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Building Resilient Infrastructure for Italy in 2050

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Abstract

Italy's critical infrastructure is at a decisive turning point. Climate change is altering the conditions for which water, energy, transport, digital and logistics networks were originally designed, while ageing, lack of maintenance, institutional fragmentation and territorial inequalities are increasing their vulnerability. This brief explores four ideal-type and extreme scenarios for the future of Italian infrastructure to 2050. These are not forecasts, but tools to show how various combinations of governance, technology and territorial capacity can produce benefits, imbalances and unintended consequences.

- **Scenario 1:** A future where local areas innovate independently, but the absence of national coordination widens territorial disparities.
- **Scenario 2:** A future where digitalisation and artificial intelligence strengthen efficiency, but create new dependencies, exclusion and new forms of vulnerability.
- **Scenario 3:** A future where rules and standards ensure control, but produce rigidity and limited adaptive capacity.
- **Scenario 4:** A future where fragmentation, emergency management and individual adaptation dominate, with increasing inequalities.

The analysis aims to stimulate an informed discussion among decision-makers, infrastructure operators, companies, communities, and citizens on the choices to be made today, on the risks of piecemeal action and on the conditions needed to build a more resilient and more equitable infrastructure system which is better prepared for the future.

Keywords

INFRASTRUCTURE, ADAPTATION, RESILIENCE, CLIMATE CHANGE, GOVERNANCE

1. What’s at stake

Resist or adapt: the infrastructure challenge

Climate change is significantly modifying the environmental and operating conditions within which Italian critical infrastructure is designed and managed, gradually redefining the key climate parameters. The evolution of the climate, characterised by the rising frequency and intensity of extreme events and by progressive and persistent changes in average temperatures, is moving faster than indicated by many of the first climate forecasts made in the early years of this century. Globally, at the start of the century exceeding the +1.5°C threshold compared to pre-industrial (1850-1900) levels, i.e. the limit indicated by the 2015 Paris Agreement as the threshold to stay under in order to limit the most urgent impacts of climate change, was expected for around 2040, while today (2025) global warming has already reached around +1.4 °C and this threshold could be exceeded by the end of this decade (Copernicus Climate Change Service, 2024). In Europe, warming has reached around +2.1 °C compared to pre-industrial levels, with a marked acceleration since the 1980s (European Environment Agency, EEA, 2024). In Italian cities too the change is clear: in the last thirty years annual average temperatures have risen by almost 1°C and tropical summer nights (i.e. with minimum temperature > 20°C) have multiplied, with increases in some cases exceeding 30-40 nights in the summer compared to the historic data in the country’s main urban centres (Spano et al., 2021).

The **Italian critical infrastructure system**, which includes water, energy, transport, telecommunication and logistics networks, together with the plants and connections that guarantee its operation, is the backbone of the country’s economic and social life and its exposure to numerous and interconnected climate risks is rising quickly (Carraro, 2022). Heatwaves, intense and extreme rainfall, droughts and forest fires alternate and combine with slower phenomena, such as the rising sea level that threatens ports and coastlines, the salinisation of groundwater that compromises water quality, subsidence that weakens the stability of infrastructure in many urban and non-urban contexts, with cascading effects on production systems and ecosystems, from agriculture and aquaculture to air quality and water resources, and with potentially magnified impacts along economic and local supply chains.

A **further critical issue is the profound mismatch between current and future climate conditions and the assumptions on which most of the infrastructure now in operation was designed**, in Italy as in the rest of Europe, based on historical climate conditions which no longer exist. Many structures are still based on historical climate data which no longer represent the real conditions in which they must operate and those they will face over their useful lives (EEA, 2024; Polo López et al., 2025a). This problem is further exacerbated by the uncertainty around climate forecasts. The collection of models offers a range of possible future developments, where the depth of the uncertainty may be comparable or greater than the expected climate shift due to some variables and local scales (Intergovernmental Panel on Climate Change, IPCC, 2021), and this uncertainty tends to propagate along the whole infrastructure decision-making process. These considerations raise questions about the bases for traditional infrastructure planning (Buhl & Markolf, 2023).

Vulnerability, which is defined by the IPCC as the propensity or predisposition of a system to be negatively influenced and which includes the sensitivity to impacts and limited capacity to adapt (IPCC, 2022), manifests itself unevenly across the country, due to structural shortages of financial resources, limited availability and training of technical personnel, and a lack of adaptation plans. In many local situations there is a lack of operational tools, updated regulatory frameworks, or technical staff capable of supporting infrastructure assessment and transformation processes. But also large urban centres have criticalities, especially in highly urbanised areas, where human pressure places increasing pressure on ageing or congested infrastructure.

Making this situation even more critical is the **systemic character of the risks**. Infrastructure does not operate in isolation, but is deeply interconnected (Hallegatte et al., 2019; EEA, 2024). An interruption to the electricity grid, for example triggered by a climate event, may compromise urban mobility, communication, the distribution of drinking water, the operation of hospitals, with a cascade effect on various essential services. This cascade effect, which is described by numerous European assessments as being among the main emerging risk factors, can develop quickly and with amplified impacts, above all without shared protocols and predictive tools, which can reveal the inter-dependence among infrastructure. Just by way of example, in Italy the flood in Emilia-Romagna in 2023 interrupted the Bologna–Rimini and Bologna–Ravenna rail lines for days (Ministry of Infrastructure and Transport, 2023; Brath et al., 2023), while the summer heatwaves in 2022 caused widespread blackouts and delays on the rail network due to faults in electrical systems (RaiNews, 2022a, 2022b). Events of this type highlight the systemic nature of climate risk, where vulnerabilities propagate along the infrastructure inter-dependencies rather than staying confined to individual sectors.

