FIVE SCENARIOS FOR NEXTGEN INFRASTRUCTURE

BY PASCALE JUNKER

Infrastructure resilience can buy us time in the Age of the Polycrisis. What critical infrastructure is required to revive the economy today, and bring future generations back within planetary boundaries?

The transition of infrastructure is hardly mentioned in global megatrend outlooks. A blindspot? The ones we have are built and maintained on fossil fuels and have not been conceived to withstand the weather extremes ahead of them. They also risk hitting material availability and carbon intensity walls: from steel and cement to glass, aluminium or plastic, today all major building materials are high carbon. Infrastructures take ages to plan and build, and are mostly way over budget (How big things get done, 2023), in a time where we race against ecological tipping points and budget cuts. Some parts of the world are confronting a fossil legacy of infrastructure overbuild, impossible to maintain (IMF, 2024) or to renew, others to catching up on basic infrastructure underbuilt. In all cases, the economic and societal impact of **infrastructure failure** would be disastrous.

Functioning infrastructure, just like energy, which allows for our every move and endeavour, are being taken for granted. This infrastructure promises short-term economic opportunities and multiplier effects (jobs, tax revenues, etc.) as well as long-term resilience for future generations. In a dysfunctional world, as the one painted by continued and simultaneous trespassing of planetary boundaries and shortfalling of social needs, infrastructure might be the last entities standing and serve as a bulwark against economic and societal collapse. What is their future in a BANI (Brittle, Anxious, Non-linear, Incomprehensible) world marked by resources constraints, supply chain disruptions, climate extremes, cyber exposure and economic insecurity?

Image Source: Canva

The magnitude of works required to transition to a post-fossil world is sometimes compared to that of the reconstruction of Europe after World War II. It was that cataclysm that sparked a major public works boom, but not without first designing a continent-wide, place-specific, long-term plan: the Marshall Plan.

Today a new plan is needed.

The strategic questions planners and decision-makers now have to confront are different from former public works waves, since those were based on abundant and cheap fossil energy and materials. Consider the following:

- How can we construct and reconstruct every 15 to 30 years — when previous generations of renewable energy installations reach their end of life — new cohorts of wind, solar and batteries installations, and how to handle the accumulating waste?
- What should we maintain and build first and foremost, in the context of resources scarcity, supply chain disruptions, uncertain demographic evolutions and limited available space resulting in necessary trade-offs between different land uses (residential, social, industrial etc.)
- What should be done at the national level, and what should be done in cooperation with neighbouring countries or in an intra- or inter-continental fashion?
- How can critical infrastructure be protected from cyberattacks and extreme weather, and remain affordable and insurable (Horizons Canada, 2024)? Should power lines be buried to protect them from heatwaves and storms, or kept above ground to avoid flood damage?

From there, some major global infrastructure trends frame further analysis:

- **Infrastructure is increasingly vulnerable** to biophysical, cyber-, technological and economic security risks, in a context of material, land, water or energy limits, global algorithmic interdependence and surveillance and militarisation of economic dependencies or economic coercion;
- An **insufficient awareness** of these vulnerabilities, in general, and of the urgency to adapt critical infrastructure to climate change, in particular, could lead to a dramatic deterioration of existing infrastructure. The exposure of investments and assets to physical and economic damage and the risk of infrastructure failure is generally underestimated (WEF, 2024). In a *too little, too late scenario*, half the asset value could be destroyed by 2050 (*EDHEC INFRA, 2023*);
- **Societal expectations** for transformative, affordable, inclusive and reliable public infrastructure (see the indignation over *mega water basins*, new motorways or wind parks, or the state of disrepair of railways or motorways…), which contribute to social cohesion, civic resilience (Futures of civic resilience EU, 2024) and politicizing of economic policy (*Chatham House*, 2022): The cost of the infrastructural transition cannot be borne by the poor (UNDP Breaking the gridlock, 2024);
- Generational infrastructure renewal has to compete for **scarce financial resources** with other essential incremental investments, be it for adaptation to climate change and biodiversity destruction, defence, or AI; and

- **Construction materials unable to keep pace.** Access to strategic raw materials could limit decarbonisation (IMF, 2023). There is a tension between the need to reduce the material and energy footprint of infrastructure, and the need to deliver robust and fortified (Bloomberg, 2024) construction projects that resist external shocks.

The way these questions will be addressed and how these trends will play out depends on the highly uncertain, location-specific evolution of many variables – demographic evolution, material dependencies, trust in policies and institutions, political and societal priority-setting, risk-awareness, engineering skills, fossil fuel subsidisation, insurance coverage for physical loss and damage, territorial saturation, resources protectionism and near-shoring, global cartelisation of value chains (Futuribles, 2024), recycling industries maturity, technological convergence or disruption, cloud sovereignty - to name but a few.

