Policy brief – September 2025 - Governing Infrastructure for the Public Good and a Sustainable Future

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Context and Problem Statement

Essential services such as energy and water supply, telecommunication, transportation networks as well as health and social care form the backbone of modern society. These systems are collectively referred to as Critical Infrastructures (CIs) due to their indispensable role in maintaining societal well-being and economic stability. We focus on the public good character of CIs services, the benefits when adopting innovative technologies to enhance resilience and the external effects to the economy and society in a special analysis presented in the academic article (Zherdev et al., 2025). The continuous and reliable operation of CIs is vital for public safety, quality of life, and the functioning of the economy and key institutions. As such, CI governance and resilience are matters of public interest and strategic importance: these services often exhibit the characteristics of either pure public goods, which are non-excludable and non-rival in consumption, or commonpool resources, which are non-excludable but subtractable (e.g. drinking water or electricity infrastructure during peak demand).

CIs play a key role in ensuring the secure and reliable supply of essential services to the economy and society that generate positive external effects, such as supporting (regional) economic development, improving well-being and fostering social cohesion. However, when services are disrupted, resources are overused, supply is unequal, or operations cause environmental harm (e.g., air pollution or emission of greenhouse gases), they can also produce negative external effects.

These additional benefits or costs are often not included in the transaction price. External effects can vary in size and scale considering both market and nonmarket interactions, indirect, spillover effects and cascading effects. These external effects cannot be fully internalised in the price, as carbon taxation partially achieves. Therefore, interaction and collaboration between public and private actors is needed to develop policy actions with broader spillover and cascading effects of CIs' service provision.

CIs are increasingly interconnected, often aging, and reliant on digital technologies, making them vulnerable to emerging failure modes. As a result, the move from traditional asset protection towards a broader focus on system resilience is needed. New technologies can play a key role in supporting this transition by enabling better detection, prediction, and response planning. Thus, adopting technologies that are supported by artificial intelligence and machine learning, including access control, and remote infrastructure inspection, is essential for reducing uncertainty and accelerating decision-making. This is particularly important in the context of climate change, complex interdependencies across infrastructures, and growing demands for operational efficiency.

The urgency of these issues has become increasingly evident in the European context, where floods, droughts, storms, and the COVID-19 pandemic have exposed the vulnerabilities of utilities and underscored the dependence of economies and societies on uninterrupted service provision. The resilience of CIs, namely, the ability to prepare for, absorb, recover from, and adapt to adverse conditions, is a critical factor in safeguarding societal stability, public health, and economic continuity. It is critical that European CIs possess not only resilience but also the capacity to adapt to evolving risks and the agility to swiftly recover from both anticipated and unforeseen disruptions. Despite the rapidly evolving threat landscape and the increasing complexity and digitalisation of CI interconnectedness in Europe, CI operators and public authorities, however, are still in the process of developing comprehensive strategies to manage these risks.

The European Union and the United Nations have made important progress in addressing vulnerabilities in critical infrastructure, recognising them as major systemic risks to both

European and global stability. Recent initiatives, including the Critical Entities Resilience directive (CER) (2022), the revised Network and Information Systems Directive (NIS2) (2022), and the UNDRR principles on resilient infrastructure (2022), reflect this commitment. The EU, however, still lacks a comprehensive framework to ensure the broader economic, social, and environmental impacts associated with the deployment and use of new technologies, as well as the need for clearer and more structured financing frameworks, are accounted for.

This policy brief presents outlines a strategic roadmap to support the integration of new technological solutions through targeted policy reforms, updates to standards and requirements, and the harmonisation of regulatory frameworks. The objective is to systematically embed financial, social, and environmental sustainability principles into the governance frameworks of critical infrastructure across the European Union, with particular emphasis on the responsible adoption of emerging technologies.

This brief is intended for EU policymakers, national authorities, critical infrastructure operators, and strategic decision-makers involve in the design, governance, security, and continuity of Europe's essential systems.

This brief highlights the importance of ensuring that new technologies are adopted in a sustainable way to strengthen the resilience of CIs. While recent EU legislative advances, including the NIS2 and CER Directives, establish an important foundation for protection and resilience, they remain to some extent incomplete. Persistent challenges, including fragmented security standards, limited integration of broader social, economic, and environmental impacts, and inconsistent technology adoption practices continue to hinder coordinated responses and delay effective, timely, and sustainable implementation.