This vulnerability feeds a growing risk of **climate inequality**: the ability to adapt to climate change is an implicit indicator of the right to infrastructure, accentuating existing gaps between better equipped areas and those left behind. In this sense, the climate crisis acts as a multiplier of local weaknesses and risks becoming a structural factor of marginalisation. In Italy, the National Climate Change Adaptation Plan (*Piano Nazionale di Adattamento ai Cambiamenti Climatici* – PNACC) (MASE, 2023) explicitly recognises these gaps: some regions and large cities in the Centre-North have already drawn up dedicated strategies (such as Regional Adaptation Plans or Sustainable Energy and Climate Action Plans (*Piani d'Azione per l'Energia Sostenibile e il Clima*, PAESC) for the cities of Bologna, Milan or Turin), while large areas of southern Italy and the islands still lack operating instruments and adequate technical capacity. This imbalance, the Plan stresses, makes it necessary to have a national framework to define common criteria and support less well-equipped administrations in translating planning into concrete actions, strengthening the institutional and technical capacity of the most vulnerable territories.

Interconnections with other sectoral challenges

Adapting infrastructure to climate change cannot be addressed in isolation: it is closely interconnected with the main transitions underway, from decarbonisation to digitalisation, from land management to public health. Intervening on one component means modifying local, operational and social balances that impact well beyond the individual technical sector (Hallegatte et al., 2019). Without resilient energy infrastructure, the energy transition cannot ensure the stability of supply, above all given climate extremes (IEA, 2021). Without secure and integrated digital networks, urban innovation and the management of adaptation will be fragile or inaccessible (OECD, 2020). Without climate-adapted transport, sustainable mobility runs the risk of systemic interruptions (EEA, 2023). Every investment must therefore take into account the inter-dependencies and long-term impacts that infrastructure choices generate on economic, local and social systems (Aspen Institute Italia, n.d.; Intesa Sanpaolo IMI, n.d.). The lack of coordination across sectors can generate chain effects, amplifying damage and blocking the capacity for a public response. Infrastructure is an enabler for economic development, technological innovation and territorial stability, requiring investment and governance strategies that can integrate economic, social and environmental aspects (Deloitte, n.d.; Freshfields, n.d.). Due to this, infrastructure must be conceived as hybrid systems that interact with data, policies and communities. Infrastructure adaptation is therefore a test bed for the capacity for integrated governance, where environmental, urban, healthcare and digital policies converge in a coherent and territorial vision of resilience, in line with analyses which highlight the role of infrastructure in defining territories' growth and competitiveness trajectories (Il Sole 24 Ore, n.d.; Utopia Lab, 2025).

A strategic challenge

The issue is not therefore limited only to the technical side. Infrastructure resilience is today a strategic choice for the country, in the context of profound climatic, socio-economic, technological and geopolitical transformation. Designing infrastructure that can absorb and adapt to rising climate stress means guaranteeing operational continuity, security, institutional stability, collective trust and economic efficiency, preventing the economic and social waste of avoidable crises or which have unintentional consequences. In this framework, adaptation is not a mere technical adjustment, but a lever to transform the growth model, which is a pre-condition for a modern and fair State and for a competitive advantage at European level. From this viewpoint, adaptation stands as an investment policy and not as a cost, with economic, social and environmental benefits distributed over the long term. The challenge of adaptation requires not just public strategies, but also collaboration with private operators, network and infrastructure operators and investors, since much of the strategic infrastructure is not directly under State control. The **public-private partnership** is therefore essential to guarantee operational continuity, facilitate the empowerment and freedom of the local community, share data and know-how and implement resilient solutions on a large scale, maximising the effectiveness of investment in adaptation policies.

Addressing this challenge therefore implies a **forward-looking and systemic vision**. It is not sufficient to repair the damage after the impact: it is necessary to **assess the evolution of risk trajectories**. The IPCC defines risk as potential negative consequences for human or environmental systems, including impacts on human lives, livelihoods, health, economic and cultural goods, infrastructure, services (including ecosystem services), ecosystems and species (IPCC, 2022). This assessment requires integrating climate change and socio-economic change in designing infrastructure and in adopting robust and flexible approaches to planning that can gradually adapt to the emergence of new information and risk conditions. This means **promoting adaptive infrastructure and involving territories in decision-making processes** (Berke & Lyles, 2013;

Stanton & Roelich, 2021; Singh et al., 2023). On this theme, the Climate Change, Infrastructure and Mobility Report (Carraro, 2022) states that every euro invested in resilience generates around five in damage avoided, as well as producing a positive multiplier on social justice. Transforming infrastructure is in fact the test ground for the country's ability to navigate climate uncertainty by building up shared and territorial resilience.

Relevance for the Sustainable Development Goals (SDGs)

The adaptation of critical infrastructure to climate change is central in implementing the 2030 Agenda for Sustainable Development (SDG), in particular to achieve the goals relating to resilient infrastructure, sustainable cities and climate action (United Nations, 2015). **A systemic vision requires tools to analyse and construct future scenarios to enable understanding of the interactions between systems, anticipate problems and assess development alternatives**. While, on the one hand, it responds directly to the goal for industry, innovation and infrastructure (SDG 9) on the building of resilient and sustainable infrastructure, on the other, it cuts across numerous aspects of fair and long-lasting development. Without secure and adaptive infrastructure, or a global vision, it is hard to guarantee universal access to essential services (SDG 6), build inclusive and safe cities (SDG 11), or enable the just energy transition (SDGs 7 and 13). Resilient infrastructure is a pre-requisite for continuity of education, public health, inclusive digitalisation, but also for territorial cohesion and combatting inequality (SDG 10), including the promotion of gender equality and female empowerment (SDG 5). Every infrastructure failure does not just represent technical damage, but is a material interruption to paths to sustainability. In particular, in already marginal areas, the absence of investment in resilience can worsen social and spatial divides, undermining climate justice and institutional credibility (SDG 16), degrading Italy's soft power internationally and "tripping up" economic, social and human development. **Investing in adaptation therefore means transforming sustainability from an abstract principle to a concrete condition**: accessible, measurable, shared. Thus infrastructure becomes a place where the pact between State, territory and the citizen is enhanced and renewed, contributing to the dynamics of trust and civil responsibility with laws and policies which are often short-term and localised.