To better prepare and avoid critical infrastructure failure, **5 global scenarios for infrastructure by 2100** could be considered in planning ahead:

SCENARIO 1: CIRCULAR AND CLIMATE-ROBUST TECHNOSPHERE

Faced with growing crises and uncertainties, resources-poor, demographically stagnant, and infrastructure-rich nations strengthen their prerogatives and declare their inherited built environment as a finite stock that has reached its maximum extent. There would no longer be additional land take or use of virgin materials, but a continuous recycling and maintenance of the existing building stock and brownfields. An infrastructure park that no longer expands in size is easier to maintain, decarbonize, and adapt to weather and environmental disruptions than a constantly expanding one. The effort, therefore, focuses on repairing and adapting the existing infrastructure, with rapid renovation waves and a flourishing second-hand materials market, combining both, embedded high- and revisited low- construction technologies.

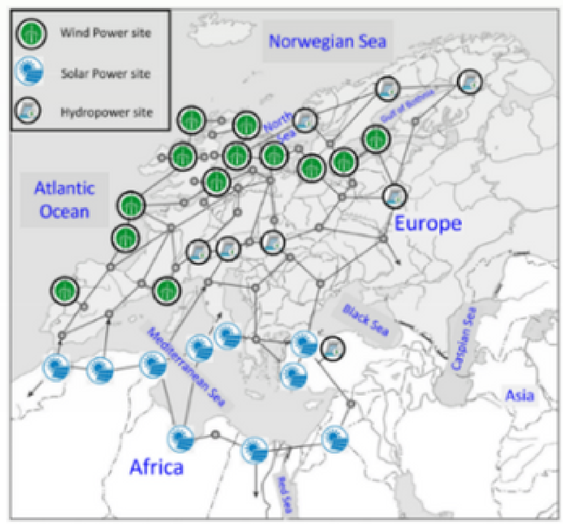
Vernacular architecture and techniques from the past and from places that have long experienced hot temperatures stand as examples for places that are accustomed to milder climates. Africa teaches the world how to build sustainably, selectively and robustly. The adapted future infrastructures store carbon and water and produce more energy than they consume. They resist adversity and protect people and assets.

The Pantheon, Rome, 125 AD: the largest unsupported, self-repairing, concrete dome in the world since 2000 yrs

SCENARIO 2: SHARED CONTINENT-WIDE MEGA-INFRASTRUCTURE

A building boom is underway, driven by the goal of achieving energy and digital transitions, or to catch up on basic infrastructure coverage, or to accommodate a fast-growing population. Different regions find different solutions according to their natural and topographical endowments. On some landmasses, large-scale critical and strategic infrastructures (energy, water, communication, etc.) are being shared between neighbouring cities, regions, countries or even continents. Cost savings by mutualisation and scaling allow these infrastructures to be executed at competitive cost and time, to pay the extra cost for robustness in the face of climate extremes or to spread the maintenance burden.

Low carbon energy is produced where it is economically the most viable. For Europe, this would mean solar in the south, wind and hydro in the north. Mountain energy storage is planned 200 years ahead. Strong interconnection of national electricity grids and new submarine cables allow this energy to be distributed to major urban and industrial centres. Major coastal cities and industrial facilities are relocated inlands, away from the sealine exposed to submersion. A cargo sailing fleet adapts its cabotage along the new coastal routes and harbours. Long-distance water networks balance between water-surplus and water-deficit regions and connect places by waterways. Modern trans-continental railway networks, trans-Siberian style, make it possible to travel carbon-free and fast from Istanbul to Singapore.



Trans-continental power interconnections,
Imdalullah et al 2021.

SCENARIO 3: VIRTUAL AND WEAPONISED INFRASTRUCTURE

Infrastructure and data are being taken over by the private sector. At the intersection of the digitalisation of defence and space technologies, infrastructure on Earth becomes increasingly abstract and virtual, promising to consume less land, materials, energy, and water. Instead of building a new power plant, production and demand are optimised and balanced to avoid shortages. Rather than increasing car ownership and building new highways, mobility becomes a service on demand. The factory of the future is place-unbound, cloud-connecting assembly at different locations.

Image Source: Canva

Contrary to the promise, dematerialisation doesn’t come true (data centres, chips, servers, computers, air conditioning, antennas, cables, etc., are made of matter). In fact, resources needs of the digitalisation increase (France Stratégie, 2024), pushing mining of rare earth elements and construction materials into virgin territory, outer space or the deep-sea. The resulting algorithmic economy, although being highly energy-intensive, allows for a 4-day working week and generates new public revenues from taxing data. However, it is also vulnerable to cyber-attacks, digital failure or malicious take over, which leads to the rise of a private defence market for cyber-protection, security and a "militarised" infrastructure.

