UNIFE vision paper
A Climate-Resilient Rail Industry for Europe's Future
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Executive Summary[1]

The climate crisis increasingly affects the European railway system through more frequent and severe extreme weather events that disrupt infrastructure, operations, and supply chains. For instance, a website mapped the impact of the June 2026 heatwave on European railways, with 20,000 additional trains cancelled across 8 Member States. Another example is the floods in Spain in 2024: 274.6 km of commuter train lines and 149.1 km of high-speed rail lines were rendered inoperable, with EUR 184.6 million invested in repairs and rebuilding.

Rail transport is essential to decarbonisation, sustainable mobility, and economic resilience in the European Union (EU). While climate change mitigation remains the most cost-effective strategy for limiting future climate impacts and avoiding rapidly increasing adaptation costs, many climate impacts are already unavoidable and are being felt today. Rising climate-related disruptions are undermining service reliability, eroding customer confidence, and slowing modal shift ambitions. As a result, adaptation measures must be accelerated alongside mitigation efforts. This is particularly important in the rail sector, where long planning, development, and asset renewal cycles require resilience investments well in advance.

On the rail supply industry side, the stakes are high. Climate shocks are increasingly causing temporary production shutdowns, supply disruptions, and cost increases, potentially leading to long-term competitiveness losses and, in the worst case, factory closures or relocation to less hostile climates.

Released in March 2026, the EU Agency for Railways (ERA) report on *Rail Resilience to Climate Change* highlights the growing need for a structured, system-wide approach to resilience, including improved data, risk assessment methodologies, and regulatory adaptations. In 2026, the Community of European Railway and Infrastructure Companies (CER) also released its position paper, *A climate-resilient railway for Europe's future*, calling for a comprehensive EU framework that integrates resilience across infrastructure, vehicles and operations, supported by enhanced funding and harmonised standards.

[1] This vision paper is the follow-up to the UNIFE vision paper on *Leading the Shift to More Sustainable Transport*, released in June 2025.

Climate resilience is an organisation's capacity to anticipate, assess, prepare for, respond to, and continuously adapt to actual and expected climate impacts, thereby reducing vulnerability, maintaining critical functions, and seizing relevant opportunities over time. The term "organisation" applies at both the company and value chain levels for specific rail activities or projects.

Constantly operating a saturated system has several implications over the life span of the assets and cumulative risks to passengers using the system. Excessive wear and overloading will shorten maintenance cycles for key rolling stock components, cause permanent infrastructure damage, and may trigger safety incidents, compounded by reduced capacity to respond to extreme climate events. Hence, addressing the rail system's climate resilience is essential to its proper functioning and safety.

UNIFE, the European Rail Supply Industry Association, supports ERA and CER's objectives and emphasises a critical missing dimension. While existing initiatives rightly highlight the need for a coordinated European resilience framework, a key dimension remains underrepresented: **the role of industrial capabilities and product design in achieving system-wide resilience.**

As a designer and provider of rail products and technologies for systems, rolling stock and infrastructure, the rail supply industry is a key enabler of climate resilience. In fact, a climate-resilient railway system requires:

- Resilient industrial activities and supply chains to ensure a continuous supply of rolling stock, infrastructure products and spare parts;
- Resilient industrial services to ensure the lifelong availability and maintainability of rolling stock and infrastructure;
- Resilient infrastructure, rolling stock and systems.

UNIFE calls for a shift towards a "*resilience by design*" approach, embedding climate adaptation at the core of rail products, systems, and industrial ecosystems, recognising the industry's key role in climate-resilient railways. With this approach, the key principles should be proportionality, clearly defined responsibilities, and practical sense, while ensuring the overall regulatory framework becomes simpler rather than more complex. The European institutions should address risks effectively without creating unnecessary complexity or imposing additional requirements that add no real value.

1) The rail industry's contribution to system-level resilience

Rail is central to Europe's sustainable mobility ambitions. Yet, it is **increasingly exposed to evolving climate change and extreme weather conditions**, which will become more frequent and may cause service disruptions, damage to critical and costly infrastructure, and additional maintenance interventions. For example:

- **Floodwater** can damage electrical cables, motors, or electronic components of signalling systems. Bridges and culverts can fail structurally. Rolling stock can also be affected if the water level reaches the motors. Water intrusion and leakage in tunnels and underground infrastructure can lead to additional damage. Flooding of depots can affect maintenance activities and rolling stock availability. Subsequent landslides can damage or carry debris onto the train line and trigger ground instability, affecting track geometry and infrastructure integrity.
- **Storms and extreme winds** may carry debris onto tracks and tear overhead lines. Debris accumulation and damage to wayside equipment will increase inspection and maintenance needs.
- **Wildfires** cause extreme heat that deteriorates railway tracks, wooden and concrete sleepers, ballast, and the encapsulation of embedded rails. They will also restrict access and pose safety risks for maintenance teams.
- **Heatwaves and cold waves** can also generate heat or cold stress for users and reduce the performance of electronic components or HVAC. This can cause malfunctions in signals, switches, and monitoring systems, and increase demand for cooling or heating to maintain passenger comfort and safety. For track infrastructure, prolonged heat periods and elevated rail temperatures increase compressive forces in continuously welded rail and reduce the safety margin against track buckling.
- **Drought and water scarcity** can lead to soil shrinkage, affecting track stability.
- **Permafrost thawing** can lead to ground instability in northern regions, causing safety issues from deformation of track foundations, misalignment of track, and damage to civil structures such as embankments, bridges and tunnels.
- **Increased long-term ambient humidity** in some regions: higher, persistent humidity may accelerate corrosion of railway equipment (incl. rolling stock) and infrastructure, leading to malfunctions in certain rolling stock components (electrical cabinets, electronic connectors, sensors, braking systems, HVAC...) and signalling systems.

A particular challenge is the **permanent variation in average temperatures** due to climate change. These changes will make operating in extreme temperatures for longer periods necessary, affecting both rolling stock and infrastructure:

- Steel expansion under high temperature differentials can lead to rail buckling, particularly for urban rail (light rolling stock).
- A faster rate of degradation of railway components, for instance, for sleepers and fastening systems, with effects such as long-term ageing of concrete, polymer, and

elastomer components; retention of fatigue strength; stiffness and electrical insulation; and reduced resistance to UV exposure, moisture or flooding.

- Long-term exposure to extreme temperatures reduces component durability and shortens asset lifecycle.
- Modifications to tension design and maintenance of catenary lines.
- Need to adapt design tolerances and maintenance strategies to account for thermal expansion and contraction (e.g. bogies).
- Lower performance or degradation of electronic components, leading to malfunctions in signals, switches, and monitoring systems, increased failure rates, and reduced performance of assets, resulting in additional maintenance interventions.

All the climate events mentioned can damage the catenary system, causing power outages and immobilising electrified transport. Monitoring and maintenance are thus increasingly vital. Addressing these challenges is a priority for the rail sector. Resilience depends on infrastructure robustness, operational planning, and the reliability and adaptability of rolling stock, infrastructure, systems, and components throughout their life cycle.

While existing analyses, including ERA's work, have focused mainly on infrastructure and operational impacts, **EU institutions should also recognise the contributions of technology development, rail product design, continuity of the manufacturing supply chain, and rolling stock maintainability as enablers of the rail sector's resilience to the climate crisis.** Indeed, the rail supply industry plays a central role through:

- Designing, manufacturing and delivering rolling stock and systems with operational lifespans of 30 to 40 years in an evolving climate;
- Integrating robustness and reliability requirements at the design stage for components, subsystems and onboard technologies to withstand extreme weather events and recover from disruptions;
- Enabling maintainability, repairability and spare-part availability under disruptive conditions.

Rolling stock manufacturers must adapt to climate change while maintaining a pragmatic, system-level perspective. Rolling stock resilience should be proportionate to that of the wider railway system. For example, enhancing trains' flood resistance provides limited benefit if infrastructure becomes inoperable due to landslides, just as designing vehicles for extreme wind conditions has limited value when fallen trees disrupt tracks or overhead contact lines. Similarly, extending the operating range of onboard equipment to temperatures above 50°C may offer little practical benefit if rail infrastructure itself cannot remain operational under such conditions because of track buckling or other heat-related failures.
Therefore, the entire rail sector should address climate resilience through a coordinated, system-wide approach, with clearly defined responsibilities and interfaces across public authorities, infrastructure managers, operators, and industry.