2. The current framework

The adaptation of Italian critical infrastructure today sees widespread fragility, as recognised both domestically and at European level (Carraro, 2022; EEA, 2024; MASE, 2023). The impacts of climate change are already showing up along the whole life cycle of infrastructure: from design to construction, from maintenance to management. However, **the public and private response is still fragmented**, largely reactive, and bereft of a systemic vision.

In terms of climate, the most recent data show an acceleration in the trends seen compared to the past. In Italy, the average increase recorded over the last thirty years is +0.9 °C, with the number of tropical nights trebling and growth of up to +30% in the frequency of extreme rainfall events. In the Po Valley drought periods have increased by 10–15 days a year, while along the coasts the average rise in the sea level has reached 3.5 mm/p.a. (1993–2023), with forecasts of +0.5–0.8 meters by 2100 in a scenario of stringent mitigation (MASE, 2023).

The forecasts for 2050 in a scenario of stringent mitigation (see *Figure 1*) predict for Italy a general increase in the average temperature of around +1.5–2.5 °C, accompanied by a fall in average rainfall, especially in the Centre-South, and by a widespread increase in the intensity of extreme events. In parallel, we can see a sharp increase in the number of tropical nights, especially in coastal and southern areas, and an increase in heavy rainfall over most of the country. These facts establish the context of growing pressure within which the country's infrastructure must operate in coming decades. Extreme events such as floods, intense rainfall and landslides can produce significant economic and social impacts, interrupting transport and energy networks, damaging critical infrastructure and compromising productive activities such as agriculture.