Key Insights

This policy brief is based on the study for the academic article (Zherdev et al., 2025). This examination for the article includes eight semi-structured interviews conducted between March and June 2025 with CIs' managers and technology developers involved in the Horizon Europe SUNRISE project (2022). It focuses on the energy (electricity) and water sectors in Italy, Spain and Slovenia, and examines the functions of Demand Prediction and Management (DPM) and Remote Infrastructure Inspection (RII) technological solutions developed within the project. The analysis is complemented by an online survey of 12 CI employees, including five RII and seven DPM adopters, representing seven water and five energy utilities conducted within the project. The study for the academic article explores the social, economic and environmental impacts of these technological solutions in CI service provision, with the aim of helping operators reduce risks and enhance benefits.

The DPM solution is a software application that employs advanced artificial intelligence and machine learning models to generate demand forecasts for key resources within CIs' sectors, including water, energy, transport, and healthcare. It is particularly effective during periods of disruption, such as pandemics, where it identifies patterns, bottlenecks, and underlying causes to support the optimisation of resource allocation.

The RII solution is an AI-powered tool for remote inspection of physical infrastructure, particularly effective in hard-to-reach or high-risk areas. It reduces reliance on manual inspections by combining satellite imagery, UAV sensors and machine learning to detect anomalies with precision. Enhanced by Visual Large Language Models (V-LLMs), the system can efficiently process diverse inspection scenarios, supporting timely identification of risks and structural issues.

Key benefits

The findings of the study (Zherdev et. al., 2025), indicate that the technologies deliver a range of benefits, including improved forecasting, enhanced anomaly detection, faster response times, greater operational efficiency, and more effective knowledge exchange and resource optimisation. Notable improvements in forecasting accuracy were reported in energy sector regarding demand prediction, leak detection and consumption management. Usability was also identified as a key strength, with intuitive interfaces supporting accessibility and informed decision-making. Survey responses reinforced these insights, highlighting increased inspection efficiency in both energy and water sectors, moderate relevance for routine operations, and heightened importance during emergency situations. UAVs were widely recognised for their role in reducing worker exposure to hazardous environments.

Continuity and resilience in service delivery were enhanced by both technological solutions. They enabled early anomaly detection, improved infrastructure planning, reduced downtime, and increased service availability. DPM was particularly effective in balancing supply and demand in remote mountainous areas and strengthening disaster preparedness. RII consistently supported inspection efficiency and safety, offering benefits such as early fault detection, infrastructure protection, and reduced capacity losses. Both technologies were seen as valuable for maintaining service continuity during emergencies. DPM excelled in forecasting and preventing undersupply, while RII was effective in safeguarding infrastructure and lowering damage-related costs. Key advantages included timely detection of anomalies and infrastructure damage, as well as mitigation of capacity utilisation challenges in both routine and crisis conditions.

Participants in the interviews and surveys emphasised the importance of technological solutions in enhancing disaster preparedness, particularly in strengthening prevention and response capabilities. Representatives from the energy sector cited advancements in disaster prediction, resource allocation, and rapid infrastructure assessment. Meanwhile, stakeholders from the water sector highlighted improvements in recovery planning, anomaly detection, demand forecasting, and readiness for droughts and floods. Overall, there was strong confidence among respondents in the effectiveness of these technologies in mitigating the impacts of natural hazards.

Key identified challenges

Fragmented Governance Across EU, National, and Local Levels

Governance of CIs involves multiple layers, including EU directives, national legislation, regional oversight, and local permitting processes. Clear sectoral differences are evident. Energy utilities operate within structured European frameworks, such as ENTSO-E and the Green Deal, with a strong focus on renewable integration and technical standardisation. In contrast, water utilities face a fragmented regulatory landscape. They must balance multi-use resource management with sustainability objectives. Besides, enforcement gaps persist, particularly in relation to water reuse obligations, where compliance remains limited despite formal legal requirements.

Outdated Regulations Limit Innovation

The deployment of RII technological solutions is shaped by existing regulatory frameworks. While some companies reported well-defined approval procedures involving civil aviation authorities and multiple government ministries, others indicated uncertainty around licensing requirements. Operational restrictions, including bans on Beyond Visual Line of Sight inspections, were identified as barriers to effective monitoring. These findings reveal inconsistencies in regulatory oversight and varying levels of awareness among companies regarding compliance obligations.