2) Rail technologies as key enablers of climate adaptation

Climate resilience shall be implemented at the infrastructure, vehicle and system levels, where performance under extreme conditions directly affects service continuity, in present and future climate conditions.

a) Solutions developed by the rail supply industry to enhance climate resilience

Concrete examples of products, solutions and technologies already developed by the rail supply industry to enhance climate resilience include:

Infrastructure level:

- **Climate-resilient track superstructure solutions** to maintain track geometry, lateral resistance and functional performance during prolonged heatwaves and other extreme weather events.
- **New sleeper geometries and rail fastening concepts** should combine enhanced lateral track resistance with compatibility with mechanised tamping and lining processes, and support the rapid restoration of track stability after maintenance interventions. This is particularly relevant where maintenance windows are increasingly constrained by prolonged periods of elevated rail temperature and summer conditions.
- While measured rail temperatures typically remain below about 65°C in service, the rising number of hot days is increasingly constraining maintenance activities. **Innovative track systems with enhanced track stability** could expand maintenance windows, reduce operational restrictions, supporting higher infrastructure availability.
- Climate resilience should also **consider cold-weather effects**. Rail and weld failures remain a challenge in low temperatures. Future track systems with improved load-distribution characteristics could reduce local stress concentrations and mitigate the impact of substructure irregularities, enhancing the resilience of the overall track system. More resilient track structures could reduce dynamic force peaks, limit infrastructure degradation and preserve track geometry over time.
- The effects of heavy rainfall and water-saturated formation layers should also be investigated. Innovative track systems with **improved load-transfer mechanisms** could reduce stresses transmitted to weakened substructures and help maintain acceptable track performance in adverse conditions.

Potential benefits of future climate-resilient track systems include:

- improved stability of track geometry and slower deterioration;
- extended maintenance intervals and reduced maintenance demand;
- improved distribution of static and dynamic loads;
- greater tolerance of variations in substructure conditions;
- reduced sensitivity to extreme weather impacts;
- faster recovery after climate-related disruptions;

- longer service life of track components;
- lower lifecycle costs and higher asset availability;
- enhanced operational reliability on heavily utilised networks.

From a systems perspective, innovative track technologies could become an important element of a broader "resilience by design" approach by supporting infrastructure availability, maintainability, operational continuity and rapid recovery across the asset lifecycle.

Vehicle level:

- Qualification of **electronic systems** across extended temperature and humidity ranges;
- Protection of **critical components** (e.g. braking, traction) against water ingress;
- Advanced **HVAC systems** ensuring passenger safety and comfort in extreme climates;
- Monitoring systems enabling real-time **performance tracking and predictive interventions**.

These solutions illustrate that adapting the rail sector to a changing climate is **a design and engineering challenge for the rail supply industry**, one that requires innovation, development, and testing. As climate change scenarios continue to be refined based on current socioeconomic choices, **the European rail supply industry will require further technological development, cross-value-chain cooperation, and specification updates**.

b) Future European R&I for climate adaptation in the rail sector

Future European research and innovation (R&I) for climate adaptation should address climate-related risks, as resilience must also be embedded in technologies operating within the railway system. As this requires a stronger focus on industry-driven innovation, UNIFE stresses **the need to continue expanding R&I for climate-resilient railways, building on *Europe's Rail* flagship project 4 *Rail4Earth***. This project has already helped the European rail supply industry develop a clear strategy, define railway resilience technically, quantify resilience objectives, and start updating standards and developing new technical solutions.

Key priority areas for technology development identified by the rail supply industry include:

- Development of materials and components capable of withstanding wider temperature ranges, humidity and environmental stress;
- System-level development and validation of the interaction between rail, fastening, sleeper, ballast or slab track, drainage and substructure under combined climatic and mechanical loading, including measurable indicators for track stability, maintainability, recovery time and residual service life;
- Integration of onboard and wayside monitoring and diagnostic systems to detect early signs of degradation;

- Deployment of predictive maintenance solutions to minimise service disruption and optimise interventions;
- Use of digital technologies to support decision-making and maintain system performance under degraded conditions;
- Focus on risk assessment tools mainly to cover the cost impact of an extreme event and climate change;
- Focus on alerting systems to anticipate an extreme event and make the appropriate decisions as soon as possible.

Such solutions directly contribute to maintaining system availability, improving operational reliability and reducing recovery times following climate-related events.

UNIFE therefore calls on the European institutions for continued **dedicated funding within EU research and innovation programmes**, including through a successor to *Europe's Rail Joint Undertaking (Europe's Rail)*. This dedicated funding will continue to **accelerate the development, testing and industrial deployment of these technologies, ensuring that climate resilience is addressed at both the system and product levels**.