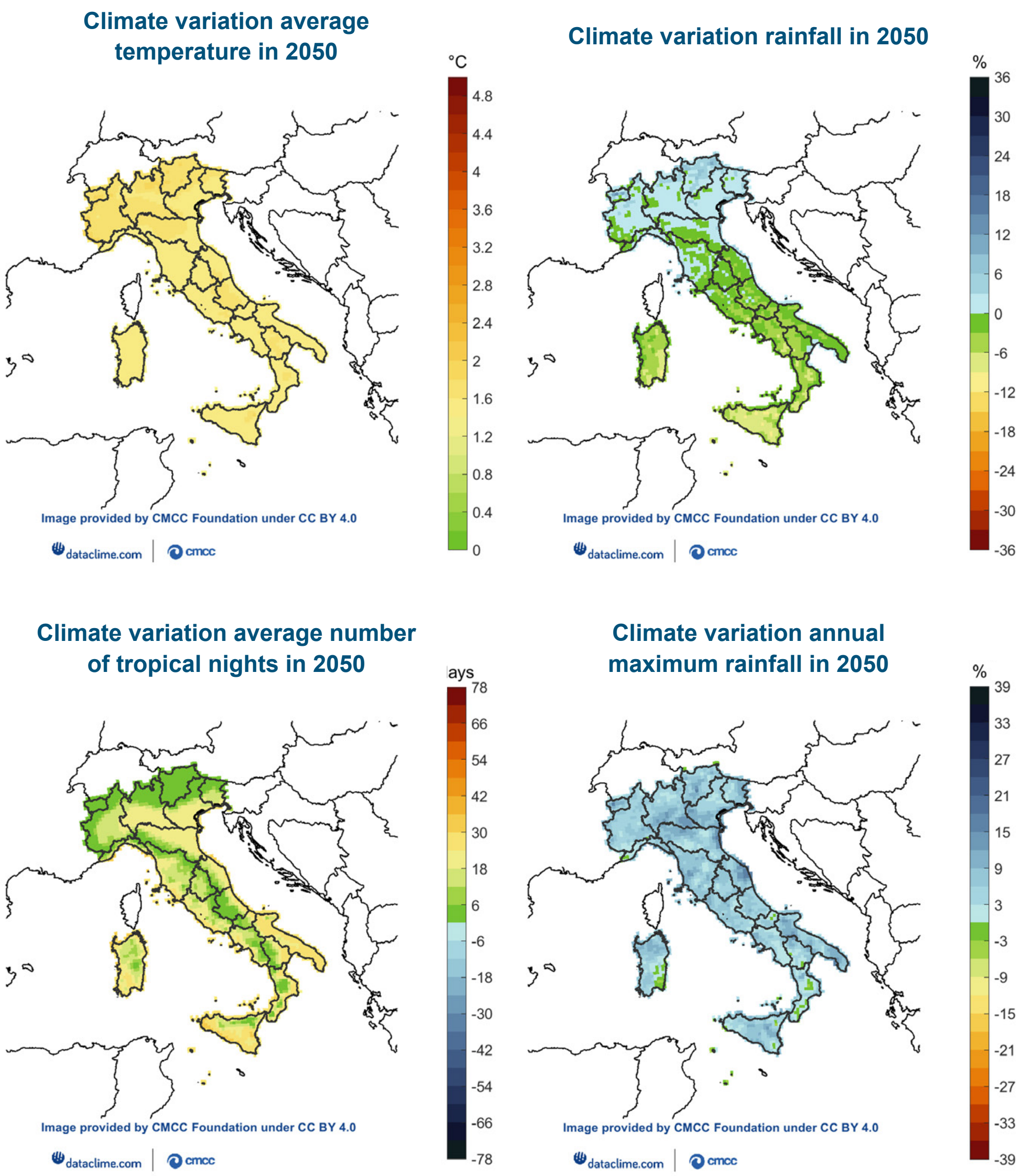

Figure 1 – Climate forecasts in 2050 (2036–2065 compared to 1981–2010) in Italy, in the RCP4.5 scenario (stringent mitigation): variation in average temperature, average rainfall, tropical nights and annual maximum rainfall, obtained as the ensemble mean of Euro-CORDEX regional models. The elaborations are taken from the CMCC Dataclime platform (www.dataclime.com)

The estimates of direct damage to infrastructure (see *Figure 2*) indicate that the annual damage in Italy is expected to increase from ~0.42 bn €/p.a. (1981–2010) to ~2 bn €/p.a. in 2030, with a forecast of ~5 bn €/p.a. in 2050 in a scenario of stringent mitigation. The biggest increase involves transport (~2.80 bn €/p.a. in 2050) and energy (~0.57 bn €/p.a. in 2050). Considering the macroeconomic effects, the estimated total losses amount to ~11.5–18 bn €/p.a. (0.33–0.55% of GDP) in 2050; every 1€ invested in adaptation generates ~5–6 € including damage avoided and co-benefits (Carraro, 2022).

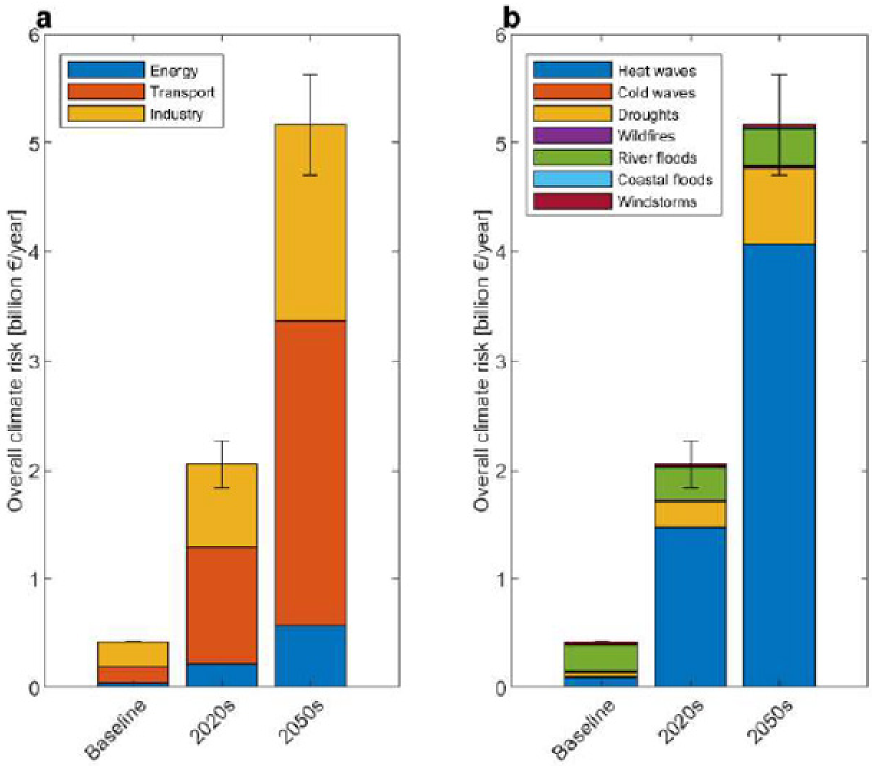

Figure 2 – Overall climate risk for critical infrastructure aggregated at national level for each time period. (a) Distribution of damage by sector; (b) distribution of damage by climate risks. The time periods under consideration refer to: 1981–2010 (baseline), 2011–2040 (2020) and 2041–2070 (2050). Confidence intervals reflect inter-model climate variability. Simulations produced in Forzieri et al. (2018). Figure taken from Carraro (2022).

According to the Joint Research Centre (JRC, i.e. the in-house scientific service of the European Commission) and other European bodies, **the technical criteria against which much existing infrastructure was built are no longer adequate** (Polo López et al., 2025a,b). The reference climate maps, which are still based on historical time series, do not fully reflect the speed with which climate change is modifying environmental conditions and make it impossible to anticipate developments which may well not be linear. At the same time, the Eurocodes, i.e. **the European technical standards which set out the rules for designing and building civil works, are still being updated to include, for the first time, climate change considerations** (Polo López et al., 2025a).

To these design gaps we may add the **progressive ageing of infrastructure and the accumulated delay in maintaining existing networks**. According to national estimates (Bank of Italy, 2021; Carraro, 2022; Chamber of Deputies, 2024), more than a third of Italian public infrastructure has passed 50 years without any significant structural interventions. This trend is part of a broader one seen in numerous advanced countries, where the ageing of infrastructure and maintenance deficits are a growing source of vulnerability for infrastructure systems (EEA, 2024; OECD, 2024; ASCE, 2025).