SCENARIO 4: STRANDED, CARBON LOCKED-IN INFRASTRUCTURE

The world, or part of it, fails to decarbonise its infrastructure, which remains dependent on fossil fuels, losing value and becoming stranded. Carbon lock-in refers to the technologies, infrastructure, institutions, and norms that are inconsistent or incompatible with a low-carbon future. This applies to all fossil fuel-related infrastructure and investments, whether private or public, financial institutions, or pension funds, with revenue losses extending to workers, suppliers, and beneficiaries of social transfers. Stranded assets are also those which are not adapted to extreme physical disruptions. In a final push, the fossil fuel industry advocates for Carbon Capture, Storage and Use (CCSU) infrastructure and large-scale geo-engineering technologies to continue production, arguing this is the only way to control emissions and temperature in time.

Due to the energy density of fossil fuels, returns on investment remain high for a while, but eventually, with mounting carbon prices and physical climate damages, economic losses are likely to be borne by governments and the future generations. Everybody loses.

Image Source: Canva

SCENARIO 5: DECENTRALISED MICRO-INFRASTRUCTURE AND FRACTURED RESILIENCE

In this scenario, transcontinental infrastructure planning fails, and the national level evaporates in the face of the challenges. A single energy market does not function, the private market does not offer universal coverage and electricity transfers between countries are too limited. As a result, decentralised entities – cities, municipalities, private companies, or citizen organisations (community co-ops) – take charge of their basic infrastructure and essential supplies. Local resources (skills and know-how, water, sun, wind, topography, soils and minerals, biomass, geothermal energy…) are combined locally to ensure better autonomy for the benefit of communities and resident businesses.

However, this system of prosumers, island grids, peer-to-peer trading and local self-sufficiency alone does not generate enough surplus to sustain heavy industry or expand energy-intensive data centres. Some regions turn inward or enter into power struggles. Others cooperate, depending on shared living spaces, trust and common resource uses.

https://www.smpnet.tech/post/power-grids-unplugged-how-islanding-is-changing-autonomous-energy

Whether the future turns out to be just one or a combination of scenarios depends on the place, the policies implemented, the time required and the resources available. In any event, to make big and complex critical transition projects possible, resources have to be saved elsewhere through construction projects forgone, dismantled, reused, simplified, downsized, mutualised, or centralised.

In order to make a real dent into the preparation for a world with a less welcoming climate, risk assessment, resilience adaptability planning and failure preparedness have to be built into every level of infrastructure governance. Because the world faces resource constraints, prioritisation and protection of critical assets, massive investments in adaptation to environmental disruptions, trust and cooperation, pooling of resources, cross-border co-constructions, social utility, easing of restrictions on state aid, revision of technical specifications to make them more robust, major energy savings and nature regeneration, mobilisation of grey-, green- and behavioural solutions are **no-regret answers in all scenarios.**

Infrastructure reflects the centuries-old concept of humankind as the ruler of nature and the world (Sitra, 2024). These days, the call is one for composing with nature and society to preserve the **man-made environment.** The crux of the matter will probably lie in the commensurate and timely mobilisation of funding. With current high discount rates, returns on investment in long-term infrastructure are not appealing. To attract massive private funding, public incentives need to change in order to make investing in these essential public goods, a business case.

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Having worked for 20 years in international development cooperation, of which six years posted in Africa, Pascale Junker has gained extensive technical expertise in the areas of forestry and agriculture, nitrogen budgeting, sustainable constructions, energy transition, climate change, as well as in strategic natural resources planning. Deputy Head of the Spatial Planning Department from 2017 to 2020, Pascale Junker has co-created the Luxembourg Spatial Master Plan by 2050 and authored a foresight book entitled Luxembourg in 2050 – A resilient, low-carbon and circular Territory. In 2021 she co-formulated Cabo Verde's Nationally Determined Contribution (NDC) and National Adaptation Plan (NAP) 2030 for compliance with the Paris Agreement and UNFCCC rules and procedures.

An alumni of SOAS, University of London, as well as Trinity College Dublin, Mrs. Junker earned two Master degrees, one in Contemporary History and one in Applied Environmental Economics. In 2015, she was awarded the title "Champion of the Biosphere" by the Stockholm Resilience Center under Prof. Johan Rockström.

From 2021 to 2024, Pascale Junker was Head of Luxembourg Strategy, the Strategic Foresight Directorate of the Luxembourg Ministry of the Economy. Among the flagship products of Luxembourg Strategy are the Vision ECO2050 for a resilient, inclusive and competitive national economy and *the Doughnut for Luxembourg.*

Pascale runs her own consulting company called Pascale Junker Foresight - All that Matters.