For the rail sector, the successor to *Europe's Rail* should embed climate change resilience across its agenda for operations, infrastructure, technology development, and supply chain continuity to keep the sector fully operational, resilient to climate disruptions, and globally competitive. In particular, UNIFE highlights three priorities:

- **Integrate climate resilience across the entire rail system:** The successor to *Europe's Rail* should embed climate resilience as a core objective across operations, infrastructure, rolling stock and technologies, promoting a "*resilience by design*" approach to ensure long-term system performance under evolving climate conditions.
- **Strengthen innovation and the deployment of resilient technologies:** Increase support for high-technology-readiness-level activities and for the industrial deployment of climate-resilient solutions, including rolling stock, onboard systems and digital tools, ensuring that R&I results effectively translate into operational resilience.
- **Ensure the resilience of industrial and supply chain ecosystems:** Integrate into the successor to *Europe's Rail*'s priorities the continuity of manufacturing, maintenance and the supply chain in an ever-changing climate, recognising their critical role in maintaining rail system availability and competitiveness under climate disruptions.

3) Climate-proof criteria in specifications for lifelong performance

Rail product development must evolve to systematically integrate climate constraints into engineering practice, ensuring the climate resilience of future rail systems. This includes:

- Designing for future climate scenarios rather than historical conditions;
- Supporting the definition of performance requirements for evolving and extreme operating environments;
- Integrating resilience criteria into technical specifications, material and component selection, and validation processes;
- For track systems, resilience criteria should balance increased lateral resistance with efficient maintenance.

Neglecting these considerations during design can raise lifecycle costs with higher maintenance, early component failure, and lowered asset availability. Over time, this may lead to more retrofitting and operational issues, harming economic performance and system reliability. Assets' Total Cost of Ownership (TCOs) will rise.

The ERA report on *Rail Resilience to Climate Change* emphasises the need to enhance data collection, incorporate climate risks into regulations, and foster stakeholder collaboration. **UNIFE recommends integrating climate resilience by design through a unified rail ecosystem approach** (public authorities, infrastructure managers, operators, industry), **creating harmonised methodologies and datasets.**

The client (public authorities, infrastructure managers, or operators) must clearly specify what it wants in the specifications. Climate-proof assets should follow climate projections and adaptation plans. For instance, the international high-speed rail service *Eurostar* announced in July 2026 that it will future-proof its next generation of trains entering service in 2031, with air conditioning designed for temperatures up to 55°C.

However, according to the ERA report on *Rail Resilience to Climate Change*, "*only 37% of the infrastructure managers and Network Rail are using climate projections and Intergovernmental Panel on Climate Change's scenarios to design new assets. In addition, a bit less than half of the infrastructure managers have developed an adaptation plan.*" **If not, it can lead to inefficient over- or under-specification of rail products or poor prioritisation of subsystem adaptation.**

Beyond integrating into technical standards, UNIFE emphasises incorporating climate-resilience criteria into procurement and conformity assessments to strengthen climate-change adaptation. They should be regional and risk-based rather than rule-based, and should not uniformly apply environmental limits across all European applications.

4) Climate resilience in rail sector's industrial activities

The climate crisis also affects manufacturing sites, service facilities, supply chains, and rail equipment delivery. Recent extreme weather events in Europe show that such disruptions can directly affect industrial production and project timelines, with immediate consequences for rail system availability and service continuity.

The industry faces several critical challenges: water and energy consumption, ageing and inadequate infrastructure, and dependence on suppliers who are themselves subject to unforeseen circumstances. Many factories, including recently built infrastructure, are not designed to withstand increasingly frequent extreme weather events. During the heatwave in spring and summer 2026, some sites had to shut down to conserve water, overheated electrical grids failed, and data centre air-conditioning systems were not designed to withstand temperatures above 40°C.

For example, water scarcity and imposed water restrictions can limit water availability for manufacturing, maintenance and cleaning. Water scarcity may also affect certain suppliers' ability to secure raw materials whose extraction and processing are highly water-intensive, particularly in the mining sector and in certain energy value chains. **This constraint may reduce production capacity, increase energy sourcing costs, and risk supply chain continuity**.

A reliable and climate-resilient rail industry and supply chain require resilient manufacturing activities, robust supply chains, and the integration of climate adaptation strategies across industrial processes. **Strengthening industrial resilience is essential to ensure the reliability, availability and long-term performance of the railway system as a whole**.

UNIFE calls for dedicated funding in the next *National and Regional Partnership Plans* (NRPPs) to increase the climate resilience of industrial activities, aligned with EU goals, particularly those with high eligibility under the EU Taxonomy. Critical to a sustainable transport system and EU competitiveness, the rail industry is a key asset to protect against the adverse effects of climate change.

The EU and Member States have set decarbonisation targets with quantified, time-bound plans, but this is not the case for adaptation: there is no binding regulatory framework. It is crucial to **establish mandatory EU adaptation programmes for all critical production sites**.