Technical fragilities are joined by institutional and territorial ones. The governance of adaptation is distributed across various levels (national, regional and local), with responsibilities which overlap or are poorly defined, in line with what is seen in other European contexts (EEA, 2024; IPCC, 2022; Biesbroek et al., 2015). These difficulties are reflected in sharp **territorial inequalities**. The metropolitan areas of the Centre-North have started pilot projects, often supported by European funds or public-private partnerships. On the contrary, numerous inland, coastal or mountainous areas, above all in Southern Italy, struggle to access resources and to develop competitive projects. This gap translates into an uneven ability of local territories to prevent and manage climate risks, as well as having a “reactive” rather than “proactive” approach to the climate phenomenon. It is a trend also seen in Europe to a greater or lesser extent depending on the availability of resources, administrative skills and analytical tools (EEA, 2024; IPCC, 2022). Recent analyses on territorial resilience in Italy show a strongly varied distribution of capacities to respond to environmental, economic and social risks across local regions and systems, with marked differences among the urban areas that are more integrated into economic circuits and peripheral or marginal territories. Under these conditions, **territories with less institutional capacity tend to adopt more reactive than proactive approaches in managing**

climate risks. The unequal distribution of territorial resilience is also shown by recent analyses developed by the CMCC (Marzi et al., 2019; see Figure 3), which examine various aspects in order to assess the resilience of the areas under consideration: access to services, quality of institutions, living conditions and population density, social cohesion, education, state of the environment and protection of ecosystems, economic capacity and distribution. The study shows that **Italian territories' capacity to respond to climate changes varies significantly across regions and local systems, reflecting structural differences in economic, institutional and infrastructure resources**.

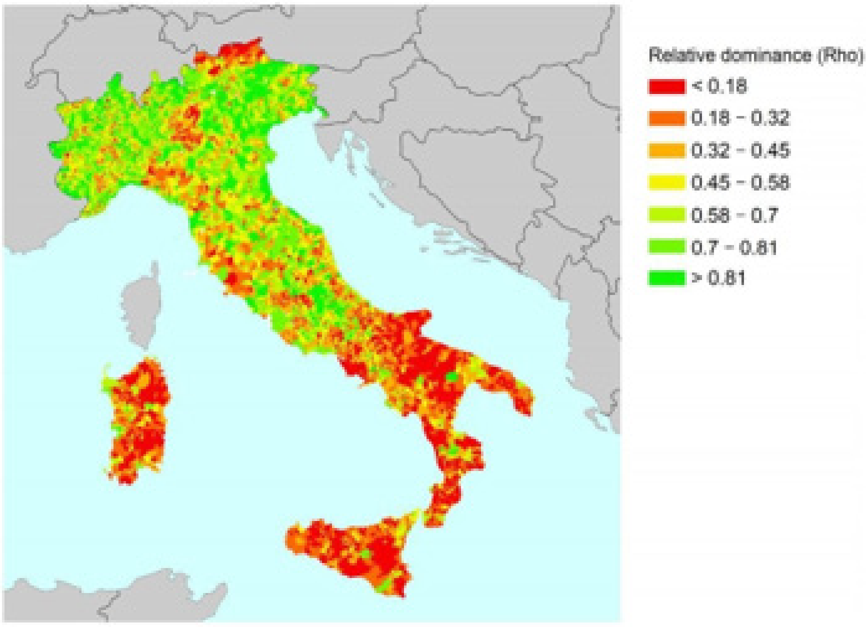

FigurE 3 – Composite index of resilience to disasters at the municipal level in Italy, constructed by combining social, economic, infrastructure, institutional and environmental indicators. The values are normalised on a scale of 0–1: values close to 1 indicate greater territorial resilience to natural disasters, while values close to 0 indicate lower levels of resilience and greater vulnerability.

Alongside structural disparities are social, cultural and perceptual aspects. In many communities, adaptation is perceived as a technical and remote issue with no direct impact, highlighting a lack of transparency and, consequently, a lack of trust in the system. The lack of participatory processes limits the building up of awareness and trust. Without people's active involvement in decision-making processes, even the best technical solutions risk not being accepted or backed over time. This is the reasoning behind the EU Mission on Adaptation to Climate Change (European Commission, 2025), one of the five research and innovation missions launched by the European Commission under the Horizon Europe program. The Mission aims to support at least 150 European regions and communities on the path to climate resilience by 2030, offering instruments for planning, knowledge and financing to support local and regional authorities.

Nonetheless, despite these initiatives, significant weaknesses remain in the ability to translate available knowledge and tools into effective decision-making processes. Information and knowledge often remain confined in separate disciplinary fields (for example environment, water, town-planning) and struggle to converge into integrated and usable tools. The digitalisation of infrastructure is moving forward, but unevenly, exposing it to new risks of technological dependency and IT vulnerability; at the same time, advanced tools, including artificial intelligence, can contribute to the resilience of infrastructure systems only if supported by adequate investments in skills, data interoperability, and security. Furthermore, in terms of financing, structured tools to incentivise fair and early adaptation are often lacking. Existing funds are often fragmented, tied to projects and timeframes, and distributed across different programs and levels of government, with limited capacity to converge into integrated long-term strategies (European Commission, 2021; Chamber of Deputies, 2024; ASviS, 2025). The result is the predominance of reactive or sectoral interventions, rather than investments aimed at systemic risk management. This arrangement seems particularly critical in the light of the most recent economic findings which indicate that failure to act on climate entails significantly higher costs than preventive investment, while adaptation measures can generate multiple economic returns in the long term (WEF, 2024). The current situation therefore reveals **a system which acknowledges the need to adapt, but which still struggles to transform that awareness into a fair and agreed operational strategy**. The climate emergency requires **scaling up**: not just to design more resistant works, but to build an enabling environment made of data, rules, skills and collaborative processes. Compared to other European countries, **Italy demonstrates significant delays**: while nations such as the Netherlands or Germany adopted national adaptation strategies and consolidated monitoring systems some time ago (BMUV, 2020; Government of the Netherlands, 2023), only in 2023 did our country take on its first National adaptation plan, with clear gaps in translating scientific knowledge into operational initiatives (EEA, 2024; MASE, 2023).