Weak Private Sector Role in Financing Mechanisms

All case studies indicated a reliance on public resources, although the funding mechanisms varied. Water utilities commonly accessed EU grants, research initiatives, or hybrid models combining tariff-based systems with public funding. In contrast, the energy utilities were expected to finance investments through internal budgets. Despite these differences, public resources were widely regarded as essential for sustaining long-term investment.

Societal Effects

Economic Effects: Reduction of Service Interruption Losses

Interviewees consistently identified economic benefits, notably through improved service reliability and reduced disruptions. Both DPM and RII technologies were seen as effective in limiting financial losses and contributing to regional development, particularly in sectors such as tourism and irrigation. RII was also recognised for its role in workforce transformation, enabling staff to transition from routine duties to more value-added functions. Survey responses indicated a moderate potential for lowering personnel and operational costs.

Environmental Effects: Lowering Emissions and Improving Efficiency

Utilities reported environmental benefits linked to the adoption of new technological solutions, including reductions in energy consumption and emissions through improved efficiency, predictive analytics, and the replacement of helicopter inspections with drones (UAVs). Water conservation was supported by enhanced demand forecasting, leak detection, and more efficient pumping systems. Survey responses generally reflected positive expectations regarding environmental outcomes, particularly in relation to energy and emissions, although views on potential water savings were mixed.

Social Effects: Ensuring Equitable Access and Privacy

Prioritising well-being and essential services were central points across sectors. Water utilities maintained strict classifications for uninterruptible services, while energy utilities emphasised equitable access. Both sectors highlighted the need to protect vulnerable groups. Water utilities also noted social gains from improved distribution security, anomaly detection and public awareness. Survey responses on spatial inequality were mixed, though many anticipated more equitable resource distribution. Data related risks emerged as a key concern among interviewees. Respondents from the energy sector emphasised the importance of anonymising and protecting sensitive data. Water utilities highlighted public concerns regarding the use of drones, calling for greater transparency and strict compliance with GDPR. Mitigation measures included the integration of impact assessments. Survey findings reinforced these concerns, citing algorithmic bias, forecast manipulation, and cybersecurity risks for the DPM solution, as well as privacy, data security, and discrimination risks for the RII solution.

Assessing Broader Impacts for Societal Benefit

The adoption of emerging technologies is vital for infrastructure operation; however, many existing approaches to assessing their broader impacts remain narrowly focused, tending to regard technologies as a risk factor rather than a driver of societal change. The CER directive

(2022) mandates risk assessments and resilience strategies, but these are largely scoped around continuity of service rather than broader societal adaptation. In addition, indicators that capture public interest in the governance of utilities continue to be limited. Addressing this gap requires a comprehensive understanding of the economic, social, and environmental impacts of utilities across multiple scales, including micro, local, regional, and national levels. Such an approach is essential for the development of resilient and sustainable strategies for critical infrastructure. Nonetheless, reconciling diverse user needs and converting feedback into practical and effective measures remains a significant challenge.

Policy Gaps

The key findings from the surveys and interviews, which focused on public good impact indicators, were subsequently compared with current international legislative frameworks. Despite widespread consensus on the need for a sustainable transformation of utilities, a persistent misalignment remains between high-level political objectives and operational realities. This misalignment can be traced to four central gaps: governance fragmentation, regulatory inertia, structural financing weaknesses, and inadequate performance metrics.

Fragmented governance structures. The regulatory landscape is characterised by overlapping, and at times contradictory, layers of authority across European, national, and local levels. Such fragmentation generates inefficiencies, increases compliance burdens, and produces uncertainty for utilities attempting to implement political targets. The absence of harmonised frameworks weakens accountability and undermines the coherence of policy delivery.

Innovation barriers. Innovation in utility services is constrained by outdated licensing regimes and insufficient enforcement of sustainability standards. Regulatory processes remain slow and rigid, particularly in water management, where path-dependent rules often privilege traditional infrastructure solutions over adaptive and nature-based approaches. Weak enforcement further dilutes the incentives for utilities to adopt more sustainable practices, perpetuating technological lock-ins.

Unsustainable financing models. Utilities continue to depend heavily on subsidies and public transfers to fund infrastructure and service delivery. While such support mechanisms are politically expedient, they fail to establish durable financial models capable of attracting private capital and distributing risks appropriately. The result is a structural financing gap that limits utilities' ability to plan long-term investments aligned with sustainability objectives.

