriam Bueno Lorenzo	Miteco	Government	Spain	6 July 2026
Jasper Ingram	Prorail	Infrastructure manager	Netherlands	10 July 2026
Miranda Vazquez	Redeia	Transmission system operator	Spain	15 July 2026
Pablo Rodriguez Herrerias	Redeia	Transmission system operator	Spain	15 July 2026
Gabriel Castañares Hernandez	Renfe	Service operator	Spain	9 July 2026
Ira Shefer	RGI	Private sector association	EU	19 June 2026
Andrzej Ceglaz	RGI	Private sector association	EU	19 June 2026
Catherine Lelong	RTE	Transmission system operator	France	16 June 2026
Alexandre Viviers	SNCB	Service operator	Belgium	10 July 2026
Annick De Keyzer	SNCB	Service operator	Belgium	10 July 2026
Anne Guerrero	SNCF Group	Operator	France	12 June
Xavier Bonnet	SNCF Group	Operator	France	12 June
Alex Desmet	SPF Transport	Government	Belgium	20 May 2026
Séverine Hermand	Sweco	Private Sector	Belgium	18 MAy 2026
Martijn Steenstra	Sweco	Private Sector	Belgium	18 May 2026
Rowdy van Grieken	Tennet	Transmission system operator	Netherlands	11 June 2026
Lissa Sum	Transnet	Transmission system operator	Germany	24 June 2026

Who owns the risk? Allocating responsibility for climate resilience of critical infrastructure in EU Member States

Adèle Tanguy, Julie Pouzol, Marta Torres Gunfaus (IDDRI)

The Institute for Sustainable Development and International Relations (IDDRI) is an independent think tank that facilitates the transition towards sustainable development. It was founded in 2001. To achieve this, IDDRI identifies the conditions and proposes the tools for integrating sustainable development into policies. It takes action at different levels, from international cooperation to that of national and sub-national governments and private companies, with each level informing the other. As a research institute and a dialogue platform, IDDRI creates the conditions for a shared analysis and expertise between stakeholders. It connects them in a transparent, collaborative manner, based on leading interdisciplinary research. IDDRI then makes its analyses and proposals available to all. Four issues are central to the institute's activities: climate, biodiversity and ecosystems, oceans, and sustainable development governance.

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CONTACT

adele.tanguy@iddri.org

Institut du développement durable et des relations
internationales 41, rue du Four – 75006 Paris – France

WWW.IDDRI.ORG

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