3. Scenarios

In order to construct scenarios and visions on infrastructure that is climate-change resilient, it is necessary to start from the **transformational elements** which best reflect the structural, institutional and territorial tensions that currently run through Italian society. The use of scenarios makes it possible to explore plausible futures without assigning them probabilities, but highlighting the implications of the different decision-making trajectories.

Infrastructure is not just physical works, but involves systems which organise and enable the functioning of contemporary societies. Networks, plants, digital devices and public space structure social, economic, political and territorial dynamics, influence governance capabilities and impact on the access to fundamental rights. **Their functionality extends well beyond the technical aspect, integrating with processes of economic development, social cohesion, institutional governance, cultural transformations and climate adaptation, while at the same time reflecting implicit visions of development, security, equity, and future**.

The analysis of the current framework has made it possible to determine a set of areas and uncertainties (Table 1) which can influence infrastructure adaptation in Italy.

Area	Uncertainty explored
Climate	Future intensity and frequency of extreme events
Technology	Dissemination and accessibility of adaptive digital solutions
Governance	Level of coordination among multilevel institutions
Public finance	Continuity and coherence of mechanisms to invest in adaptation
Society and territory	Unevenness in local capacity to respond and plan
Civic culture	Evolution of the perception of climate risk on the part of citizens and operators
Data and knowledge	Quality, sharing and use of information on climate risks in planning, prioritising and anticipating

Table 1 – Areas and critical uncertainties considered for the analysis of infrastructure adaptation

The **uncertainties** represent systemic polarities which shape the future of infrastructure resilience, directly influencing territorial cohesion, climate justice – in the sense of the fair distribution of the impacts of climate change and adaptation capacities among territories and social groups (IPCC, 2022) -, institutional effectiveness and the quality of life. They cut across conflicts between rapid innovation and adaptation capacity, between centralisation and local autonomy, between strategic vision and emergency response. The infrastructure of the future will be the visible outcome of these tensions: protective instruments or vulnerability factors, levers for cohesion or drivers of inequality.

The uncertainties analysed cover **three main dimensions** which are interdependent:

- structural and physical. External shocks and responses available in terms of innovation and adaptive solutions;
- institutional and economic. Who decides, how adaptation is coordinated and financed;
- socio-cultural. The capabilities, perception and key information which enable, or, on the contrary, may slow down choices.

This breakdown shows the **multilevel vision** adopted: the uncertainties are not sealed compartments, but are strongly interconnected. An institutional or financial delay can annul a technological innovation, just as a distorted perception of risk can hinder the implementation of well-designed strategies; at the same time, access to technologies can depend on public investment and territorial capabilities.

The uncertainties set the ground for strategic reflection. Two key factors emerge from these – **decision-making capacity** and **territorial cohesion** – which are used to build up the **matrix of scenarios**, since they determine how institutions, territories and society respond to climate change.

The first key factor regards the **prevalent type of decision-making approach over coming decades**. This can be read along a continuum: from forms of looking forward based on preventive planning, simulation and proactive management of risk, to mainly reactive means driven by emergencies and ad hoc adaptations. Between these extremes, there are possible intermediate configurations: contexts in which different approaches exist (for example at territorial level), or situations characterised by decision-making inertia, where the capacity to respond is limited or discontinuous.

The second key factor concerns the **form of territorial governance**. In this case too it is configured along a continuum: from coordinated, multilevel models that can integrate policies and reduce inequalities in infrastructure, to fragmented configurations characterised by varying local responses and by the absence of an agreed direction. Between these extremes intermediate arrangements may emerge where coordination is partial or unequal among territories, giving rise to patchy forms of adaptation and to sharply variable response capacities.

The intersection between these two factors generates a **matrix which covers four scenarios** (*Figure 4*). Each represents a coherent configuration of choices, decision-making capabilities and levels of coordination, showing how different trajectories can strengthen – or compromise – the resilience of the infrastructure system.

By the nature of this brief, it has not been possible to have a process of full participation in creating scenarios – as should normally happen – but rather there has been a discussion among experts. The aim of the brief is to **stimulate an informed and scientifically valid discussion**.

The matrix is not in fact a forecast, but a tool to support strategic reasoning in uncertain conditions.