Deficient indicators and valuation systems. Current measurement frameworks fail to capture the full range of societal costs and benefits associated with utility operations. Externalities such as environmental degradation, public health impacts, and resilience gains are rarely internalised in either tariff structures or investment appraisals. This leads to systematic undervaluation of sustainable options and reinforces short-term, cost-minimising decision-making within utilities.

Taken together, these gaps explain the persistent divergence between political ambition and utility practice. Bridging them requires coordinated governance reform, modernisation of regulatory frameworks, the establishment of stable financing mechanisms that leverage both public and private resources, and the development of comprehensive indicators capable of integrating externalities into decision-making processes. Without such measures, utilities will remain structurally constrained in their ability to contribute to the achievement of long-term policy objectives.

Policy directions

Bridging the identified gaps requires a comprehensive and integrated policy approach, strengthening resilience while ensuring that the public interest remains at the centre of decision-making.

A first priority should be the **development of multi-level indicators of public value**. These indicators must go beyond narrow economic measures to capture the broader economic, social and environmental impacts (including indirect and cascading externalities) of resilience-building investments. By embedding such indicators into impact assessments, funding eligibility criteria, and regulatory monitoring, policymakers can ensure that public interest considerations are systematically integrated into decision-making processes. This would allow resilience to be assessed not only in terms of efficiency but also in terms of its contribution to broader societal goals, such as equity, sustainability (economic, social and environmental), and long-term well-being.

Equally important is the issue of **sustainable and balanced financing**. Reliance on public resources alone will be insufficient to meet the substantial costs of technological modernisation and climate adaptation. Instead, shared responsibility models are needed, combining public subsidies, EU-level funds, tariff contributions, and carefully designed public–private partnerships. Such a diversified financing approach would provide utilities with predictable and stable resources while ensuring that the societal benefits of resilience investments are distributed fairly across communities and regions.

Regulatory frameworks also need modernisation and harmonisation across governance levels. Outdated rules that limit the adoption of innovative practices, such as the use of UAVs (drones) for infrastructure inspections, should be updated, while enforcement mechanisms should be strengthened to secure compliance with sustainability and resilience obligations. Improved alignment between EU directives and their national or local implementation requires clear accountability and coordination mechanisms, ensuring coherence while respecting subsidiarity.

At the same time, **governance models must promote collaboration across institutions and sectors**. Utilities benefit from structured platforms (formal and informal mechanisms like coordination bodies, digital and data-sharing platforms, and community engagement mechanisms) that allow them to cooperate with public authorities, regulators, and communities. Such platforms support transparent and participatory decision-making, increasing both the legitimacy and effectiveness of resilience measures. National measures for the aggregation of smaller utilities into larger entities (as reported in the interviews with utilities) could improve efficiency, reduce costs, and enhance resilience capacity. However, this process should be designed with safeguards to preserve equitable access to essential services, particularly for vulnerable communities.

Finally, **transparency, participation, and ethical safeguards must become the foundation of infrastructure governance**. Public trust depends on utilities adopting robust privacy protections, mitigating algorithmic bias, and communicating openly about the use of new technologies and data-driven solutions. Institutionalising impact assessments that explicitly address ethical and social considerations would help ensure that innovation strengthens resilience without undermining equity, accountability, or democratic oversight.

Conclusion

The resilience of Europe's critical infrastructures cannot be secured through technological solutions alone. While innovations such as demand prediction systems and remote infrastructure inspections demonstrate strong potential to enhance reliability, efficiency, and sustainability, their successful integration requires coherent governance, sustainable financing, and a commitment to public interest. Policymakers must move beyond fragmented, technology-centric responses and instead adopt comprehensive frameworks that balance technical performance with ethical considerations, financial viability, and social accountability.

Resilient infrastructures ensuring uninterrupted service provision is related to protecting vulnerable populations, supporting regional development, and ensuring environmental sustainability. The public interest in secure and sustainable service delivery justifies continued public support and regulatory oversight, but this must be complemented by private sector contributions and community engagement. By aligning utilities' practices with policy ambitions and internalising externalities across economic, social, and environmental dimensions into decision-making, Europe can ensure that its critical infrastructures are not just resilient to disruption but also drivers of long-term societal well-being and sustainable development.

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