Resilience investments are critical to maintaining competitiveness and ensuring the continuity of essential transport services, including military mobility. In this context, investing in resilience should not be seen as an additional cost but as a prerequisite for achieving climate objectives and maintaining rail as the backbone of a sustainable European transport system.

5) Policy recommendations

The climate crisis is a systemic threat to the European rail supply industry, reshaping the conditions under which the railway system must operate. While infrastructure remains critical, the rail supply industry is indispensable for enabling adaptation through resilient technologies and products. A climate-resilient future for rail requires:

- A system perspective;
- Strong public-private cooperation;
- Sustained investment in innovation.

UNIFE calls on EU institutions to align policy frameworks with the realities of industrial design, deployment, and system performance, and to address risks effectively without creating unnecessary complexity or imposing additional requirements that add no real value, particularly by adopting the following recommendations:

A. Recognise the rail supply industry as a core pillar of railway system resilience

The European rail supply industry is a critical enabler of sustainable mobility within the *EU Climate Adaptation Strategy*. This should mean unlocking faster funding access and streamlining permitting, not increasing reporting burdens. Beyond infrastructure and operational planning, this includes recognising the role of industrial actors in developing and delivering resilient technologies, maintaining supply chain continuity, and providing the long-term lifecycle support needed to ensure reliable railway performance in a changing climate.

B. Support innovation and industrial deployment of climate adaptation technologies

The EU should dedicate a climate resilience module in *Europe's Rail's* successor programme, focused on deployment-ready technologies. The "*Fast-Track*" mechanism under the *Net-Zero Industry Act* could be a useful reference point. It can accelerate the development, validation, and market uptake of rail technologies that enhance climate resilience. **Funding instruments should continue to address both infrastructure and rolling stock**.

C. Integrate climate resilience requirements into standards, procurement and conformity assessment

Climate resilience criteria should be progressively enhanced in standards, such as requesting CEN to revise relevant EN standards, such as EN50125-1[2] or EN14067[3], **as well as in public and private procurement specifications, product requirements, and conformity assessment processes**. More systematic integration of these criteria is needed to ensure railway assets and components are designed, selected, and validated for long-term performance under evolving climate conditions, strengthening the sector's adaptive capacity. Such requirements should be based on harmonised climate scenarios, agreed resilience KPIs and demonstrated system-level

[2] Railway applications - Environmental conditions for equipment - Part 1: Rolling stock and on-board equipment
[3] Railway applications. Aerodynamics

risks. They should be **regional and risk-based rather than uniformly applying environmental limits across all European applications**. Procurement should recognise demonstrated lifecycle performance, maintainability, replaceability, recovery capability and total cost of ownership.

D. Protect and strengthen the climate resilience of rail industrial activities in Europe

The EU should establish **targeted funding and industrial policy measures to strengthen the climate resilience of rail manufacturing, maintenance, and the supply chain** across Europe, particularly where these activities align with EU sustainability objectives and are relevant under the EU Taxonomy framework. As a key industry supporting sustainable transport, competitiveness, and Europe's decarbonisation, the rail supply sector should be recognised as an economic asset and protected from climate change impacts. **EU adaptation programmes for production sites would also be crucial**.

E. Strengthen climate data, risk assessment and engineering frameworks

The EU should **support the development of harmonised climate scenarios, datasets and risk-assessment methodologies tailored to the rail sector**, enabling their direct use in engineering design, product validation and investment decision-making. For infrastructure, these frameworks should explicitly cover sleepers, fastening systems and the entire track superstructure. Assessment methods should reflect expected increases in traffic and cumulative loading, as climate resilience must safeguard long-term track availability and enable rapid restoration after extreme events under higher network utilisation.

Together, these measures will enable a coherent, innovation-friendly framework to support the long-term resilience and competitiveness of the European rail system.

UNIFE stands ready to work with EU institutions and stakeholders to ensure that:

- The rail industry remains fit for a changing climate;
- Rail continues to deliver safe, reliable and sustainable mobility for society.

About UNIFE

UNIFE, the European Rail Supply Industry Association, has operated in Brussels since 1992, representing European train builders and rail equipment suppliers. The association represents more than 120 of Europe's leading rail supply companies – ranging from SMEs to major industrial champions – that are active in designing, manufacturing, maintaining, and refurbishing rail transport systems (including trains, metros, trams, and freight wagons), as well as subsystems and related equipment. UNIFE also brings together national rail industry associations from 13 European countries.