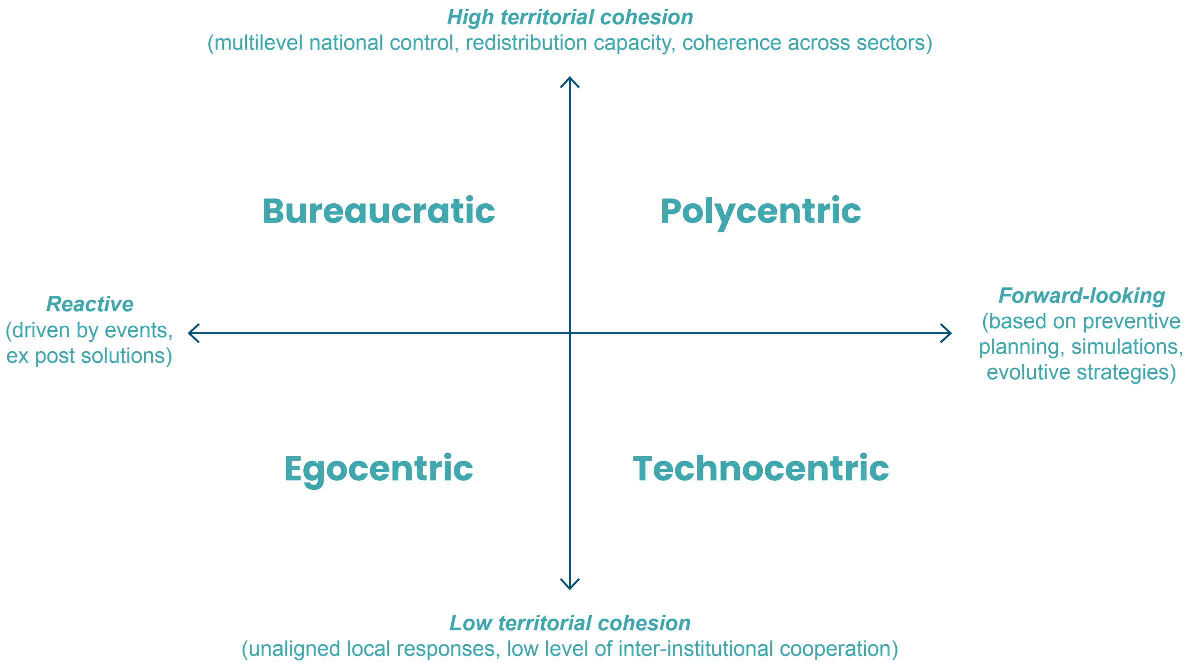

Figure 4 – Matrix of scenarios created starting from two key factors: decision-making capacity (vertical axis) and territorial cohesion (horizontal axis).

The **polycentric scenario** describes distributed adaptation based on strong bottom-up innovation and by a capacity for local vision. In this future, Italy promotes strongly territorial and decentralised adaptation. Regions, urban centres and some internal areas equip themselves with their own instruments: digital twins, local climate plans, shared co-planning. National governance leaves significant room for autonomous initiatives, facilitating civic resilience, but without consolidating multilevel coordination. Some territories are models of distributed adaptation; others are still exposed. The interconnections between networks are horizontal and often not formalised. The risk is of a divided country where access to safe infrastructure depends on the local ability to mobilise resources and vision.

The **technocentric scenario** is a future where technical ambition goes too far and trust in innovative solutions becomes excessive. Italy accelerates its infrastructure transition: smart networks, predictive planning, artificial intelligence to regulate energy, water and transport flows. Decisions are taken centrally, coordinated by a strong power and backed by European standards, such as decrees issued by a single centre of command. Nonetheless, the speed of the change exceeds the capacity for control. Some systems, which are overloaded or too dependent on automation, trigger unforeseen collapses. The less digitalised territories are excluded from the benefits. Innovation generates new forms of vulnerability, including in society, and public trust wavers.

The **bureaucratic scenario** shows an Italy which has chosen the path of defence and technical prudence. The State maintains tight control but is oriented towards a conservative approach: it invests in large-scale infrastructure projects and in consolidating existing infrastructure, without raising doubts about the model. The solutions are solid but rigid, standardised and backed by inflexible protocols. Local communities do not take part in defining priorities. Resilience is interpreted as containment and protection, not as a driver for transformation. The system holds, but remains static: it does not learn, adapt or anticipate. Every extreme event weakens the stability of the system, generating discontinuity, delays and institutional tensions.

The **egocentric scenario** is the collapse of adaptation. The infrastructure system is fragmented and fragile, without control or common rules: every authority acts for itself, plans remain paper dreams, funds are lost in never-ending emergencies. Networks suffer frequent interruptions and are managed haphazardly. Trust in institutions evaporates: citizens survive by adapting on their own or by abandoning the most fragile territories. Resilience is reduced to individual survival, rather than to a collective project.

4. The vision

The vision to 2050 is put together by selecting the elements that are considered desirable from each of the scenarios explored. The scenarios are not conceived as models to be replicated, but as explorative instruments: each highlights problems and potential drivers for transformation. The vision is constructed by selecting and intentionally recombining these elements, to define a desirable and coherent trajectory. This approach is coherent with forms of foresight which combine explorative scenarios and regulatory visions to guide public policies (European Commission, 2021).

Table 2 sets out which characteristics have been considered as a driver for transformation, which have been partly integrated, and which have been deliberately excluded. On this basis, a trajectory takes shape aimed at resilient, fair and systemic transformation of Italian critical infrastructure. The following roadmap is not a forecast or simply another scenario, but an ideal scenario to be inspired by and to take as a reference model for development.

Scenario	Elements included in the vision	Excluded elements (to be avoided)
Polycentric	Territorial empowerment. Public co-planning. Local digital instruments. Plurality of contextualised solutions	Absence of central coordination. Inequality across territories
Technocentric	Smart infrastructure. Predictive modelling. Integrated data for governance	Blind reliance on technology. Digital exclusion
Bureaucratic	Trustworthy institutional controls. Common rules. Infrastructure safety standards	Technical rigidity. Lack of local adaptability
Egocentric	No element adopted	Institutional fragmentation. Permanent state of emergency. Erosion of trust

Table 2 – Elements selected and excluded for construction of the vision to 2050, derived from the comparative analysis of the four scenarios

The selection uses a backcasting approach, starting from a desirable future to identify the actions needed now.

According to this vision, in 2050, Italy has a deeply transformed infrastructure system: adaptive, fair, interconnected. Infrastructure is no longer only physical works which react to climate and non-climate events (EEA, 2024), but vital organs of a country which anticipates, cooperates and learns. **Adapting to**

climate change is no longer a residual item in public accounts or a technical exercise, but a guiding principle which orients planning, investment and governance. In this future, extreme heatwaves, unexpected rainfall and sea level rises are no longer unforeseen threats, but variables integrated into daily planning: networks adapt, territories respond, communities are prepared.

Water, energy, transport and digital networks are designed with modular and smart approaches based on dynamic and updated climate scenarios. Each territory makes use of accessible digital tools to monitor, simulate and negotiate choices about infrastructure. Open data (from hydro-meteorological alerts from the National Weather Alert System (*Sistema Nazionale Allerta Meteo*), to satellite and climate datasets over various time horizons from Copernicus, up to hydrogeological risks maps from ISPRA) are integrated at all decision-making levels: from the smallest municipalities to national coordination centres. These instruments, which were once used only to respond to emergencies, in 2050 make it possible to **act ahead of time, to share responsibility and to build trust**.

In this future, **territorial equity has become a pillar of resilience**. Each municipality, regardless of its size or its geographic location, has access to resources, skills and platforms to design adaptive infrastructure. Communities take part in processes through forms of transparent co-planning, which create value from local knowledge and daily experience. **Planning is no longer done "for" the territories, but with the territories**. This approach reduces structural inequalities and strengthens multilevel coherence across national, regional and local institutions.

Infrastructure itself has evolved: it is no longer only flow channels, but interconnected and digitalised infrastructure systems that can detect problems, reorganise in real time and contribute to collective wellbeing. Projects are no longer limited to passively "making safe", but include regenerative functions: they contribute to public health, social inclusion, environmental protection.

Governance of adaptation has become a shared and ongoing responsibility. An integrated system of rules, incentives and standards orients public decisions, rewarding resilient, inclusive, evidence-based solutions. Investments in infrastructure are assessed not only for their cost, but also for their transformative capacity: their utility is measured in years of guaranteed resilience, in people involved, in crises avoided, in reduced economic losses. In a context of growing climate risks, failure to act can entail extremely high economic costs: according to the World Economic Forum, economic impacts linked to climate risks have more than doubled in the last twenty years and could reach annual losses in the order of trillions of dollars in coming decades (WEF, 2024).

Citizens have taken on a new role: no longer as mere spectators but as co-protagonists in adaptation. New generations grow up in educational contexts which valorise understanding risk, public planning, the relationship between climate and society, promoting inclusive participation that also focusses on gender equality. Climate literacy has become a collective good, as has looking after infrastructure.

In 2050, uncertainties transform into drivers of resilience: the climate is managed through dynamic scenarios, technology is accessible, coordinated governance, stable public finance, local communities as protagonists, informed civic culture and data integrated into decisions. Together they build a system that can learn from change and transform it into an opportunity. In this vision, the Italian infrastructure system is robust, fair and reliable: infrastructure of the future, anchored to reality but capable of transforming it, the result of a collective decision to live with the change in the right and far-sighted way. Elements of this vision can already be seen today in concrete experiences in Italy and Europe, such as the Bologna climate adaptation plan (BLUEAP) or the Climate adaptation strategy of the City of Rome, the Delta Programme in the Netherlands and the infrastructure data of the European Copernicus program, which show how advance planning, multilevel coordination and integrated use of climate information can be translated into practice (Comune di Bologna, 2015; Roma Capitale, 2024; Delta Programme, 2023; European Commission, 2024).

5. Policy orientations

The scenarios and the vision to 2050 describe a possible future where **infrastructure adaptation is the lever for the country's resilience**. Infrastructure adaptation to climate change can no longer be understood as a subset of environmental policy, or as a technical competence to be delegated exclusively to planning alone. It is necessary to recognise it as a **strategic and crosscutting field**, which requires coherent governance, distributed ability to anticipate problems and a reformulation of public investment models. Coming years offer a narrow window of opportunity: the risk is not just to undergo more frequent extreme events, but also to follow a path of systemic regression which it will be hard to escape from, or, if the choices are forward-thinking, to start a spiral of growth and strengthening resilience.

To work effectively, policies must be equipped with an **enabling national framework** to update regulatory instruments, financial guidelines and decision-making models. A national strategy is needed to anticipate and adapt infrastructure, in line with European guidelines and with the PNACC (the latter also thanks to the creation of the observatory), to integrate updated climate data, define essential levels of resilience and promote coherence across urban, energy, water and transport plans. This also requires a revision of technical codes and design standards, which are still today founded on historical climate data and barely focussed on an evolving climate future.

In parallel, it is necessary to **strengthen territorial capabilities**, especially in small municipalities and in internal areas. Adaptation policies cannot be divorced from recognising the pre-existing infrastructure inequality. In order to reduce this gap, it is necessary to create clear redistribution mechanisms and anticipate systemic trends: not just financing, but also technical assistance, sharing digital instruments and training paths. Digital twins, climate platforms, predictive tools must become accessible and standardised and not reserved to the most advanced situations.

A third direction regards the **construction of multilevel governance**: without stable national control and without the effective involvement of local bodies, adaptation will remain uneven and fragmented. Control is needed which is not just central but capable of enabling local choices that are coherent with a common, long-term framework. Institutions should invest in co-planning processes, public platforms for data transparency and shared indicators in order to assess the effectiveness of choices and to construct and analyse future scenarios.

Finally, **the cycle of public infrastructure spending must be rethought from a climate viewpoint**. Every investment, including outside of works explicitly linked to such risk, should be assessed in terms of integrated resilience, climate impact and adaptation value. This implies redefining the metrics by which the efficiency and fairness of projects is judged, including the long-term view and the ability to prevent knock-on effects.

In short, **infrastructure resilience must become a criterion guiding public policies, not an add-on emergency response**. Italy can draw on know-how, technologies and institutional networks to scale up in this way. But it requires explicit political will that can combine vision, coherence and territorial justice. Only in this way will infrastructure become not only a barrier against risk, but also a driver for cohesion and progress.

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